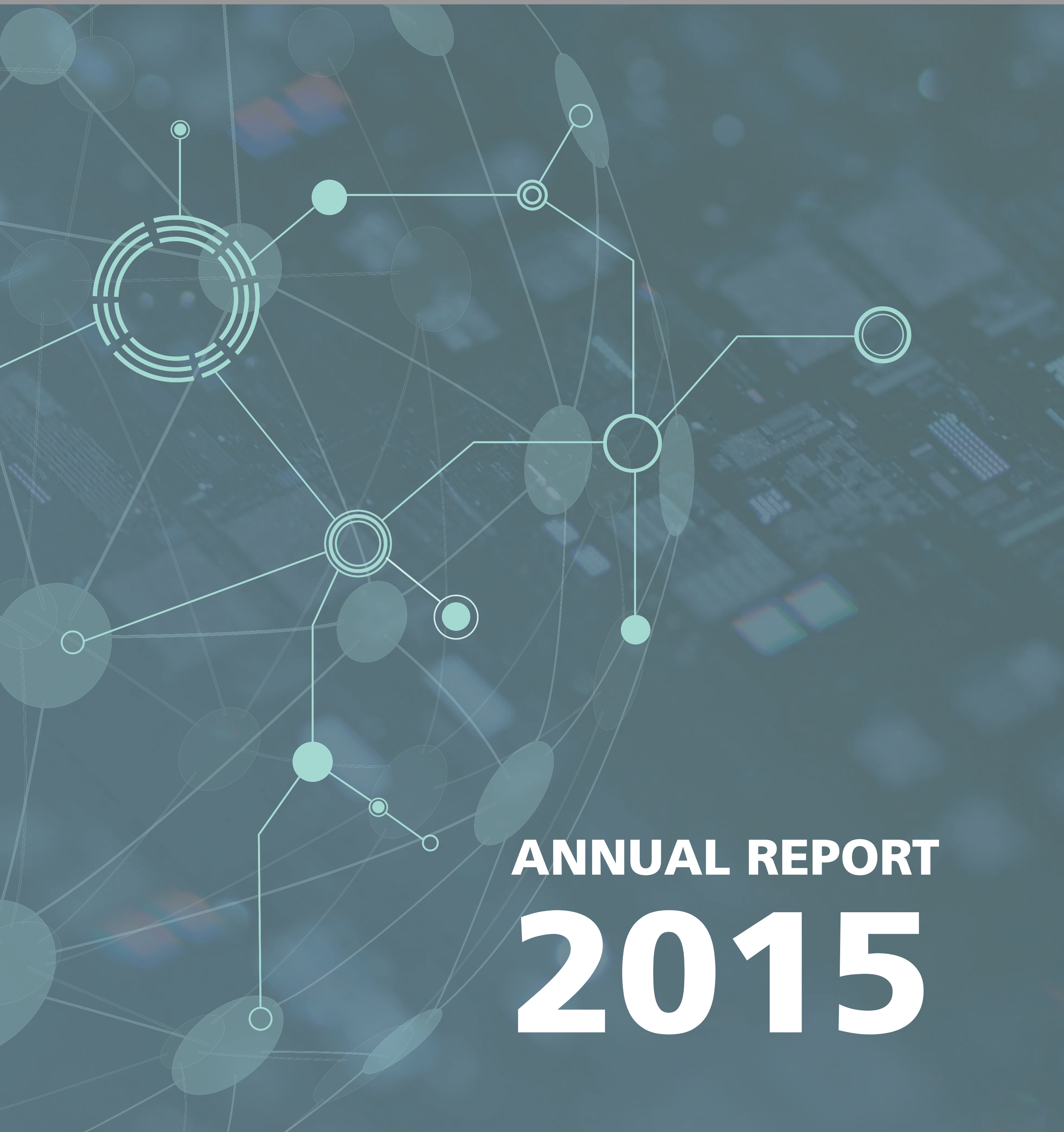
Fraunhofer

IMS

FRAUNHOFER INSTITUTE FOR MICROELECTRONIC CIRCUITS AND SYSTEMS



ANNUAL REPORT 2015

Contents

Dear readers,
dear friends and partners,

They weighed one kilo or less and their functionality was solely limited to communication. Mobile phones, which hit the market in 1985, resembled portable phone booths and only had low transmission power due to the small-celled, analog C-network used. In the same year, Commodore revolutionized the home computer market with its Amiga 1000: with unprecedented graphics performance, the system possessed 256 kB of RAM, and at well under 10 MHz, it was very fast for that time. Thirty years ago, computer-calculated vehicle bodies in the automobile industry enabled peak aerodynamic values for the first time, hence lowering fuel consumption.

Fraunhofer IMS was founded in 1985. Thirty years have passed since then. The technological developments from the year of its birth up to the present day have been overwhelming. In March 2015, together with Prof. Reimund Neugebauer, president of the Fraunhofer-Gesellschaft, and NRW Minister of Science, Svenja Schulze, we had an official celebration at the Fraunhofer-inHaus-Center to mark our institute's anniversary. On page 32 you can read about how we celebrated our birthday.

Thirty years of IMS – the past and present are worlds apart, especially in microelectronics. In the middle of the 80s, huge structures, few sensors, exclusively wire-bound solutions and discreet superstructures determined microelectronic developments at the institute, which moved to the newly constructed building in Duisburg two years after its founding, bringing the cleanroom into service for the development of new CMOS components on 4-inch wafers. In the course of technological advancement and in order to ensure optimization and the enhancement of efficiency, we shifted to 6-inch wafers in 1996, and eight years later to 8-inch wafers.

During the past three decades, Fraunhofer IMS has successfully distinguished itself from other research facilities through special technologies and developments, such as high-temperature electronics or new post-processing procedures. Today, gate array technologies that are programmable in the field, multi-sensors, wireless networks and developments for energy harvesting dominate our researchers' daily work.

On the occasion of our institute's anniversary, we are obviously not only looking back on the beginnings of microelectronics in the Ruhr Valley. We are also using the opportunity of current developments in industry 4.0 in order to once again make us fit for the future and contribute our know-how to one of the main topics of tomorrow efficiently.

As one of today's key technologies, microelectronics is the basis of the fourth industrial revolution, whose threshold the industry is currently passing. Unthinkable in 1985, industry 4.0 marries production with modern information and communication technology. After the steam engine, assembly belt, electronics and IT, "smart factories" will manufacture all products in the future. Therefore, clever, digitally interconnected systems enable self-organized production in which humans, machines, facilities, logistics and products communicate and work together directly with each.

Production and logistics processes are combined intelligently. Hence production will be more efficient and flexible.

In order to bring you, dear reader, closer to the research and development work of Fraunhofer IMS in this field, we have chosen seven projects we will present under the main topic of this year's annual report: "industry 4.0." As you are able to learn from our project descriptions starting on page 18, our supply of microelectronic development achievements for the fourth industrial revolution is

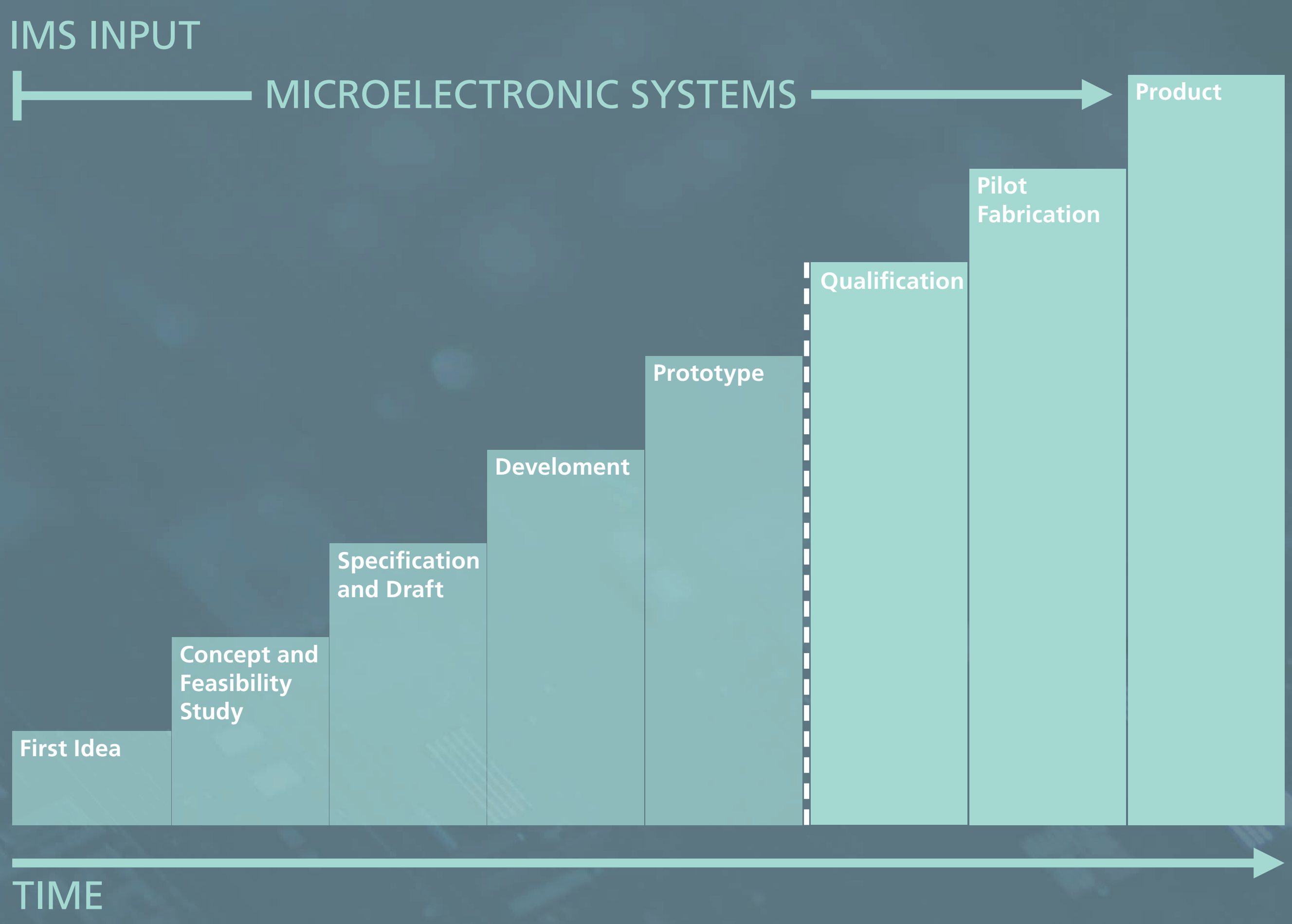
quite diverse and has the huge potential to shape the fields of facilities, energy supply, mobility and production efficiently and sustainably.
For example, Fraunhofer IMS has developed a sensor system for the monitoring and control of a reflow soldering process that enables wireless temperature measurements for the process regulation within the oven, so that a production process does not need to come to a complete standstill after the malfunction of a single sensor element. For the production process in the high-performance electronics of Infineon Technologies AG, we further developed this measurement system in order to ensure a malfunction-free production process even at surrounding temperatures of up to 125 °C. On pages 34, Nils Hellmich from Infineon Technologies AG reports on the joint project and collaboration with Fraunhofer IMS in this year's customer interview.

