Fraunhofer
ICT

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

# ANNUAL REPORT 2017/2018

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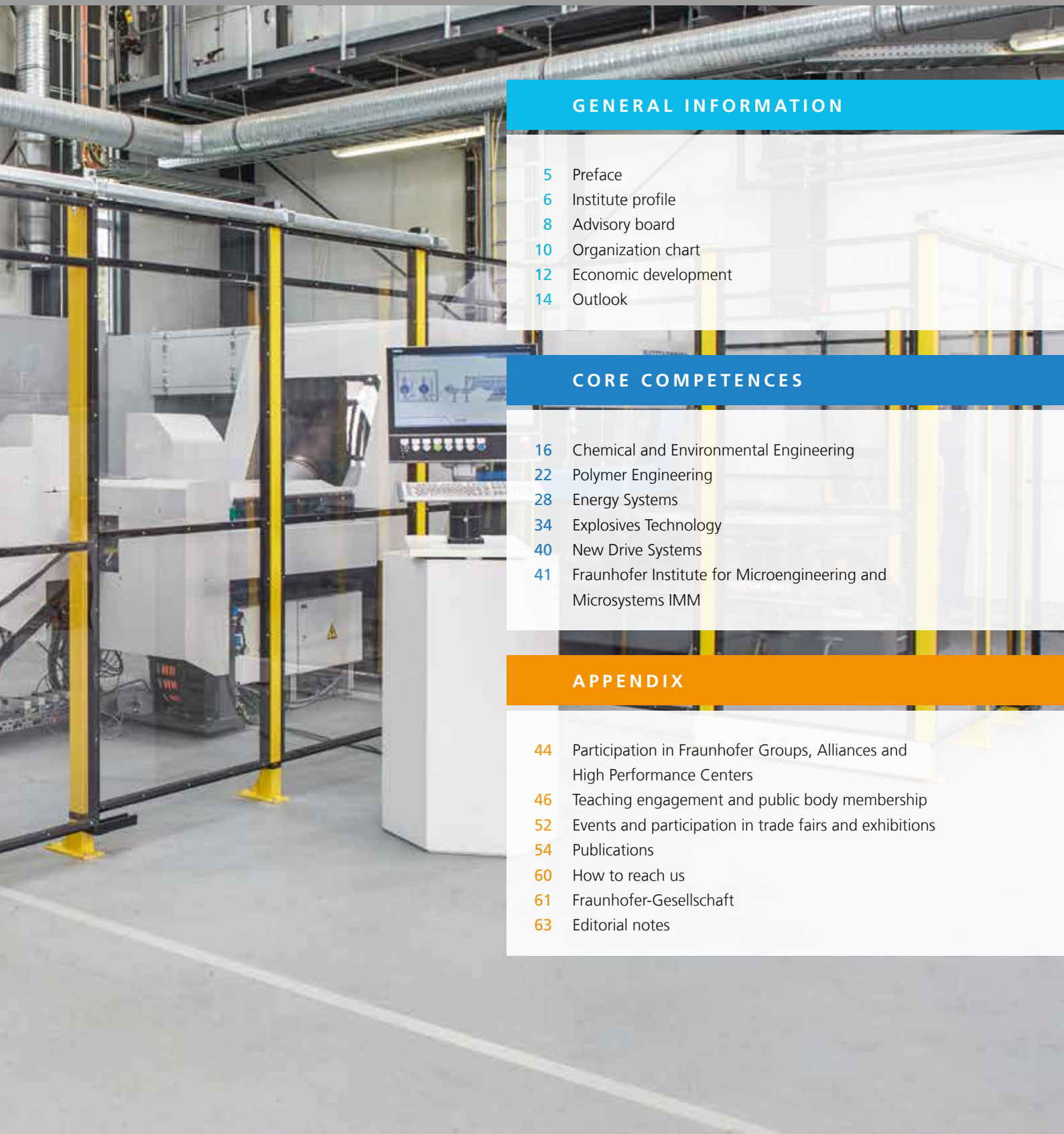

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# GENERAL INFORMATION

# STRENGTHENING OUR CORE COMPETENCES

We have been very successful on the research market for many years. Indicators developed by the Fraunhofer-Gesellschaft allow us to measure and objectify this success. Our research results are of course a fundamental indicator, but it is also important to have a variety of funding sources, including national and European programs. This enables us to cover a wide range of projects, from new topics with mid-term commercial relevance (3–5 years, or sometimes longer) through to specific bilateral cooperations with clearly defined research and development aims, for implementation in industry.

Our former Project Group for Functional Lightweight Design in Augsburg was combined with other units to become an independent institute in July 2016, and the institute in Mainz became the independent Fraunhofer Institute for Microengineering and Microsystems IMM in January 2018, so we have now refocused our attention on our sites in Pfinztal and Karlsruhe.