Using synergies, bundling competencies, broadening know-how – with the participation of the Fraunhofer-Gesellschaft in the lead project "Theranostic Implants," Fraunhofer IMS backs the development of medical systems and implants. In the context of the lead project, twelve Fraunhofer Institutes came together to develop intelligent implants. The challenge for the scientists was to develop smart sensors on the basis of microtechnical procedures and encapsulate these to enable the sensor implant to permanently stay within the human body. Fraunhofer IMS occupies itself cross-departmentally with one of three sub-projects and currently develops a system for hemodynamic controlling, which creates the foundation for a stable, long-term monitoring of physiological parameters. Therefore, the implant is transplanted into the cardiac region. The various measurement elements capture blood pressure, temperature, as well as the patient's position and activities. A voltage sensor and other sensors serve the self-monitoring of the implant functionalities. An extra-corporal read-out device receives the data and evaluates it. This makes it possible to monitor important health parameters, such as blood pressure, heart failure, liver functions and intracranial pressure.

Another positive example of successful cooperation is the Fraunhofer joint project "HOT-300" which was successfully completed with a final presentation in December 2015. In this project, besides the Fraunhofer IMS, the four Fraunhofer Institutes ENAS, IKTS, IWM and IZM developed new approaches for systems integration, which allows the enhancement of operating temperatures of integrated circuits and microsystems of up to 300 °C. In front of 65 representatives from the industry, the institutes presented developments from the fields of construction and connection technology, component and materials development, as well as methods for reliability analysis. The arrangements for further elaboration on the results and topics with partners from the industry can conclusively be regarded as a lasting result of the event and the Fraunhofer joint project.

Finally, I would like to express my gratitude to all employees of the institute for their work and consistent commitment to face the bigger and smaller daily challenges constructively and sustainably. I would also like to thank our customers for their trust and the good collaboration – here's to the next 30 years!

FROM CONCEPT TO PRODUCT



In this chapter:

We offer our services and know-how across various sectors. Our circuits and systems are being applied in particular where our customers are concerned with the creation of unique selling points and competitive advantages. Thus our customer can serve its target market ideally.

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.

Our business units

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

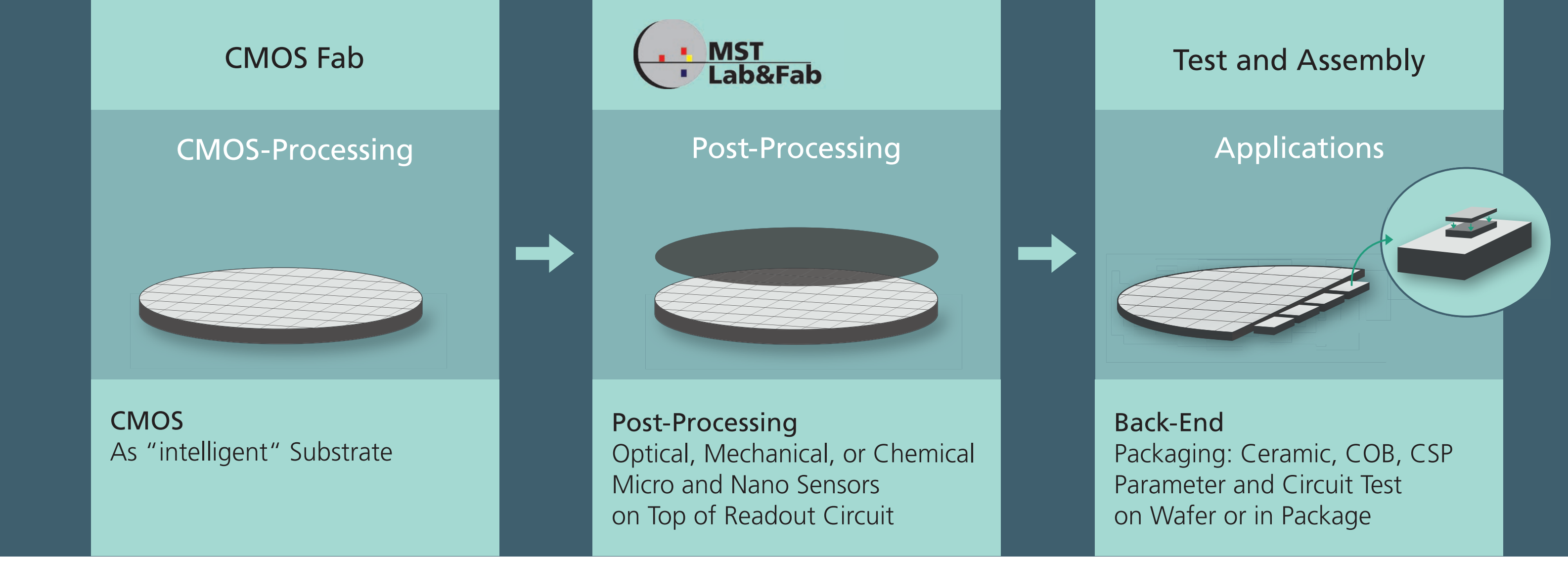
Step by step to project success

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*



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

CMOS line

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

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

Microsystems technology lab & fab

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

Laboratories

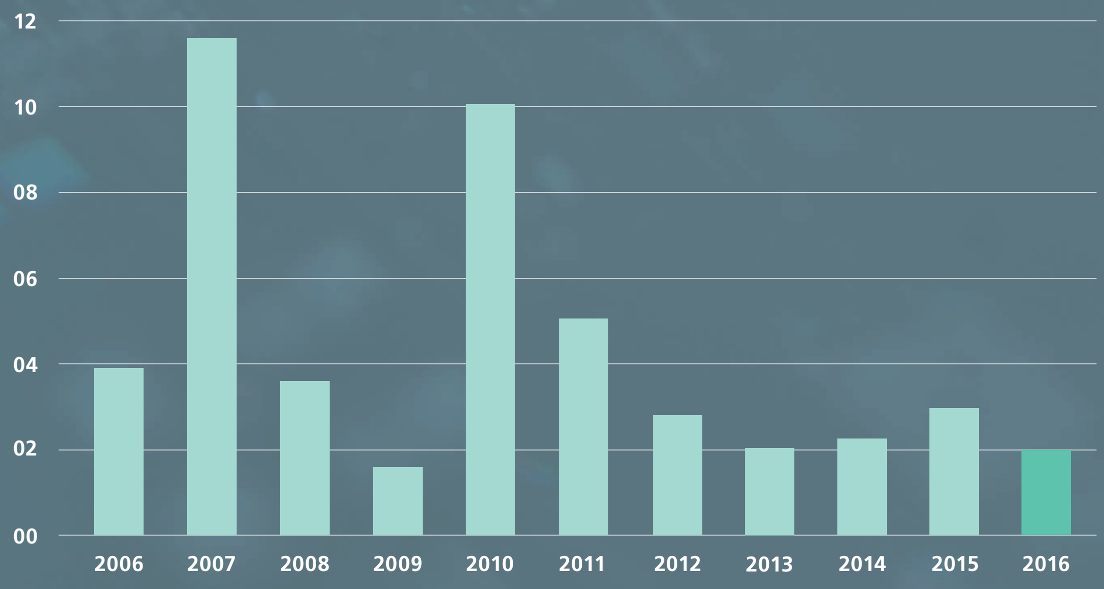
Biohybrid sensors	45 m²
inHaus-Center	3500 m²
Laboratory space	800 m²
High-frequency measurement chamber	24 m²

TÜVRheinland® CERT ISO/TS 16949

TÜVRheinland® CERT ISO 9001

STAFF MEMBERS

CAPITAL INVESTMENTS (in million euros)



“It is our vision to structure the fields of application facility, energy supply, mobility and production continuously more comfortable, secure, efficient and autonomous with microelectronic developments”

Prof. Anton Grabmaier

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
Dr. Vogt

ELECTRONIC ASSISTANCE SYSTEMS
Kemmerling

MARKETING, SALES
Bollerott

QUALITY ASSURANCE
Kelter

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Krohne Messtechnik GmbH

Dr. Stefan Dietzfelbinger
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Chirurgische Klinik u. Poliklinik, TU München

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RWE Effizienz GmbH

Dr. Hans-Jürgen Wildau
BIOTRONIK SE & Co. KG

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IR IMAGERS
Dr. Weiler

BIOHYBRID SYSTEMS
Görtz

INHAUS-CENTER
Dr. Kloster

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Ralph Lauxmann
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Stadt Duisburg

Prof. Diane Robers
EBS Universität für Wirtschaft und Recht

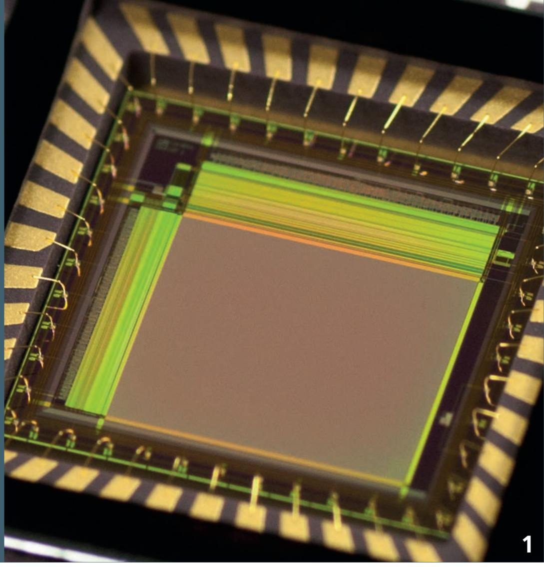
Angela Schöllhorn
Intel Mobile Communications GmbH

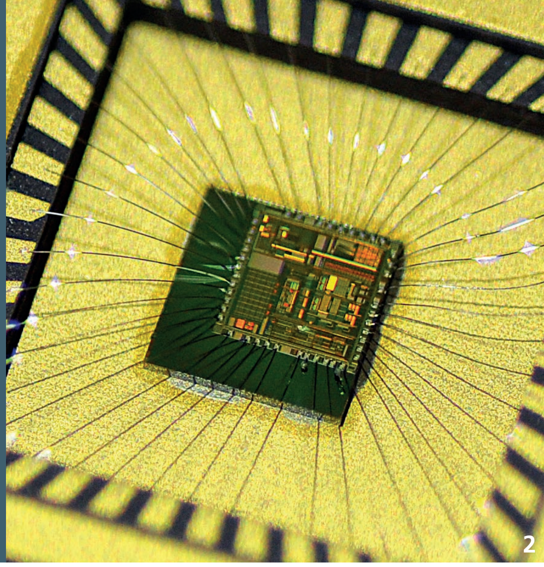
Dr. Otmar Schuster
GEOhaus

Prof. Frank-Hendrik Wurm
Universität Rostock

8 Business units

1 Innovation center





DEVICES AND TECHNOLOGIES

Our in-house CMOS line is the technological foundation of our institute. It provides professionally operated and acknowledged automobile quality in robust 0.35 µm technology on a 200 mm wafer. At Fraunhofer IMS, all of the processes are developed and augmented with additional process modules, such as special optical devices, pressure sensors or high voltage components.

Integrating new materials or micromechanical structures does not simply happen by accident, because a CMOS line needs to impose restrictions in order to maintain a high level of quality. That's why we assembled a separate microsystems-technology line (MST Lab & FAB) for the "post-processing".
CMOS wafers serve as an intelligent substrate. They contain control and readout circuits, signal processing and conversion, as well as external interfaces for wireless power and data transmission.

On these wafers, these substrates, layers and structures are separated in order to create new components. The overall aim of this development is compact, "intelligent" microsystems.

Supply and services/technologies:

- *MST process development*
- *Onto CMOS integrated microsystems*
- *200 mm (0.35 µm) wafer size*
- *CMOS process development and components*
- *SOI processes*
- *Development and consulting for the semiconductor industry*

1 *High frame rate eye sensor for lasik surgery*

2 *MEMS accelerometer readout IC*

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" ASICs 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 high temperature, high voltage and sensor systems applications.