The former Project Group for New Drive Systems on the East Campus of the Karlsruhe Institute of Technology (KIT) was evaluated positively and is currently run as a department of Fraunhofer ICT. Its topics fit in well with the regional network on mobility systems in Karlsruhe. Within this network, emphasis is placed on transportation and society, in terms of city planning for future mobility needs, digitalization for automated and autonomous driving, and vehicles and the environment, with the topics of drive trains, engine development, energy storage devices and lightweight vehicle construction.

Based on our current economic situation, our aim within each of our core competences is continuity. This means that we are further developing our core competences in explosives technology, chemical process engineering, environmental technology, energy systems and polymer technology, and investing in modern production technology in order to remain competitive.

We are making some strategic investments in the context of collaborations extending beyond the institute, i.e. in the field of lightweight design with the University of Ulsan in South Korea, and in the field of energy storage devices for renewable energies with the University of New South Wales in Sydney.

This annual report provides an overview of the direction our current activities are taking. If you would like to discuss the contents of the report, or anything you feel should be included, we would be delighted to hear from you. We consider dialogue with our partners and customers an important opportunity, as it helps us to choose the most relevant topics in the future.

With best wishes
Peter Elsner

# INSTITUTE PROFILE

**Fraunhofer Institute for Chemical Technology ICT**

The Fraunhofer Institute for Chemical Technology ICT focuses on process scalability and on the transfer of research results from laboratory to pilot scale, or even pilot-level applications. In 2017, 540 employees were working at Fraunhofer ICT's site in Pfinztal (close to Karlsruhe) and 25 in the New Drive Systems Department at the east campus of the Karlsruhe Institute of Technology KIT.

Our customers and project partners include companies concerned with chemicals and chemical process engineering, vehicle manufacturers and their suppliers, the plastics processing industry, manufacturers of materials, recycling companies, companies in the field of energy and environment, customers concerned with safety-related issues, and the construction and aviation industries. In addition, we are the only explosives research institute in Germany to cover the entire development chain for explosives, from the laboratory through to the pilot plant and system.

**Our core competences**

The core competence "Chemical and Environmental Engineering" is concerned with the design and implementation of novel, resource-efficient chemical processes, from the laboratory to the technical scale. This core competence spans the entire processing chain – from raw material processing, chemical engineering and downstream processing through to subsequent processes such as the refinement and shaping of products.

In the core competence "Polymer Engineering" we conduct application-related research on polymer synthesis and material technology, plastics processing, component development and manufacture and the recycling of plastics and their applications.

Important research topics include sustainable and affordable energy supply and efficient energy management. In the core competence "Energy Systems" we are concerned with energy storage devices for mobile and stationary systems, fuel cells, heat storage devices and material energy storage. The institute's electrochemical and chemical know-how has been accumulated over more than 30 years, laying the foundations for the development of efficient and cost-effective storage devices and converters.

Based on long-standing experience, and as the only German research institution in the field of "Explosive Technology", we assist the German Federal Ministry of Defence, the defence industry and the public sector with current challenges in the field of domestic and international security. Fraunhofer ICT covers the whole system development chain, from the raw product through to the prototype of an explosive.

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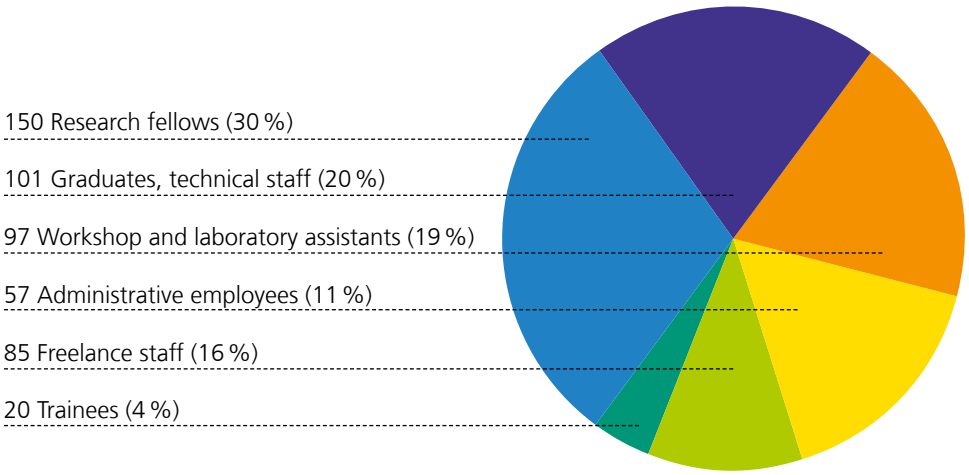
# ECONOMIC DEVELOPMENT