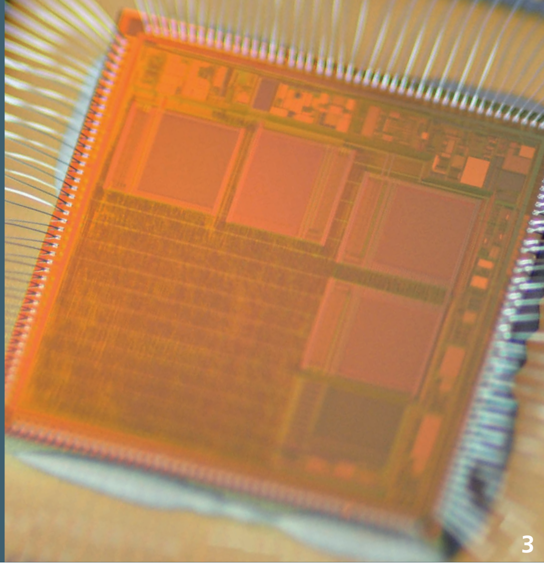
Special circuit parts or sensor system components are individually and custom-designed and integrated with standard components like sensor readout, signal processing, interface components or embedded micro controllers on an IC.

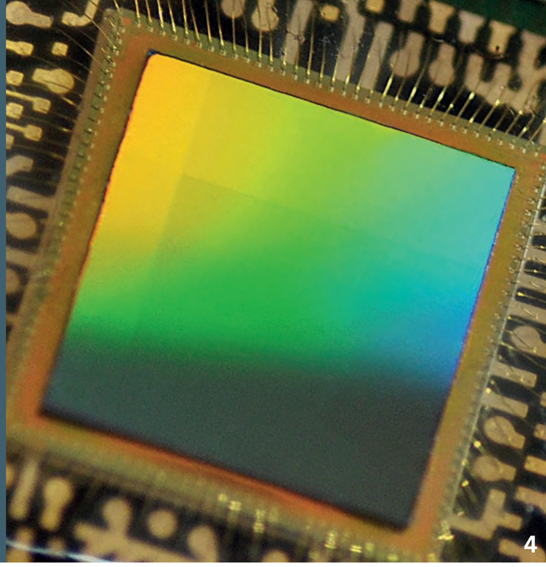
Supply and services/technologies:

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

HIGH TEMPERATURE ELECTRONICS

Microelectronics is a key technology used in more or less any application. With increasing complexity and demand for performance in harsh for harsh environments, especially at high temperatures, standard electronics has reached its limits. Depending on the grade, integrated circuits are specified for a maximum operational temperature of up to 125 °C. Nevertheless, sensors and actuators are used





IR IMAGERS

in industrial processes with high temperatures, while commonly deposited electronics are used, which requires additional space and results in a loss of performance.

Fraunhofer IMS's thin film Silicon-on-Insulator (SOI) CMOS technology makes it possible to overcome the abovementioned limits. Besides the CMOS-specific components, the technology is equipped with non-volatile memory based on EEPROM.
Based on this technology we realize integrated circuits for the extended temperature range of up to typical 250 °C and above.

We can support your entry into the field of high temperature electronics with concept and feasibility studies. We also understand your customer-specific HT ASICs, including pilot fabrication and comprehensively support system integration, including the assembly aspects.

Supply and services/technologies:

- *High temperature SOI CMOS technology*
- *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*

Infrared imager "see" in a wavelength range from the near to longwave infrared. These thermal image sensors are called focal plane arrays and are one- or two-dimensional lines of IRsensitive pixels. They are based on radiation sensitive structures and use silicon technology, where CMOS readout circuits are integrated on a microchip. That's how complete image sensor chips are developed.

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

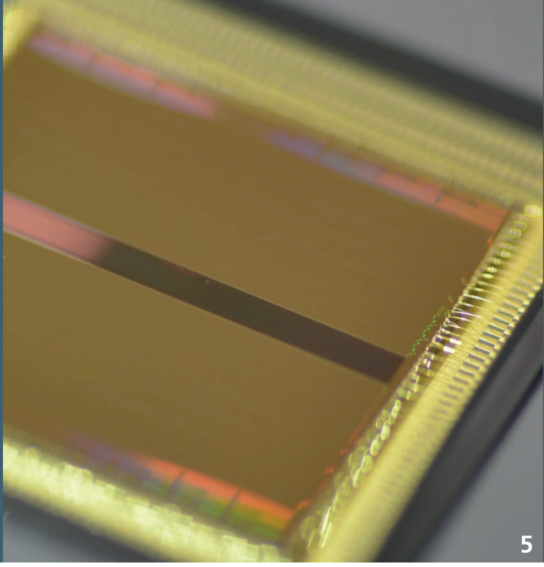
Similar safety aspects, e.g. personal security or measurement technology in process monitoring, are also important to the industrial sector. In the sensor system, the gas analysis is of increasing interest. Further applications include thermography in buildings or in medicine, but also border and building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

Supply and services/technologies:

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

3 *HT micro controller*

4 *Uncooled IR detector for thermal imaging*



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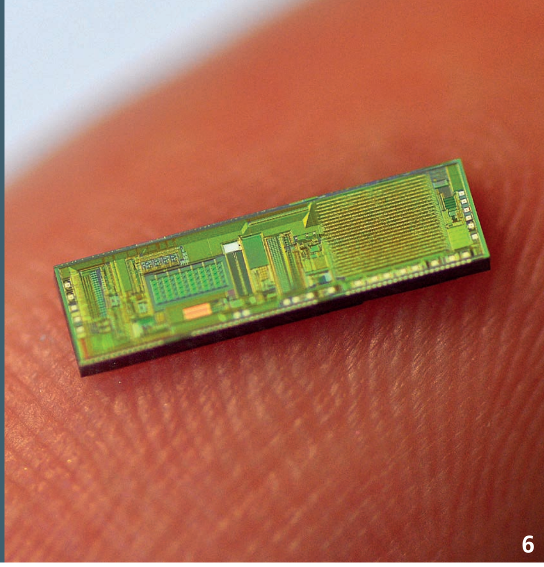

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CMOS IMAGE SENSORS

Optic 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 photodetector components 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. "Pinned" photodiodes with low dark current and little signal noise and with color filters, micro lenses as well as stitching can be integrated. 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 surface sensors*
- *Special pixels for time-of-flight, spectroscopy and more*
- *Stitching for large surface sensors*
- *UV- and XUV sensitive sensors*
- *Color filters and micro lenses*
- *Customized packaging and testing*
- *Pilot manufacturing in 0.35 µm "Opto" CMOS process*

PRESSURE SENSOR SYSTEMS

The trend in microelectronics is toward ever 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, implantable in the human body if required. For this reason beyond classic applications for pressure sensors, new fields are opened up, particularly in medical engineering.

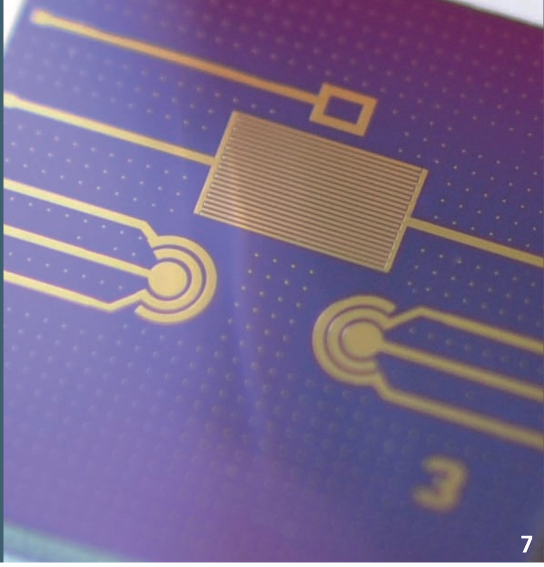
By producing these sensors as integrated capacitive pressure transducers in surface micromechanics, a connection with any kind of signal processing is possible. Our miniaturized pressure transponders can also be used for metrological applications in the industry or for measuring tire pressure in the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

- *Customized development of capacitive pressure transducers*
- *Measuring range from only a few mbar up to 350 bar*
- *Extremely high precision*
- *Transponder ability due to low energy requirements*
- *Integrated temperature sensor*
- *Customized packaging, testing and calibration*
- *Customizable digital and analog interface to meet customer demands*

5 *Xposure CMOS line scan sensor*

6 *Pressure sensor for medical implants*



BIOHYBRID SYSTEMS

The markerless identification of biological and chemical substances without extensive laboratory work is crucial for progress in medical engineering. Sophisticated measurement technology is replaced by miniaturized systems that, detect substances via a biosensor (immuno or electrochemical) by their electronic reaction.

We offer the development of these highly sensitive detection systems, which are a cost-effective and fast alternative to optic analysis in the laboratory. These nano systems can also be integrated into more complex biohybrid systems, such as lab-on-chip, if required. This is particularly interesting for customers in the field of medical engineering, who can offer simple ways for real-time examinations via non-invasive, permanent diagnosis and monitoring systems in the future.

This is possible because bioelectronic sensors can also detect medical and physical parameters. These functions are also interesting for the food industry, which can profit from the simple and fast detection of biological-chemical alterations in their products.

Supply and services/technologies:

- *Customized biosensor systems (e.g. glucose, lactose)*
- *Markerless and quantitative sensor technology*
- *Real-time monitoring in body fluids*
- *Customized electrochemical sensor technology*
- *Customized immuno sensor technology*
- *Customized packaging and testing*

WIRELESS AND TRANSPONDER SYSTEMS

Industrial production and processing processes can only supply high quality products and operate cost-effectively if the machines are optimally adjusted, if they have not had much wear and have proven durabile. For performance to these requirements it is indispensable to have measurement data that help to optimize the machine settings, to determine the maintenance requirements, to control the manufacturing steps and to make quality recordings.

Transponder systems – especially sensor transponder systems – and sensor networks feature an excellent technological basis for the registration of identification and sensor data.

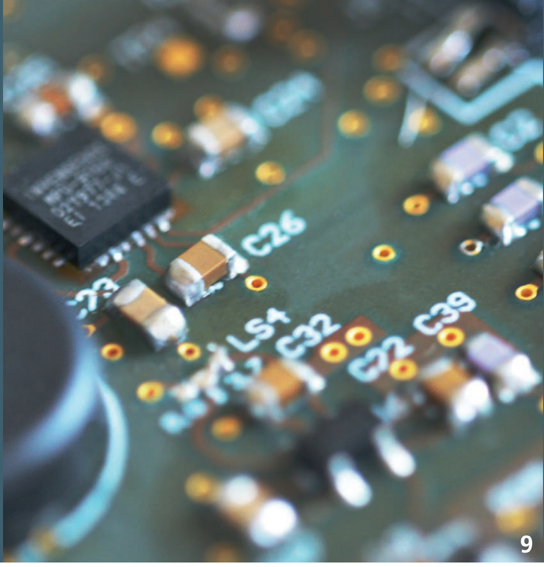
The wireless communication and power supply open up new application areas – e.g. in medicine to get measurement data from implanted sensors for diagnostic and therapeutic purposes. Other interesting application areas include the building sector and logistics.

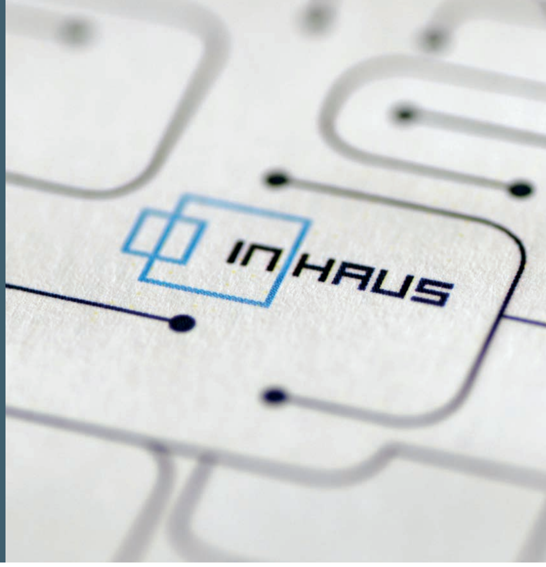
Supply and services/technologies:

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

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

8 *HF transponder*





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.