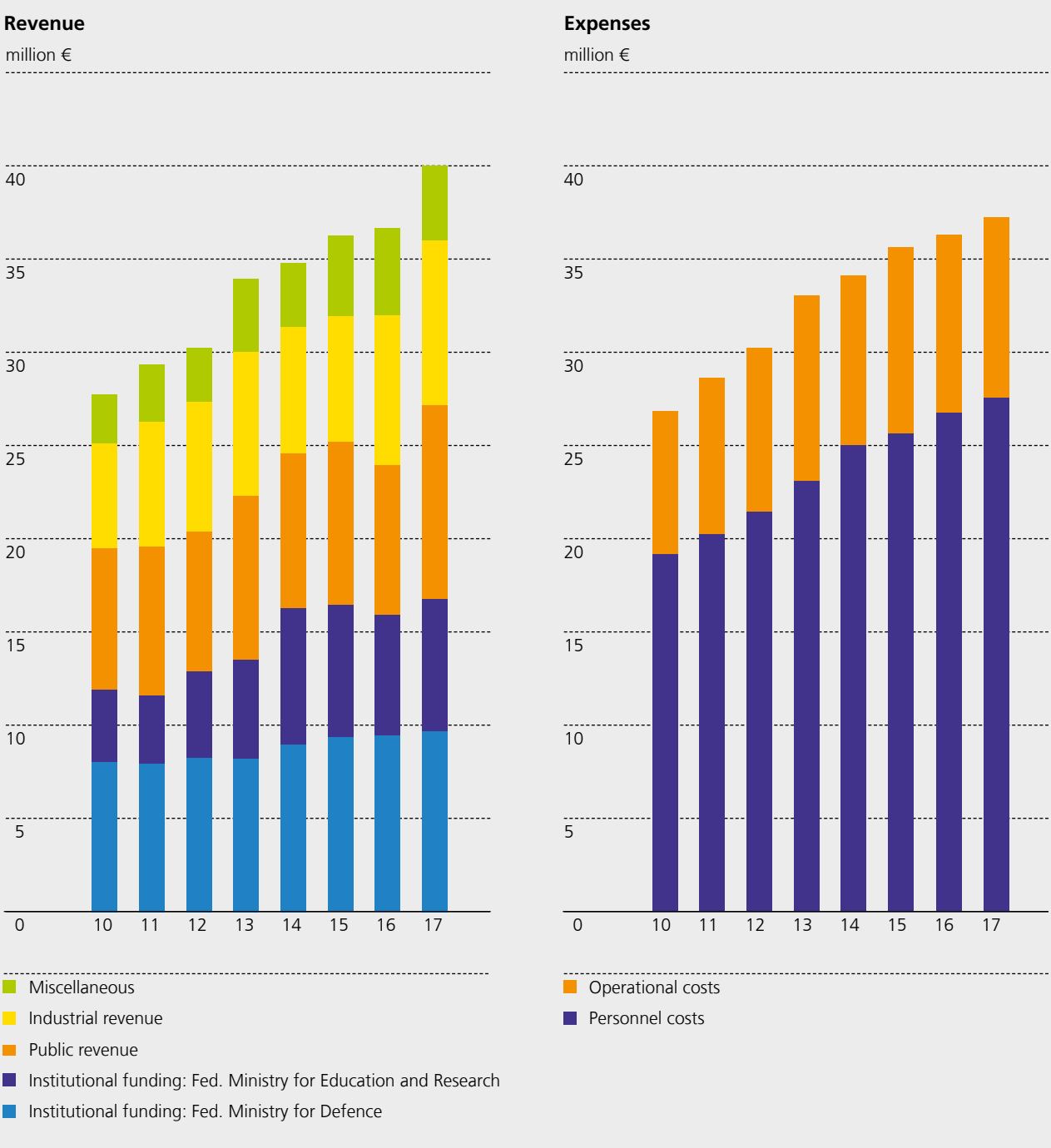
The total budget at Fraunhofer ICT's main site on the "Hummelberg" and "New Drive Systems" on the East Campus of the Karlsruhe Institute of Technology (KIT) was almost 40 million euros in 2017. Approximately 74 percent of this was personnel costs. Our research and development tasks for the German Federal Ministry of Defence had a budget of 13.5 million euros, and thus continue to be a stable foundation making up one third of our turnover. Correspondingly, our turnover in the civil sector was about 26.5 million euros, i.e. almost two thirds of our activities. In particular our industrial revenues have increased significantly to 8.8 million euros, which is a growth of 10 percent. Our percentage of industrial revenue was almost 37 percent, which is a ten-year high. Through effective management, in 2017 we were again able to save some unused institutional funding as a reserve. This forms a good basis for further investments and modernization, and also enables our employees to benefit from the institute's success, through research bonuses.

In terms of personnel, our focus is still on effective training. We currently have 20 trainees and 15 official PhD students. Of the 400 pay-scale employees, 150 are scientists, 100 are technicians, around 100 are workshop or laboratory assistants and 57 work in administration.

**Workforce structure of Fraunhofer ICT: Status December 31, 2017**



**Financial development of Fraunhofer ICT, 2010 to 2017.**



# OUTLOOK

The financial success we have achieved in the past year 2017 shows that no urgent changes are needed. This is a comfortable situation to be in, but the risk is that we will become complacent and stop pushing our own boundaries. In times of success it is therefore important to keep our focus on the future: stagnation is a step backward.

Safety at work has become an important topic in 2017, due to an increased number of accidents and resulting sick days. We are building on existing safety measures by altering processes, asking critical questions and emphasizing prevention, for example by exchanging information on near misses. Safety is another topic where "business as usual" leads to complacency and increased risk.