In our inHaus-Center, supportive solutions for residential and building environment (AAL – Ambient Assisted Living) for our customers are developed and tested. The installed products for facility management in commercial buildings are subject to strict criteria for economic efficiency and sustainable energy efficiency.

Fraunhofer IMS offers novel assistance systems for more efficiency in the nursing and hospital area. Innovative solutions in the area of energy and facility management up to solutions for the next generation office are the development priorities of the Electronic Assistance Systems business unit.

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

INHAUS-CENTER

The Fraunhofer-inHaus-Center is a unique Europe-wide innovation workshop for application-oriented and close-to-the-market research for intelligent room and building systems. The inHaus-Center bundles the potential of several Fraunhofer Institutes and more than 120 business partners for the collaborative development, testing and implementation of innovative technology, product and system solutions for residential and commercial buildings. Focused on a broad variety of applications, such as Business Office, Hotel, Resources, Residential Living and Health&Care, new concepts for rooms, innovative building materials as well as intelligent building technologies and electronic assistance are developed here in order to access new markets.

Innovative components, system solutions and services with new utilization effects by combining design, materials, building technology, microelectronics and information technology for rooms and buildings are called smart buildings and smart homes. These future-oriented solutions lower energy consumption and costs while increaseing security and lowering facility management expenditures. The Fraunhofer-inHaus-Center offers its clients a targeted range of system solutions such as know-how, services and facilities. This ensures that ideas are generated efficiently, conceptualized, prototyped, tested and demonstrated.

Research and development focus on these subjects:

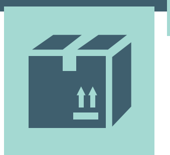
- *Building/planning with IT support*
- *Energy transparency/ -energy efficiency*
- *Logistics and operational processes*
- *Interaction between people and technology*
- *Multifunctional component building systems*
- *Sustainable construction*
- *Performance-oriented rooms*
- *Security and safety*
- *Electronic assistance*

9 *Bicycle fall detection PCB*

7 Selected projects

1 Main theme "industry 4.0"

In this chapter:

THE BASIS OF THE FOURTH INDUSTRIAL REVOLUTION

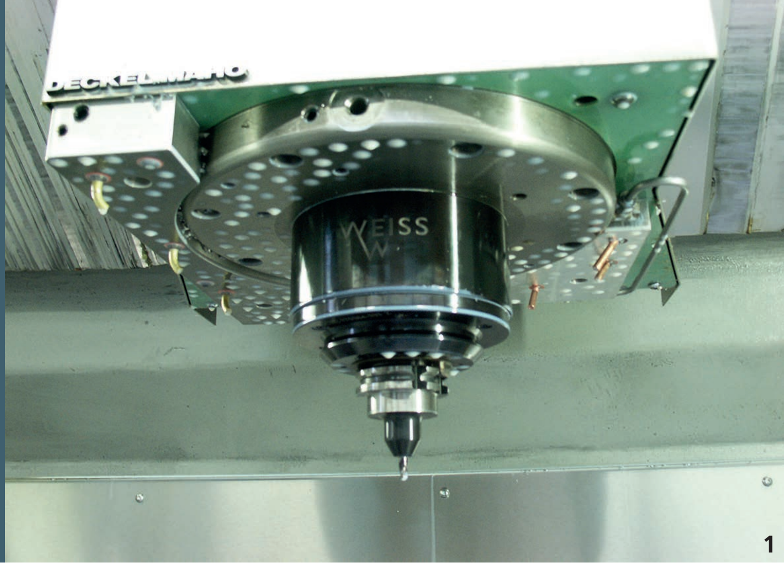
When autarchic components communicate with a manufacturing plant; technical modules autonomously initiate a repair in the case of malfunction; sensors, employees and industrial processes are interconnected intelligently; then we are talking about industry 4.0.
Driven by the World Wide Web, the real and virtual worlds increasingly merge to become an "Internet of Things" ("IoT"), and therefore the economy is at the threshold of the fourth industrial revolution. The intelligent interlocking of products with the latest information and communications technology is characterized by a high level of product individualization in highly flexible (high-volume) production. Companies and whole supply chains are to be controlled in real-time and optimized based on smart analysis processes. In accordance with customer demands, customized, high-value products are being manufactured in a cost-efficient way. From the idea stage to the development, production, application and maintenance right up to the recycling, the upcoming generation of industry will affect all phases of a product's life cycle.

By 2020, German industry wants to invest 40 billion euros in industry 4.0 applications – every year! As a study conducted by PricewaterhouseCoopers suggests, 80 percent of industrial companies will have digitized their supply chains within the next four years. The fourth industrial revolution is clearly on the rise. Stringent requirements are thereby being imposed on future production: it must be smart, alterable, efficient, sustainable, and be capable of being networked intelligently, and control and configure itself situationally and autonomously. In addition to this and according to the "industry 4.0" task force of the Federal Ministry of Education and Research (BMBF), industry 4.0 is understood as the "networking of knowledge-based, sensor-assisted and spatially distributed production resources, including their organization and control systems." Therefore, the key to success is found in the combination of information and software technical systems with mechanical or electrical components.

Microelectronics as a fundamental requirement

Derived from the above, modern electronic and microelectronic components and systems are a fundamental requirement of industry 4.0. The usage of robust sensor systems, wireless and high-frequency transmission modules, as well as energy-efficient and secure data processing structures contribute to the gradual enhancement of the proportion of automated functionalities. Apart from this, microelectronics supply important equipment for system manufacturers in order to implement the visions of industry 4.0 step by step. Therefore the "tools" supplied need to preferably be modular and standardized, performance-capable and precise fitting. Besides the minimization of microchip structures ("More Moore"), semiconductors with increasingly more features will grow in importance. These requirements are supported especially by "More than Moore" technologies, which enable the integration of a large number of features onto a microchip. These systems integration technologies will play a central role in the implementation of industry 4.0 scenarios.
"Microelectronics provide the basis of the fourth industrial revolution. As key technology of our time, its products are part of everyday life; without them there would be no smartphones or computers," says Prof. Anton Grabmaier, Director of Fraunhofer IMS. "The developments in microelectronics changed information and communications technologies decisively and forced the controls in every device to become more complex and effective, from robot to cardiac pacemakers, all the way up to domestic tumble dryers."

The following seven Fraunhofer IMS projects described once again show that with microelectronic developments, the fields of facility, energy supply, mobility and production can be created to be more comfortable, secure, efficient and autonomous. That is our contribution to the fourth revolution of industry!

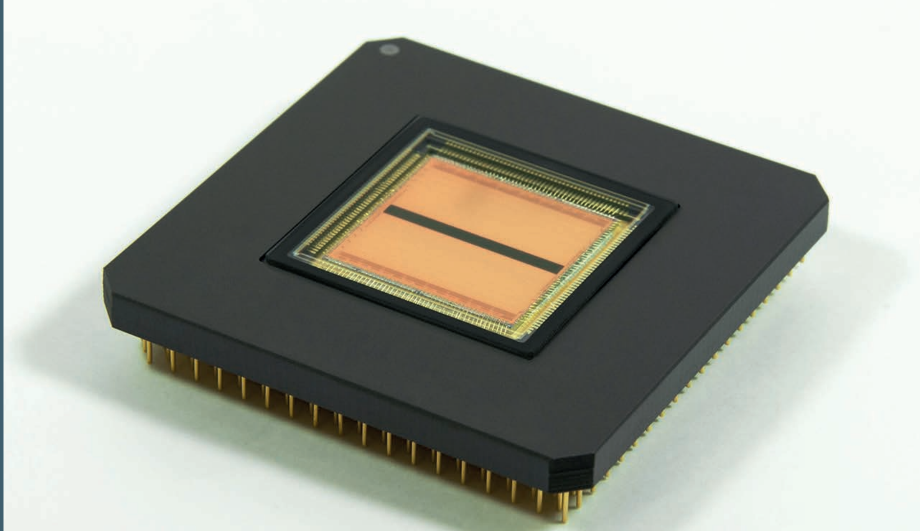


SMART OBJECTS SUPPLY LIFE CYCLE DATA ON TOOLS

By using so-called "cyber-physical systems" the Fraunhofer IMS "Cute Machining" project aims to optimize cutting production processes. In this context, the term "cutting" refers to a mechanical separation process where with the aid of cutting edges, material layers made up of shavings are cut off for the modification of the workpiece shape. Cutting production processes include turning and milling, as well as the drilling of workpiece shapes.

"Cyber-physical systems" ("CPS"), on the contrary, are systems with embedded software and electronics that are connected to the environment through sensors, so-called actors (actuating elements). They are increasingly interconnected with each other and the Internet. The system processes data from the physical world with the aid of these sensors and makes it available for net-based services, which can act upon the real world through actuators. In cutting production plants, productivity is predominantly determined by the tools applied. An important parameter for these production processes is service life, which indicates the period of time during which a cutting tool can be used before it has to be reground or replaced. However, this period of time is hard to predict. Although tool characteristics can be calculated, it is the employee himself who configures the machine shortly before a cutting process and therefore has an impact on the tool that is not noticeable. This results in a fluctuation margin of +/- 25 percent. In order to avoid downtime and damage to parts, tools are often replaced too early, resulting in 25-50 percent extra costs for tools. Another challenge when using service life is the identification of tools. In this context, that means the assignment of relevant user data to the individual tools. Tool identification more effectively configures the machine tool process. To favor component quality, a nominal size tool is selected which, due to insufficient regrind cycles, generates additional costs of up to 250 percent for the relevant groups of tools. Both tool identification systems currently available on the market are impractical. The visually readable 2D-matrix code is not stable over the long term due to pollution and deterioration, and the current RFID solution read-out distance is limited to only a few millimeters due to its metallic surroundings, and is only usable for tools of a certain size. Researchers from the "Cute Machining" project from Fraunhofer IMS and partners from industry now pursue a completely new approach, where RFID systems with a much higher frequency within the gigahertz range are applied. The tools are therefore enabled as "smart objects" by a superior database to communicate via web services and provide information for the electronic "life cycle file". This way, the tools used are applied in a process-secure manner until the end of their maximal life cycle. With the aid of this new RFID technology, tools can be distinctively identified at all steps of a process, and therefore find their way through a production process and are reprocessed autonomously. A much smaller antennas size is possible with this system. These unprecedented RFID transponder modules only expand to 5 mm² of space and thus can be easily fitted into the surfaces of tools. Furthermore, the read-out distance can be enlarged up to one meter. Therefore, RFID transponders can be read in inaccessible positions, multiple tools captured at once, and their locations can be determined within the read-out space. "The newly developed gigahertz RFID system enables tools to communicate with a superior database via web services to maintain a 'life cycle file,' to be clearly identified without eye-contact and to find their way through a production or recycling process autonomously. Furthermore, they can be used for a cutting process depending on their operative/downtime status," summarized Gerd vom Bögel, head of the business unit "Wireless and Transponder Systems" at Fraunhofer IMS on the advantages of the system. The newly created feature, which derives from the project "Cute Machining" serves the distinct identification of the physical tools because the entity of a type of tool is known in the stock. This is achieved with a unique tool identifier mounted distinctively and securely on the tool. With aid of the digital "life-cycle file" tools are individualized and possess a tool-specific classification number. The project "Cute Machining" is sponsored by the state government of NRW and the EU under the program "EFRE-NRW".

1 *Drilling spindle within the industrial manufacturing process*



2

HIGH-SPEED LINE SENSOR FOR HIGHLY-SENSITIVE INSPECTION TASKS

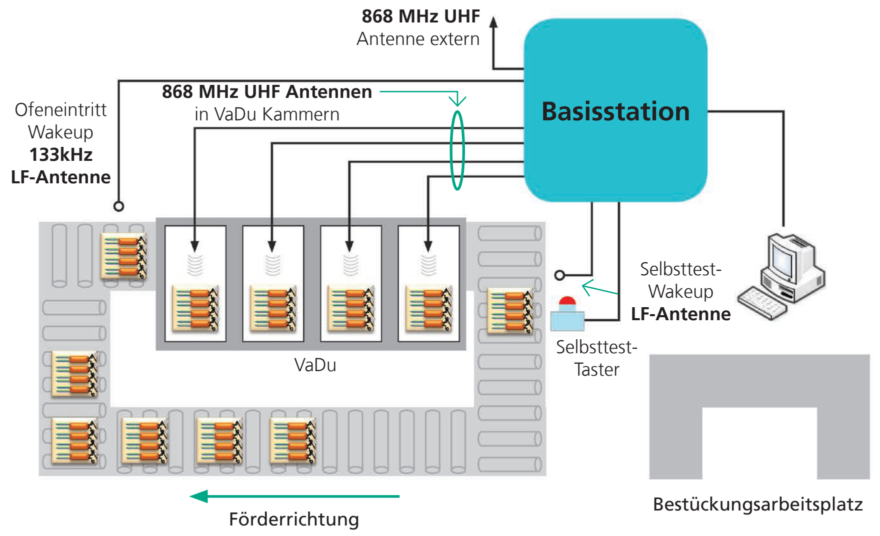
"Spinning Jenny" achieved more. Since its invention in 1764, the first industrial spinning machine for spinning wool into yarn, with its enormous increase in productivity compared to the spinning wheel, is regarded as a milestone for the industrial revolution. What started off over 250 years ago with more spindles, faster coils and rapid threads long ago became the standard for industry 4.0: superlatives determine the production process. When paper, steel or textiles move along the assembly lines within a manufacturing process, it has to occur in the most reliable, efficient and especially the fastest way possible. A growing number of products is manufactured at extremely high speed. Customers expect continuous production that delivers consistently high quality. To meet these requirements and challenges, technologies and solutions are necessary that enable the visual inspection of the quality of every single product. In a large number of optical measurement systems, very fast image capture is needed. Besides the fast pace required, distinct speed and spatial resolution are necessary. Meanwhile, today available sensors are stretching their limits: their pace is often insufficient to control quality in real time during a manufacturing process.

With "xposure," a 60-line high-speed sensor Fraunhofer IMS developed together with an Austrian research facility, the AIT Austrian Institute of Technology, those disadvantages belong to the past. "Our sensor is twice as fast nowadays as other available solutions, and at the same time delivers images of high quality with high resolution," reports Werner Brockherde, head of the business unit "CMOS Image Sensors" at Fraunhofer IMS. Not only the speed, but also the extremely high photosensitivity and the vast complexity with, for example, 2,000 analog to digital converters had to be achieved simultaneously in order to realize "xposure." "Especially the danger of cross-couplings at high cycle rates was examined and minimized in elaborate simulations," explains Brockherde. The sensor is capable of scanning objects with 600,000 line scan images per second in the monochrome variation. In the color variation, the sensor captures 200,000 line scan images per second in RGB. That is the world record for line scan sensors! At exposure times of a few microseconds, the sensor achieves full image quality with off-the-shelf diffuse lightning and lenses.

In order to attain this high speed, IMS scientists have integrated a read-out chain for every pixel column into the chip. Furthermore, they developed special photo pixels one can use to work with conventional optics despite the short exposure times. In every pixel column, the three colors red, green and blue are captured simultaneously and over the entire pixel surface. This ensures high-quality color reproduction. Another distinct feature of the sensor: the high number of lines allows the capture of objects from different viewing angles, and thus surface structures can be controlled in 3D. As a result, a new field of applications has opened up for the sensor: security printing. Latent images of holograms on bank notes can be controlled and counterfeits can be detected reliably with the sensor. The wavelength spectrum of the sensor can be expanded, for example into the UV and infrared range.

Other possible fields of application could be plastics recycling, where the sensor is capable of identifying shredded materials using their color information, therefore making waste separation easier. Another possible application is the inspection of railway tracks or contact wires of trains: even at speeds of 300 km/h, the sensor can capture pin sharp images with a resolution of 0.4 mm, capable of detecting even the smallest hairline cracks. Orbital satellites fitted with such sensors that circle the Earth with a velocity of 26,000 kilometers per hour could capture colored images of Earth's surface with a resolution of three centimeters.

2 *This 60-lines-sensor is double as fast as currently available systems*



SENSOR SYSTEM MONITORS OVEN TEMPERATURES

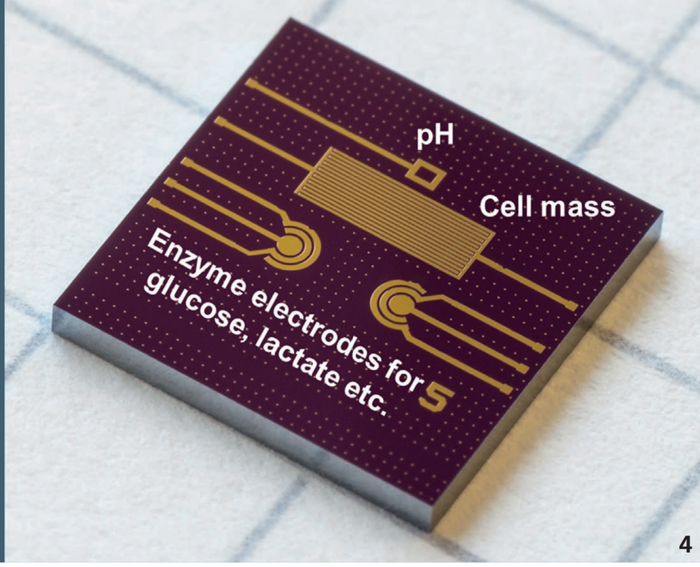
In the food industry, breads and rolls are first baked at higher temperatures between 230 and 280 °C, the so-called baking temperature. This enables the crust to form more quickly and allows the dough to stabilize. After a quarter of an hour, the temperature is reduced from 230 to 180 °C and the bake through begins. This prevents the excessively fast browning of the crust and prolongs the baking time. This procedure enhances the taste and the forming of crust and crumb. Whether baking bread, drying and curing of adhesive connections between glass and metal, or at the soldering process for the production of electronic components – in order to attain the required product quality, it is absolutely necessary to adhere to specific temperature profiles in many manufacturing processes in the industry.

For temperature surveillance, in most cases it is possible to effortlessly mount sensors at the individual measuring points and wire them for energy supply in order to read the measurement results. If, for example, sealed chambers do not allow cable penetration within a manufacturing process, the point of reference to be measured is in motion or the surroundings are not suitable for secure cable penetration, wiring requires a great deal of effort or cannot be done. The noise-free penetration of mountable surface components into vacuum induction soldering facilities within a reflow soldering process is impractical with wiring. In contrast to welding processes where joints are materially fused, soldering is only used for metallic materials. The joints are therefore not made to melt, but be warmed up. The compound originates from additional liquid applied metallic materials that function as a bridge between the joint components. In electronics, a conventional soft soldering for the soldering of components is described as a reflow soldering process.

The institute from Duisburg has developed a wireless, battery-powered prototype system based on temperature sensors that allows wireless temperature measurement for process regulation in ovens, or vacuum induction facilities to monitor and control the reflow soldering process. The measuring system is mounted directly onto the subassembly. Hence the temperature can be determined exactly. The measured data, using proprietary real-time TDMA communication protocols within the UHF-ISM frequency, is sent to a base station where up to 84 sensors can be managed simultaneously.

Besides compliance with the necessary measurement accuracy, encapsulation of the sensor is another challenge to the prototype system developed by Fraunhofer IMS. The capsule, which contains the sensor, is responsible for mechanical stability and the protection of the sensor against aggressive influences. It must be able to withstand the high surrounding temperatures during soldering, and beyond that prevent substances from degassing, which would result in diminished soldering quality. "The sensor system developed by us meets these requirements," reports Frederic Meyer, group manager of "High-Frequency Systems" from the business unit "Wireless and Transponder Systems" at Fraunhofer IMS. "Furthermore, the system distinguishes itself from other sensor solutions with the advantage that in the case of a sensor element malfunction, there would be no down time in the manufacturing process. The sensor is not mounted in a fixed position in the oven and undergoes the process together with the subassembly."

3 *Schematic illustration of the process integration*



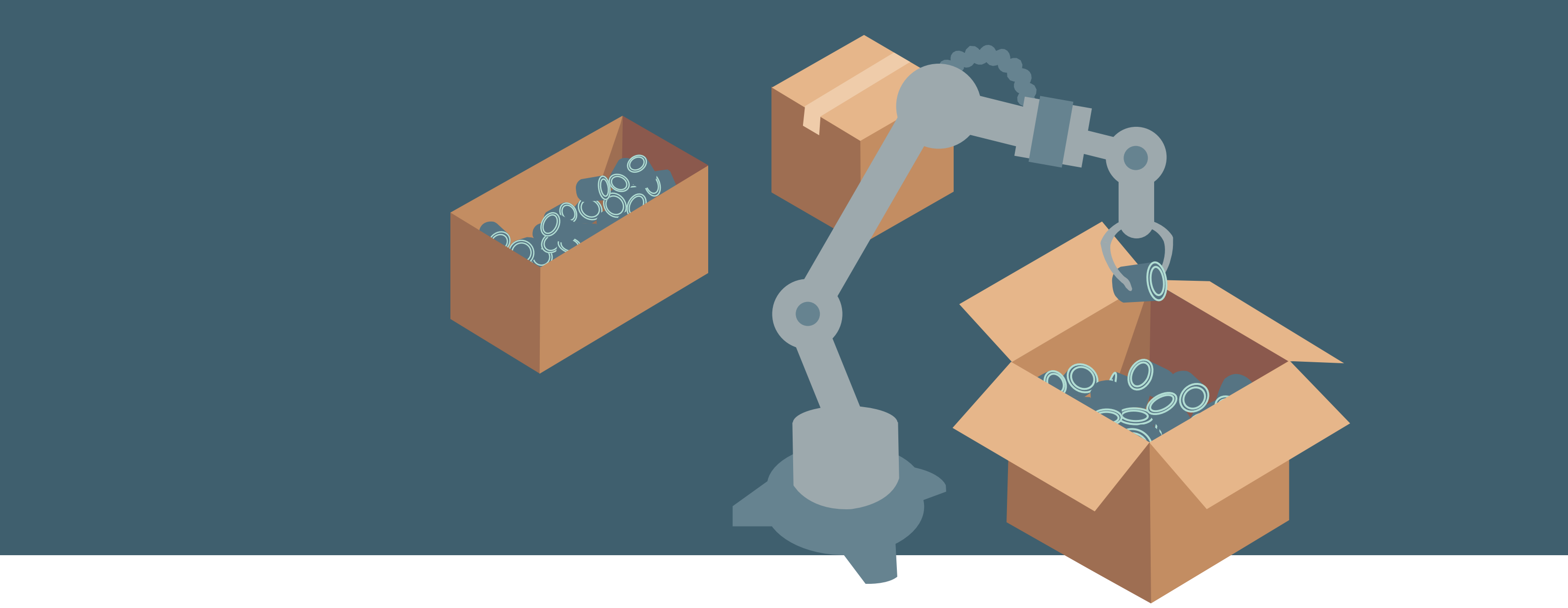
MULTI-SENSOR OPTIMIZES BIOPROCESSES

The digital interconnection between machines and products is also becoming a reality in biotechnology. That is a special challenge, since there are no fixed components, but living objects that multiply and change and are part of a process. An interconnected control must be capable of adjusting the process in real time.