We are also striving to become more sustainable. Employees have launched their own sustainability initiatives, including beekeeping on the institute grounds, blood donation, waste separation and sustainability training for employees.

After IMM in Mainz became an independent institute (Fraunhofer IMM) on January 1, 2018, we returned to our own core tasks. Our objective is to maintain our competences in the civil and defense sectors. We therefore aim to maintain a staff of up to 550, with a full-time equivalent of approx. 400 employees. This figure includes our 20 trainees and our student assistants.

We will remain attentive to necessary changes and adjustments to our organization and research topics, despite the positive environment and the current stable economic situation. The strength of an organization can be demonstrated both in good times and in bad. We're on the best possible path!

# CORE COMPETENCES

# CORE COMPETENCE
# CHEMICAL AND ENVIRONMENTAL ENGINEERING

The core competence "Chemical and Environmental Engineering" is concerned with the capacity to design and implement novel, resource-efficient chemical processes, from the laboratory to the technical scale. It covers the entire process chain from raw material processing, chemical reaction engineering and downstream processing (e.g. purification and separation technologies) through to subsequent process steps such as product refinement (e.g. crystallization and particle technology) and shaping (e.g. formulation and compounding).

Target parameters of chemical process design and process optimization include product quality, safety, cost-effectiveness and sustainability. Particularly for processes involving fine and specialty chemistry, high selectivities and yields must be achieved, and specific properties obtained in the target product.

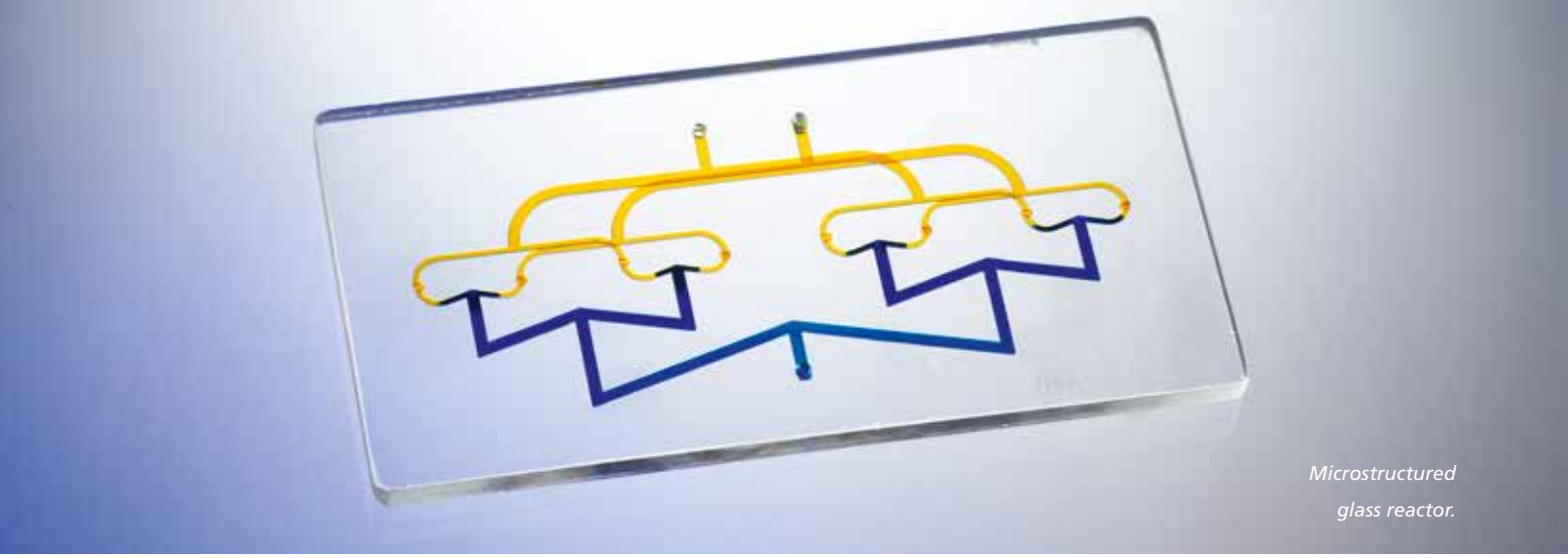
In the search for a cost-effective process, energy-efficient and resource-saving technologies are key topics of research. However, sustainability also requires the minimization of waste streams, the reuse of material fractions and the application of renewable raw material sources.

At Fraunhofer ICT we meet all these requirements through the development of modern process technologies. A considerable part of our work is exclusive, commissioned by industrial customers. A successful approach often involves a paradigm shift from discontinuous to continuous processing. For example, continuous processing involving micro chemical engineering is a key element in process design and intensification. It enables processing within new processing windows (for example high temperatures, high pressures, high concentrations, short reaction times) that are difficult or even impossible to realize using classical methods, and in which chemical reaction processes can be optimized from a technical and economic perspective. These processes are often synthesis steps used in the production of precursors or products in the field of fine and specialty chemistry.