At Fraunhofer IMS, scientists successfully integrated a miniaturized multi-sensor system onto a silicon microchip for the in-situ monitoring of bioprocesses. The system combines sensors for glucose, lactate, cell density and pH value on a chip with a surface of only 7 mm x 7 mm. As a result, it is, for the first time, possible to measure these four parameters simultaneously in-situ, which means directly within a bioreactor with especially broad measuring ranges for glucose and lactate. Compared to the individual sensors typically used in biotechnology, the sensory chip needs considerably less space, does not need sophisticated sampling from the reactor, is to be used much more easily and cost-efficiently, and can be easily sterilized. The sensors can be fabricated on CMOS chips, and in this way be combined with circuits for the read-out and transmission of measuring values.

Due to the real-time measuring of relevant process parameters, the system developed has the potential to shape a broad spectrum of biotechnological products much more efficiently, to enhance product safety and support the production of new drugs. The broad measuring ranges for glucose (1 mmol up to 600 mmol) and lactate (1 mmol up to 900 mmol) that can be achieved without dilution or other probe pretreatment, clearly exceed other solutions available on the market. Applications for the system range from fermentation processes for the production of alcohol to the production of antibodies, insulin and vaccines to cell cultures for the cultivation of tissue. Complex processes where a broad number of parameters need to be ideally adjusted can particularly profit from Fraunhofer IMS developments. Stefan Mross, researcher from the “Biohybrid Systems” business unit points out the advantages of the multisensor system: “In biotechnological manufacturing processes, a continuous measurement of relevant process parameters can decisively enhance the level of automation, the process yield and quality.” Integrated circuits for the read-out and transmission of the measured values are being developed at the institute from Duisburg. A new potentiostat for the read-out of the glucose and lactate sensors is available, which not only captures the measured values, but is also capable of transmitting these to a receiving point via a transponder chip. The wireless operation simplifies the use in biotechnological facilities and offers interesting possibilities for other branches, such as medical engineering and sports medicine, where mobile, flexible sensors are crucial. The sensor system can be adjusted to customer demands: additional sensors can be integrated or read-out circuits can be offered and further developed separately. Therefore, the offering addresses sensor manufacturers, users of bioreactors, the food and chemical industry, in addition to manufacturers of biomedicine.

4 *Multi-sensor microchip*



RFID SYSTEM FOR ROBOTS IN THE POSITION DETECTION OF BULK MATERIALS

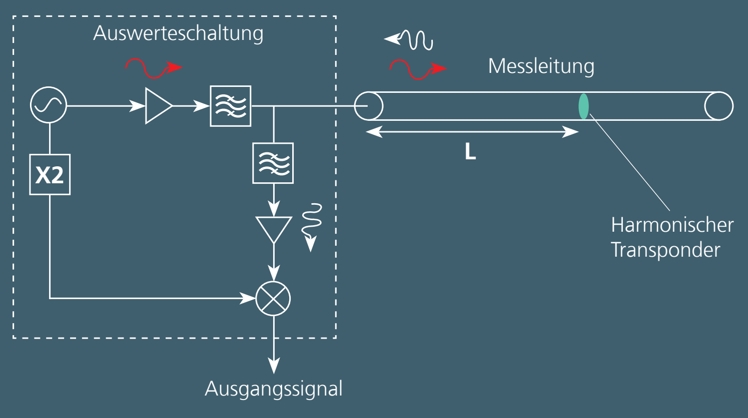
They screw and lathe, spray and sort, cut and grab – every day anew and always relentless: manufacturing robots have long since become vital to assembly automation and an inherent part of manufacturing processes. But the demands of industry 4.0 also effect the expected abilities of robots in manufacturing. Increasingly flexible production requires robots as smart industrial assistance systems with multi-modular, user-friendly user interfaces that enable a flexible interaction of machines, production systems and value chain networks. As previously simple robotic grapplers were solely capable of removing presorted bulk material from special hoppers, future assembly robots are to be able to remove individual bulk materials from a box in a targeted way. Since the bulk material can be processed in its delivered form, elaborate, manual presorting becomes obsolete. Furthermore, the robot would be flexibly useable. This is where Dr. Andreas Hennig, group manager of "Wireless Sensors" from Fraunhofer IMS begins. Together with his team, he developed a study for a RFID recognition system to enable the identification, positioning and determination of bulk materials by the robot as it "grabs into the box." The premise to this approach is that all participants within the supply chain of a product share common supply chain management using this RFID technology. The supplier of the bulk material blanks fits these directly with the tags needed for RFID recognition.

The RFID systems already available at the market are composed of a standard read-out device and an antenna array, and are used to determine the identification number of a RFID tag and to read out data from its memory. In the past, approaches using the so-called "RSSI" value ("Received Signal Strength Indicator") were pursued for the position detection of RFID tags. This value is determined by the read-out device and serves the evaluation of the transmission quality. In the course of this, conclusions based on the RSSI value about the distance between a RFID tag and a read-out device is not adequately possible. Multipath scattering through reflections, dampening influences of the surroundings, diffusion of antennas parameters, as well as different RFID tag operating states influence this value. Therefore, this value cannot be used for the precise determination of position and localization.

The near-field procedure, which was developed in the context of the study conducted by Fraunhofer IMS in cooperation with the Robert Bosch GmbH, is based on electro-magnetic coupling. In contrast to far-field procedures, which use electromagnetic wave propagation, here alternating magnetic fields within the near field are used. Problems caused by reflections and multipath scattering are omitted. The pronounced distance dependency of the field strength is used to achieve high precision. The procedure includes a coil arrangement at the head of the robot besides coils of the transponder mounted onto the work piece. The coils are coupled via a magnetic field. The magnetic coupling depends on orientation and localization. When this magnetic coupling is measured, conclusions can be drawn about the position and localization of the work pieces. Eventually, position and localization can be determined due to a special algorithm, which is integrated into the controls of the robot. For the detection of a very weak signal, the sensitive lock-in concept, known from metrology, is used.

The algorithm that was developed in the course of the study can be calculated quickly and therefore can be processed by systems with limited computing power. In order to obtain the required positioning information, the algorithm uses a 2-step procedure. In the first step, approximate position detection, based on intersection of spherical surfaces, takes place in order to determine the area to be calculated. In the second step, the precise position determination takes place based on "optimization under marginal conditions." With the procedure described, precision of up to +/- 1 mm is possible when using this algorithm.

"With our problem solving approach of using the alternating magnetic field, we can achieve a precise determination of position and localization with the functionality of RFID, which is also strong against static interference fields," Dr. Andreas Hennig sums up the advantages of RFID position detection. It can therefore be assumed that the position-determined "grab into the box" will be part of the everyday tasks of manufacturing robots in the future.



NON-LINEAR REFLECTOR FOR PRECISE DISTANCE MEASUREMENT

In order to ensure the correct monitoring and controlling of technical production facilities, precise distance measurement between two objects, or two points of reference within an industrial manufacturing facility, is often required. For example, the space between the lid of a container and the liquid's surface has to be able to be measured precisely in order to ensure an undisrupted flow in the production process. Therefore, a precise level measuring technique is always required where distances have to be measured precisely within a dynamic system. A broad number of these systems are closed or difficult to access, and as a result, distance measurement is not unproblematic.
There are basically three procedures used to measure distances: those that use light waves (laser), ultrasonic waves and electromagnetic waves.
The classic radar procedure is used when measuring with electromagnetic waves, where, based on a wave of coupled electrical and magnetic fields within the radiofrequency range, various recognition and localization techniques are possible. These electromagnetic waves expand linearly between a radar device and a reflector. The signal, which is reflected by the object and received by the radar, is time-delayed to the signal sent originally. The distance searched for is determined by the measured time offset.

In the course of a study addressing level measuring technology, scientists from the "Wireless and Transponder Systems" business unit at Fraunhofer IMS accepted the challenge of developing a new system for measuring levels. The results of several research studies, as well as an assessment of feasibility and production costs of possible procedures eventually identified a procedure where harmonic oscillation is released by using a transponder without a battery. A non-linear reflector sends waves in double frequency to the read-out device.
"Since non-linear reflector waves oscillate twice as fast as waves from a linear reflector, the whole system is simplified significantly. Above all, the read-out devices become more robust and cost-efficient," says Dr. Kamil Rezer, researcher at Fraunhofer IMS. The special challenge of the level-measuring technology study was to develop the non-linear reflector in such a way that the signal is still strong enough. "We optimized the non-linear reflector using special methods in a circuit simulation and carried out a vernier adjustment," describes Dr. Kamil Rezer, who supervised the study from its beginning.

A patent has been published for the procedure that was developed. The next step is the development of a demonstrator. To do this, an evaluation circuit on circuit board-based electronics has to be developed, built and tested. The harmonic transponder will also be constructed and optimized during the course of this development.

5 *Block-circuit of the measuring system*

6 *Liquid containers in the industy often require a precise distance measurement between lid and surface of the liquid*

7 *SOI technology and high temperature metallization allow an operating temperature range of up to 250 °C*

MEMS TECHNOLOGIES FOR HARSH ENVIRONMENT

They are tiny components that consist of a sensor element and an integrated read-out circuit. MEMS (Micro-Electro-Mechanical Systems) can process mechanical and electrical information and are crucial to modern and innovative solution approaches in electronics, and a large number of applications would hardly be possible from a cost-efficiency standpoint without them. Most of these small mechatronic microchips are sensors and actuators, and are made of silicon. Their structures can be smaller than a micrometer. Sensors and actuators make up the interface that connects the electronic data and signal processing to the real environment. MEMS are of crucial importance to industry 4.0. They recognize one or more physical quantities with a sensor element, and process data and supply it to a higher level system as analog or digital information. Localization, acceleration, humidity, temperature and pressure are among the quantities they measure. In automotive engineering, for example, vehicles need to be capable of gathering pressure data quickly and precisely in order to achieve low fuel consumption at low emissions. Pressure sensors are used for the different functionalities required, such as ABS systems or regenerative brakes. As a consequence of constantly increasing requirements from processes and products in the context of industry 4.0, sensor solutions commonly used today can no longer keep place and pressure sensors with higher performance capability are needed. Numerous sensor and actuator applications in the industry and automotive engineering require MEMS components or pressure sensors capable of reliably conducting their tasks in extremely harsh surroundings and at high temperatures. They must be able to withstand harsh environmental conditions, such as when mounted to oil well drilling heads, as acceleration sensors for engine vibration analysis or in the area of high-temperature microphones. Fraunhofer IMS currently develops a piezoresistive pressure sensor for these conditions, based on a thick-film SOI substrate with dielectric (non-conductive) isolated silicon resistors and a high-temperature resistant metallization. The term silicon on insulator (SOI) refers to a manufacturing technology for circuits based on special silicon substrates that contain a silicon layer on an insulating material that results in shorter switching time and lower power consumption at high temperatures.

Piezoresistive sensors measure pressure by using the piezoresistive effect and change their specific resistance in responds to a pressure load, whereas the resistive material is located within a thin silicon membrane. The piezoresistor changes its value in accordance with the compressive load. The dielectrically isolated piezoresistors were created in the frame of a project within the CMOS cleanroom at the Duisburg institute with the aid of established process steps from semiconductor technology, such as photolithography, oxidation and ion implantation. For high-temperature applications, piezoresistors can be isolated dielectrically by the buried oxide under the film, hence avoiding thermal induced leakage currents. Using high-temperature metallization that allows applications in the temperature range of up to 250 °C is another advantage of the process developed by the "Devices and Technologies" business unit at Fraunhofer IMS. In contrast common bulk silicon substrates reach their limits at temperatures of up to 125 °C. The process combines established high-temperature electronics (HT silicon on insulator (SOI) CMOS technology available at the institute enables the implementation of integrated circuits for the use within temperature ranges of up to 300 °C) with high-temperature pressure sensors.

Further experimental research, especially at higher temperatures in the context of sensor development, is currently ongoing.

Living Lab Day

New in 2015: At the open days visitor groups are guided through the application laboratories of the Fraunhofer-inHaus-Center.

Bau 2015 – Munich

At the world's leading trade fair for architecture, materials and systems, the "HomeGuardian" window sensor was met with great interest by the professional audience.

Meeting advisory board

The members of advisory board of the Fraunhofer IMS came together for their annual exchange at the Fraunhofer-inHaus-Center.

Photonics Event

The Institute presented its latest developments in the field of CMOS image sensors at the trade fair Photonics Event in the Dutch city Eindhoven.

Start for "NILM"

Partners of the joint research project "NILM" (Nonintrusive Load Monitoring) met at the Fraunhofer-inHaus-Center for the kick-off meeting.

"inHaus – auf den Punkt!"

The topic of the workshop series, which took place in November, was Smart Buildings – When the building surveils and the hacker opens doors.

Successful project closure for "HOT 300"

At the end of the year, the Fraunhofer joint project presented results of a construction and connection technology for microelectronics and microsystems in an operational temperature range of up to 300 °C.

Girls' Day

Female students interested in science were able to get a look behind the scenes of a research institute.

Visit of the Comissioner of the King

In context of Governor Theo Bovens's visit to NRW, the commissioner of the King from the province of Limburg visited the inHaus-Center together with a Dutch delegation and Ms. Dr. Angelica Schwall-Düren (MBEM NRW).

Semicon Messe Dresden

At the annual international exhibition for semiconductor products, materials and services in Europe, Fraunhofer IMS presented new developments at the common stand of the Fraunhofer Group.

“LINE SENSOR ‘XPOSURE’ TO SET NEW STANDARDS FOR OPTICAL INSPECTION”

Markt & Technik, November 2015

“THE DEVELOPERS OF FUTURE TECHNOLOGY”

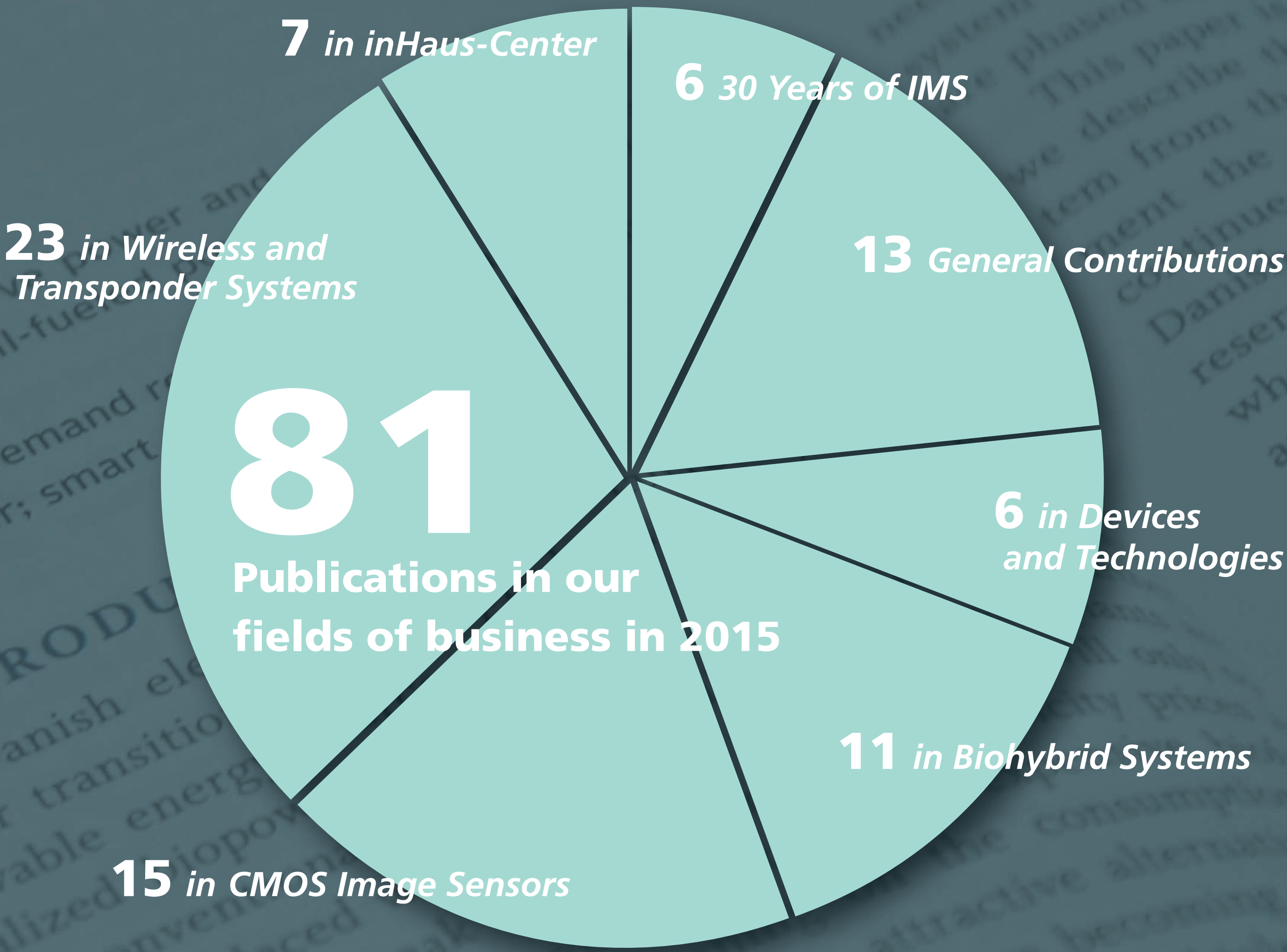
WAZ, March 2015

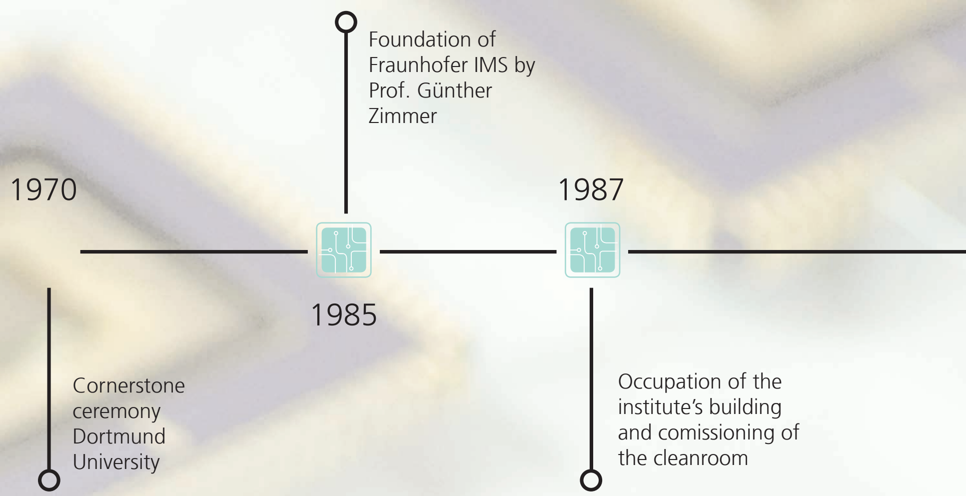
“SOLAR-POWERED SENSOR REMINDS YOU TO SHUT THE WINDOWS”

redOrbit, February 2015

“EXTREMELY LOW-COST, PAIN-FREE SYSTEM COULD BE A GAME CHANGER”

FierceMedicalDevices, July 2015


7 in inHaus-Center
6 30 Years of IMS
23 in Wireless and Transponder Systems
13 General Contributions
81
Publications in our fields of business in 2015
6 in Devices and Technologies
11 in Biohybrid Systems
15 in CMOS Image Sensors



30 YEARS FRAUNHOFER IMS

Mining and the steel industry coined the Ruhr Valley, but a structural change in the 1980s brought new activity fields to the valley. Besides commerce, plant and automobile engineering, microelectronics became part of the Valley in 1985 with the foundation of Fraunhofer IMS in Duisburg – from coal to wafer.

30 years IMS – 30 years of microelectronics. The past and today are worlds apart though. In 1985, the micro-processor is merely 14; the PC is 4 years young. The computer of this time has 256k RAM at its disposal is paced at 6 MHZ. The electronics in cars include the motronic from Bosch with electronic controlled fuel injection and transistor ignition. The commercial usage of microsystems isn't even 10 years old. The basis for Fraunhofer IMS was already found in 1970 at Dortmund University. Two years after its foundation in 1985, the newly constructed institute's building in Duisburg was opened and the cleanroom for the development of new micro-processors became operative. Further milestones for the optimization and efficiency enhancement of processors were the conversion to 6-inch wafers in 1996 and the conversion to 8-inch wafers eight years later. A crucial factor of success in the 30-year history of Fraunhofer IMS is the long-term cooperation with the Elmos Semiconductor AG, a developer and manufacturer of system solutions based on semiconductors. The development of an integrated pressure sensor, which was the forerunner to multiple pressure sensors of big companies such as Siemens or Infineon and is an important component of today's medical implants, can also be regarded as crucial to the institute's success. The foundation and the setup took place for many years under the direction of Prof. Günter Zimmer; since 2006 Prof. Anton Grabmaier holds office as the director of the institute.

In the past three decades the institute from Duisburg succeeded in setting itself apart from other research and development facilities by special technologies and developments: The high temperature electronic enables the application of microelectronic circuits within a temperature range of up to 250 °C. Conventional electronic reaches its limits at 125 °C in such harsh conditions. New procedures of post-processing serve the integration of sensors in thermography and the medical sector as well as the development of wireless systems for the industry automatization, medical implants or facility engineering and also are part of the special know-how of the institute. Coal, iron and steel were the economic pillar of the Valley for 150 years. Today microelectronics is the basis of the fourth industrial revolution far beyond the Ruhr Valley.