In addition, continuous processing is being systematically extended to further processing steps and new application fields. These include in particular the intensification of downstream processing (extraction, purification, phase separation), the size-controlled production of nanoparticles and microcapsules, the development of environmentally-friendly catalytic processes and electrochemical syntheses, and the intensification of multiphase reaction processes (gas/liquid, liquid/ liquid).

An important tool in process design is cutting-edge process analytical techniques, some of which have been developed in-house. We are achieving particularly significant progress in the development and adaptation of rapid spectroscopic and calorimetric process analysis. We can use this to monitor chemical processes with a high temporal and spatial resolution. The techniques often reveal kinetic, mechanistic and safety-related data for optimized process design. The rapid availability of comprehensive process-analytical data enables both a significant reduction in process development times and the increasing use of such data in the digitalization of chemical reaction processes - as currently proposed in the initiative "Chemistry 4.0".

*Modern process development using faster process analysis.*



*Microstructured glass reactor.*

Our comprehensive know-how in the field of explosive technology means that we have advanced competences in the safety-related design and operation of hazardous processes (explosive or toxic). In the development of high-pressure processes we also benefit from our long-standing experience in the processing of supercritical fluids. In terms of process safety and stability, tailored process monitoring and control is a core element of our development work. Our capacity to scale up synthesis and increase throughput in multipurpose, mini plant and pilot units developed in-house means that we can prepare larger quantities of substances for testing, and examine safety and economic aspects using realistic operating parameters and scales.

To enable the use of renewable raw materials we develop biorefinery processes and evaluate them from a bioeconomic perspective. Biogas processes for energy storage complete the institute's activities in the field of bioeconomics. These processes incorporate the feed materials wood, fats and oils, carbohydrates and other biomass materials which do not compete with food production. The activation of $CO_2$ (from the air) to generate short-chained alcohols using the PTL (power-to-liquid) process is the most recent development in terms of reaction technology. Because the hydrogen is manufactured with renewable energy, the PTL process enables operation at the required location independently of raw materials.

Bio-based products form a basis for various chemical platforms for the chemical industry. Economic assessments of the down-stream processes are a core part of our initial evaluations of the cost effectiveness, often supported by our holistic life-cycle assessments (LCAs). We are therefore currently working on the intensification and energy optimization of classic separation techniques through reactive extractions. Special salt mixtures enable selective extraction into the mobile phase. Especially for product streams with a low concentration, this process is more cost effective than a thermal separation process.

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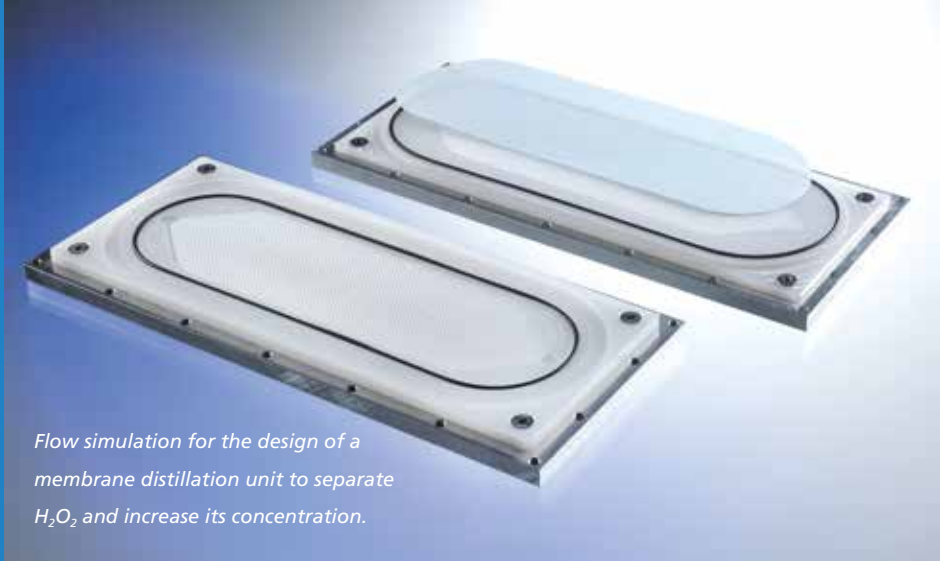
*Electrochemical reactor for $H_2O_2$ production (fivefold stack).*



*Flow simulation for the design of a membrane distillation unit to separate $H_2O_2$ and increase its concentration.*

# ELECTROCHEMISTRY MEETS PROCESSING TECHNOLOGY
# DECENTRALIZED PRODUCTION OF $H_2O_2$

In 2016, one third of electricity produced in Germany was obtained from renewable sources, and this percentage is rising. The energy transition has led to the generation of low-carbon electricity, which opens up new pathways for the design of current-driven chemical processes. In the lighthouse project "Electricity as a resource", ten Fraunhofer institutes are developing and optimizing different electrochemical methods to produce important base chemicals using this electricity. Fraunhofer ICT is developing a demonstration process for the decentralized electrochemical production of hydrogen peroxide ($H_2O_2$) and its continuous supply to a downstream chemical process.