1 *Plenty of opportunities for exchange were given for the guests in context of the ceremony*

2 *How did it used to be? How it is today and how will it be in future? At a panel discussion, the current and former directors of the institute exchanged their views together with Dr. Rebbeka Jacobi and the moderator Nicole Noetzel*

3 *Dr. Karl-Thomas Neumann, chairman of the executive board of the Opel Group GmbH and former employee of Fraunhofer IMS, gave the ceremonial lecture on "The Automobile of the Future"*

1996
Conversion to 6-inch wafers

2004
Conversion to 8-inch wafers

2006
The management of the institute is assumed by Prof. Anton Grabmaier

2006
Start of post-processing activities

FUTURE
Microelectronic developments for the application fields facility, energy supply, mobility and production

1

Congratulators

from left to right:

Prof. Holger Vogt (deputy director of Fraunhofer IMS), Madam Minister Svenja Schulze (Ministry for innovation, science and research of the federal state NRW), Prof. Anton Grabmaier (director of Fraunhofer IMS), Prof. Reimund Neugebauer (president of the Fraunhofer-Gesellschaft), Dr. Rebekka Jacobi (scientific employee)

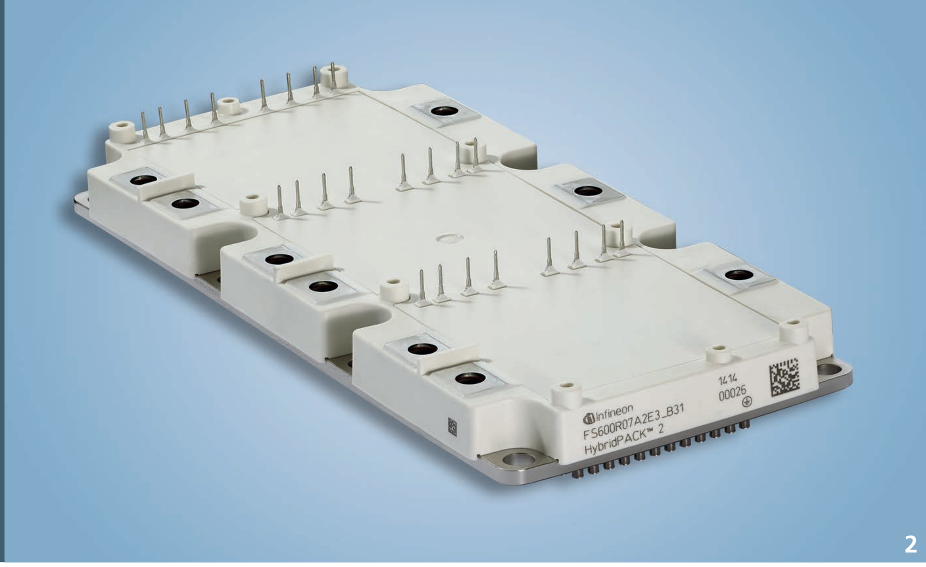
2

3

"To us the measuring system means a great technological advancement and it enhances the product's quality"

Nils Hellmich

Bachelor studies in Physical Engineering with the study focus Microelectronics were followed by master studies in Electrical Engineering with study focus on Micro- and Nanotechnologies. Since 2011, Nils Hellmich is employed as Equipment Engineer and since 2015 as Senior Engineer Assembly Power Modules in the fields of system procurement, system design, process development and process release.



2

GREAT TECHNOLOGICAL ADVANCEMENTS DESPITE TRICKY TASKS

Infineon Technologies AG has commissioned Fraunhofer IMS to develop a wireless and especially robust temperature measurement system for the smooth operation of soldering processes for high-performance electronics.

In order to achieve the specified product quality, adhering to certain temperature profiles is a requirement in many industrial manufacturing processes. Monitoring operational data is a crucial part of a successful production process, such as soldering processes for manufacturing electronic assemblies. In most cases, it is possible to mount the data collection sensors directly onto the point of reference to be measured and to wire it for energy supply and temperature detail read-out. There are applications, though, where wiring requires a great deal of effort due to several reasons. When sealed chambers within a production process complicate cable penetration, the point of reference is in motion or the surroundings are not suitable for a secure cable installation, and consequently, alternative measuring methods are necessary. Wireless temperature measurement for process regulation within an oven or in vacuum-induction soldering facilities also offers advantages for the monitoring and control of a reflow soldering process. In electronics, conventional soft soldering for the soldering of surface-mounted components is described as a reflow soldering process. The noise-free introduction of surface-mounted components into vacuum induction soldering facilities within a reflow soldering process is impractical with wiring.
For this application, Fraunhofer IMS has developed a prototype wireless, battery-powered temperature sensor system including thermal elements. The sensor system is mounted directly onto the assembly group and is therefore capable of determining the temperature at the location with great accuracy and high chronological resolution.
The Infineon Technologies AG needs a solution for its production process in high-performance electronics, which ties in exactly with the measuring system developed by the institute from Duisburg, and also meets many requirements that ensure an unimpeded production process at surrounding temperatures of up to 125 °C. These were challenges Fraunhofer IMS gladly accepted two years ago at the beginning of the commission. Besides the development of a system draft and the respective design, as well as the development of a base station for the evaluation of the measured data, the so-called "cold junction compensation" was an especially tricky task for the development. Thermic elements require the known temperature within a soldering process in order to be able to compensate for unwanted cold junctions. Therefore, the electrical potential of a reference temperature is measured and the disruptive potential is subtracted from the result. This process is known as "cold junction compensation." However, complete signal processing is linked to this process. The researchers at Fraunhofer IMS faced a tricky task in this project and achieved successful project closure.

In this interview, Nils Helllmich, Equipment Engineer in the Automation Team at the Infineon Technologies AG, reports on how Fraunhofer IMS solved this and other challenges, what exactly makes up a smooth manufacturing process and why this project is so close to his heart.

Mr. Hellmich, please explain briefly what exactly is manufactured on the assembly line and in the vacuum induction soldering process.

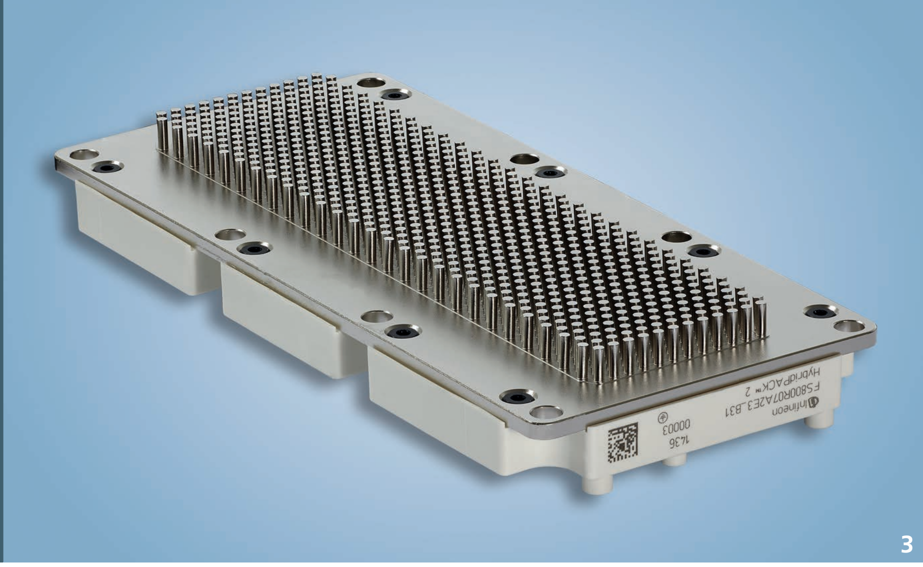
Infineon Technologies AG manufactures IGBT modules, which distinguish themselves through high electrical potential and reliability. These Insulated Bipolar Transistors, IGBT for short, are powered semiconductor devices used in high performance electronics, in power engineering, as well as in high-voltage direct current transmission technology. The performance electronics are part of the electrical engineering branch and address the conversion of electrical energy with switching electronic components. IGBT modules are characterized by good transmitting behavior, high voltages and currents, as well as efficient robustness against electrical shorts. The performance module "HybridPACK™ 2" is manufactured especially for the automotive industry. This module family is a special product series manufactured for applications of the highest power density and efficiency, and which implements the standards of the automobile industry. Vacuum soldering for the soldering of surface-mounted components onto DCB substrates is used for its manufacturing process. DCB substrates allow a neat electrical thermic compound using copper und ensure ideal heat dissipation. The assembly of components consisting of various materials takes place in the oven within a vacuum, under pressure and in surrounding temperatures of up to 125 °C. The vacuum helps to minimize the oxidation of both parts and the solder. "HybridPACK™ 2" is designed as a special module for a power range of up to 100 kW of continuous power over 600 to 800 amperes and 650 volts. That is indeed a lot!

What applications does Infineon Technologies AG manufacture the "HybridPACK™ 2" performance module for?

Infineon basically offers a broad range of IGBT solutions for various voltage and current classes for individual applications and the automotive branch. The modules from the "HybridPACK" family were solely designated for automobile applications. They are responsible for hybrid and electric vehicle engines.

Please describe your underlying requirements and the challenges of this project.

In a conventional fitting of cooled power semiconductors, the chip is soldered onto the copper surface of a DCB substrate. The copper-coated bottom of the substrate is soldered onto a copper bottom plate, which, together with a heatsink paste, is attached to a cooling element, in this case onto cooling ribs. The copper plate ensures the prolonged lifespan of the module. The unique feature of our module is the fact that the cooling ribs are attached underneath the bottom plate, preventing the thermic elements from being placed there. This requires special mounting for the manufacturing process of our "HybridPACK™ 2"module. In the course of the work scheduling, the soldering molds are prepared outside the oven and their functionalities tested. Afterward, the soldering molds are transferred to the soldering process via a conveyor belt and run through the process together with the thermic elements and the sending node. One of the most elaborate tasks that had to be addressed at the beginning of the project was the enormous temperature increase in the oven. To ensure product quality, precise thermic element measurements have to be possible at surrounding temperatures of up to 125 °C. Further requirements of ours included as few foreign substances as possible being emitted during the process, and the soldering process is not being polluted by the degassing. Furthermore, the harsh surrounding conditions require a robust setup of the system for the application within a vacuum. Formic acid, which is used as an antioxidant for the process, adds to the difficult conditions as well as the magnetic fields within the chambers.



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What solutions were developed by Fraunhofer IMS for the requirements and challenges you described?

During the two-year project, in cooperation with Infineon, Fraunhofer IMS developed a wireless battery-powered measuring system with thermic elements for the process regulation of the soldering process of our “HybridPACK™ 2”module – although the installation space was very small. The available space for the sensor element only measures 85 x 50 x 25 mm. The development was preceded by market research addressing the question of which electronics can be used. The unique feature of this robust measuring system is that it is possible to embed it directly into the manufacturing process, as well as perform precise thermic element measuring in surroundings of up to 125 °C. The system developed enables collision-free wireless communication even with a large number of given sensors, and beyond that, offers a high measurement rate. Data traceability, meaning information such as what temperature was achieved where and when, is available anytime afterwards, and is another advantage of the system. The most difficult part of the development was surely the application of the “cold junction compensation” and the processing of data that was necessary for the development of a new communication procedure. To us, the measuring system means a great technological advance and the enhancement of the product’s quality. In the future, maintenance will essentially require less effort due to applying the system, because the entire process does not have to come to a standstill in case of a possible breakdown.

How did the cooperation with the institute from Duisburg go?

Cooperation with Fraunhofer IMS went exceptionally well. After a first stage of orientation on behalf of the institute, the expected results were completely achieved after the two-year duration of the project. At the same time, the communal work was characterized by constructiveness and expertise, and I would definitely recommend follow-up projects. Although Infineon Technologies AG currently focuses on other technology branches, a future application of the system developed by Fraunhofer IMS cannot be ruled out. I wrote my master’s thesis on this project. After completing it, I assumed control of the project, and therefore this project is very personal for me.

Mr. Hellmich, thank you very much for this interview!

1-3 HybridPACK™ 2


JAVA 3D Programming
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4. Posters

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5. Patents

5.1 Granted Patents

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6. Theses

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6.2 Master Theses

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Contact

Fraunhofer Institute
for Microelectronic Circuits and Systems
Finkenstrasse 61
47057 Duisburg
Germany
Phone: +49 (0) 203 / 37 83-0
Fax: +49 (0) 203 / 37 83-266
www.ims.fraunhofer.de/en

Fraunhofer-inHaus-Center
Forsthausweg 1
47057 Duisburg
Germany
Phone: +49 (0) 203 / 713967-0
Fax: +49 (0) 203 / 713767-277
www.inhaus.fraunhofer.de/en

Editorial notes

Editorial Team	Verena Sagante
Design and Layout	Melanie Eiting Viktoria Gerage Maren Kemmerling
Adress of Editorial Office	Fraunhofer Institute for Microelectronic Circuits and Systems Finkenstrasse 61 47057 Duisburg Germany Phone: +49 (0) 2 03 / 71 39 67-235 presse@ims.fraunhofer.de

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