Hydrogen peroxide is used in a variety of synthetic/chemical reactions, as a green and selective oxidizing agent, because the only reaction product is water. It has therefore increasingly been used in large-scale chemical production, leading to a significant rise in demand. The current state of the art is the industrial production of $H_2O_2$ using the so-called anthraquinone process. However, due to the high raw material, operating and investment costs involved, the anthraquinone process is only economically viable in large production units (> 40.000 t/a). For this reason the production of $H_2O_2$ is concentrated in centralized production sites and requires a high economic effort in terms of storage and transportation logistics. Many users of smaller and medium quantities, however, would prefer to avoid the complicated logistics and storage, and to produce $H_2O_2$ themselves at their own location. The process development at Fraunhofer ICT responds to this demand.

The demonstration process enables the continuous, electrochemical production of $H_2O_2$ in the aqueous reaction system through the cathodic partial reduction of atmospheric oxygen. Key topics are the development of suitable electrocatalysts and the design and upscaling of gas diffusion electrodes and the electrochemical reactor.

Continuous processing techniques, some of which use micro-structured process components, are developed at Fraunhofer ICT for the subsequent concentration and separation of $H_2O_2$ from the electrolyte, and for the reuse of the electrolyte in the electrochemical process. Modern and safe process control and the spectroscopic online-monitoring of the downstream processing make it possible to directly reuse the oxidizing agent produced. The forward integration of the pre-treated $H_2O_2$ stream is currently being demonstrated using the example of a selective oxidation for the desulfurization of fuels. Through the parallel development of suitable oxidation catalysts, it is already possible to achieve complete reactions and fast desulfurization rates using diluted (e.g. 3 %) $H_2O_2$ solutions.

The application potential of decentralized, small-scale units for the local production of $H_2O_2$ on a kilogram-scale, which can ideally be operated with 100 % sustainable electricity, goes far beyond classical chemical synthesis processes. There is a demand for environmentally-friendly bleaching and oxidation processes in numerous other sectors, such as medical and hygiene technology, food technology, agriculture, water treatment and the textile and cleaning industry.

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# BASE CHEMICALS AND FUELS FROM $CO_2$ AND WATER

Green methanol, green higher alcohols and green oxymethylene ethers (OMEs) have the potential to play an important role in future energy storage, in the transport of chemically bound energy and as raw materials for the energy, fuel and chemistry sectors. The technologies required for their synthesis – so-called "power-to-X" (PtX) technologies – are currently under research and are being developed at Fraunhofer ICT.

"Power-to-X" means technologies which convert electricity from renewable sources into material energy storage devices, energy carriers and chemical products. At Fraunhofer ICT, energy from renewable sources (e.g. wind turbines or solar energy plants) can be used for the synthesis of tailored organic molecules with a high added value (e.g. alcohols, solvents, plastic products or other chemical products). Methanol can be produced catalytically from synthesis gas ($CO + H_2$) as well as from carbon dioxide and hydrogen ($CO_2 + H_2$). The catalytic conversion of "green" hydrogen made from renewable sources (electrolysis of water), is commonly referred to as the "power-to-X" (PtX) process, where X represents methanol ($CH_3OH$). By varying the reaction conditions (e.g. pressure, temperature) and adjusting the catalysts, more highly condensed compounds can be obtained (e.g. ethanol or oxymethylene ether (OME)). These products can be introduced into a piping system and used as fuels, chemical raw materials or energy sources. Fraunhofer ICT has decade-long experience in the field of high pressure reactions, and therefore sufficient expertise to carry out these syntheses.

The significant drawback of current combustion engines is the use of fuels made from fossil energy sources (crude oil, natural gas) which emit $CO_2$ and other pollutants during combustion. A promising pathway towards developing a sustainable combustion engine is the use of PtX processes to generate renewable and clean fuels from $CO_2$. Alcohols leave almost no soot during combustion, so they require little exhaust-gas management.

In addition, the use of these fuels means that available infrastructure, i.e. the existing network of filling stations, can be exploited. There are additional social benefits: The use of carbon dioxide and regeneratively produced hydrogen means that the controversial food vs. fuel discussion is irrelevant, and speculative business models are avoided because there is no transport or processing of biomasses. PtX plants can be implemented almost everywhere, as the only requirement is access to renewably generated electricity. As no synthesis is carried out in aqueous reaction systems, there is no requirement to treat contaminated waste water. By modulating the output, PtX plants can help to balance out variations in the grid. The production costs of PtX-based products are strongly dependent on electricity prices, so highly-efficient electrolyzers are required for the hydrogen synthesis. The catalyst is another key factor for the cost effectiveness. There is a high potential for research in this area, with the aim of making the entire concept economically viable.

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# FACILITIES AND EQUIPMENT

- Various synthesis technologies for chemical and mechanical process technology
- Pilot plant for upscaling to the 50 kg or 50 l range
- Safety boxes for the remotely-controlled reaction engineering of hazardous processes
- Microwave processing test stands and synthesis units
- Facilities for the parallel screening of synthetic approaches (including under high pressure)
- Numerous reaction calorimeters (batch and continuous)
- Cutting-edge process spectrometer for inline, online or atline process monitoring (UV/Vis, NIR, IR, Raman) in one or in multiple dimensions
- Continuous and discontinuous high-pressure plants for hydrothermolysis, oxidation, hydrogenation, and reactions in subcritical and supercritical water
- High-pressure extraction units for extraction in supercritical carbon dioxide
- Pilot plant for crystallization from solutions using supercritical fluids
- Systems to determine solubility and phase equilibria at high pressures
- Various distillation units for the thermal separation of high-boiling/sensitive material mixtures (down-flow evaporator, high-temperature vacuum rectification)
- Units for liquid/liquid and solid/liquid extraction
- Mobile equipment for reverse osmosis, nano- and ultrafiltration
- Equipment for solution and melt polymerization
- Coating processes
- Spray and melt crystallization processes
- Comminution technology
- Particle size and crystal structure analyses
- Extensively equipped chemical, spectroscopic, thermal and mechanical analysis laboratories
- Units for surface analysis, volumetric and gravimetric sorption measurements
- Computer tomography
- Environmental simulation units (climate, vibration, destructive gases, corrosion, protection category)
- Facility for the measurement of volatile organic compound (VOC) emissions from materials and components

# CORE COMPETENCE
# POLYMER ENGINEERING

Since 1994, within its core competence "Polymer Engineering", Fraunhofer ICT has successfully conducted application-related research on technical polymers, ranging from polymer synthesis and material technology, plastics processing, component development and manufacture through to recycling.

When synthesizing polymers, we mostly focus on the further development of so-called conventional polymers such as polyurethanes, polyesters and polyamides. The aim is to expand their functionalities (for example by improving temperature resistance), enabling their use in a wider range of applications. One example is the targeted synthesis of thermoplastic polyurethanes, which can be processed more easily than other thermoplastic materials. Another example is optimizing the synthesis of additives and flame retardants for new material compounds, such as those based on biopolymers. Cutting-edge flame retardant systems use phosphates or nitrogen instead of halogen-containing components.

The research group "Compounding and Extrusion" concentrates on process and material development for processing technologies. Its tasks include extractive compounding processes for emission reduction, the development of bio-based polymer compounds for high-quality molding products and additive manufacturing processes.

In the "Nanocomposites" group we investigate the manufacture, processing and characterization of functional composites which use nanoscale additives in order to obtain materials with improved electrical, mechanical or thermal properties.

The research group "Foaming Technologies" is concerned with particle foam technology and the manufacture of foamed semi-finished products in the direct foam process. The focus is on the optimization of conventional materials and, above all, the foaming of bio-based and technical polymers that are usually more temperature-resistant. By combining polymer foams with phase change materials it is possible to generate highly-insulating hybrid lightweight construction materials, providing additional possibilities to control room temperature.

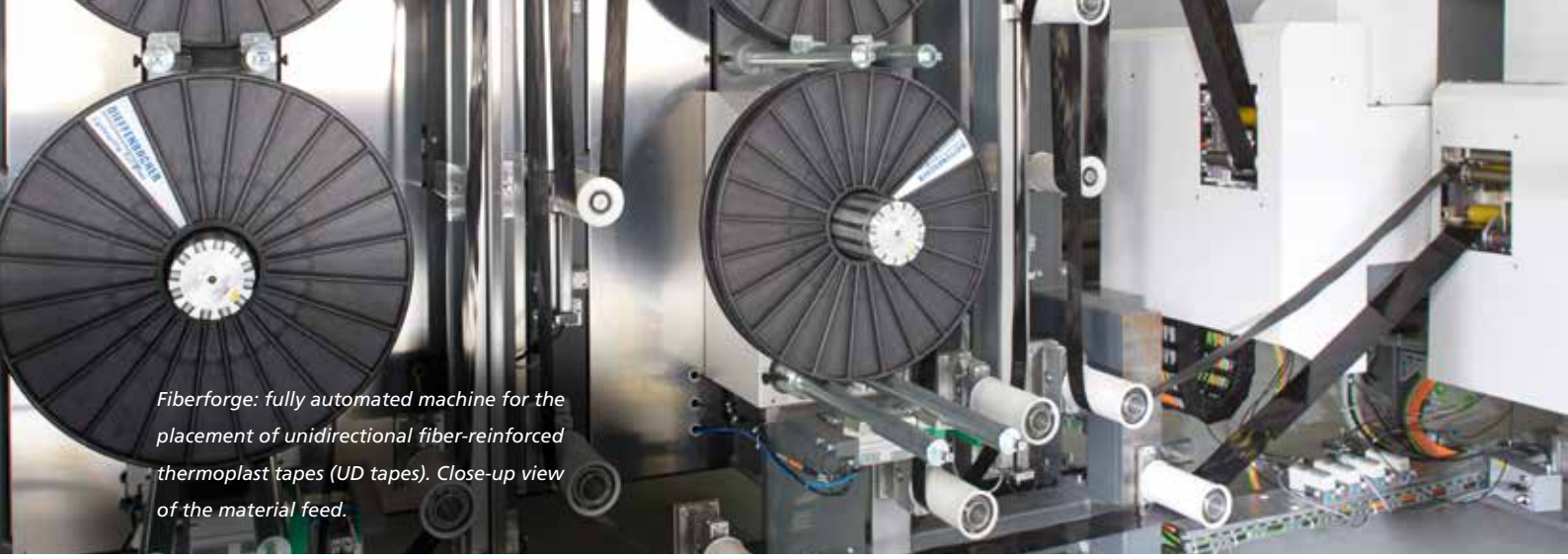
The research group "Thermoplastic Processing" emphasizes standard and specialized injection molding and compression molding processes, and especially thermoplastic fiber composite materials and their processing technologies.

In the "Thermoset Processing" group, pioneering work is carried out into material and process development for the large-scale manufacturing of long-fiber-reinforced composite components suitable for structural and surface components. Our core competences are the material development and processing of sheet molding compounds (SMCs), PU fiber spraying and thermoset injection molding.

The "High-Performance Fiber Composites" group concentrates on the further development and industrialization of resin transfer molding (RTM) processes and wet compression molding (WCM) processes for the large-scale manufacture of components made from thermoset and thermoplastic high-performance fiber composites. Important elements within the process chain are the production of textile preforms, their handling, their combination with polymer foams and metallic structures, and subsequent resin infusion.

In the "Microwave and Plasma Technology" group, we develop testing units and measurement technology for microwaves and microwave-based plasmas. Part of the research work is also the numerical simulation of the electromagnetic field. Applications include the microwave-based heating of polymers, adhesives and resin systems, and the coating or modification of surfaces using plasma-enhanced chemical vapor deposition. Emphasis is placed on corrosion-resistant layers, especially for metals and polymers, and on nanoporous adhesive layers.


*Fully automated injection molding machine to process free flowing thermoset materials and thermoplastic injection molding granules.*



*Fiberforge: fully automated machine for the placement of unidirectional fiber-reinforced thermoplast tapes (UD tapes). Close-up view of the material feed.*

In our "Plastics Testing and Failure Analysis" group, we conduct comprehensive investigations into polymer materials along the entire processing chain from the raw material to the finished component. In the event of damage or failure, we offer a systematic analysis of possible influences and causes of failure using analytical and technological measurement methods. We also offer standardized testing of standard materials, and testing of fiber composite materials and rigid polymer foams.

In the group for "Online Process Monitoring", spectral and microwave-based measurement methods are developed for integrated process and material monitoring and for process control. Industry 4.0 projects rely on the institute's extensive experience in the field of sensor technology, the process integration of sensors, and process-specific know-how in evaluating the raw data obtained.

In the "Recycling and Waste Management" group, processes and technologies for recycling polymers are developed, aiming for the complete reuse of the materials in the original application. The focus is on concepts for the recycling of composites and composite materials (GFRP, CFRP): once the fibers are recovered (for instance by using solvolysis or microwave-assisted pyrolysis processes) they can be reused to produce high-quality composites. Before polymers can be reused, many of them also need to undergo an extraction process, for example to remove flame retardants or colorants. Classic solvents and also supercritical fluids such as carbon dioxide are used for this purpose.

**Fraunhofer Project Center and alliances**

Through the cooperation between the FPC@WESTERN in London, Ontario (Canada), and Western University, the competences of Fraunhofer ICT in the field of fiber composites are combined with the know-how of the Canadian university in the fields of material and surface research. The FPC uses cutting-edge technology to process fiber composites. Research projects, in particular for the automotive industry, can therefore be carried out on an industrial scale.
The main research focus of the FPC@UNIST in Ulsan, South Korea, is on production processes for fiber-reinforced composites, new material solutions and the transfer of lightweight design into mass production. This is made possible by an interdisciplinary collaboration between process engineering and materials science for the implementation of process chains suitable for large-series production on an industrial scale. A unique feature of the FPC@UNIST is its focus on the entire value chain of the automotive industry, so OEMs, their suppliers, toolmakers and raw material producers can all be considered cooperation partners.

Close thematic networking with other Fraunhofer institutes within the Fraunhofer alliances "Building Innovation", "Lightweight Construction" and "Nanotechnology" enables us to provide system solutions from a single source.

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# LIGHTHOUSE PROJECT SMiLE
# GETTING ELECTROMOBILITY INTO GEAR

The lighthouse project "System-integrative multi-material lightweight construction for electromobility SMiLE", funded by the Federal Ministry of Education and Research, has made a significant contribution to technological progress and cost reduction in the field of electromobility. The focus of the project was the development of novel material- and technology-oriented lightweight construction concepts. SMiLE has thus established a sound understanding of efficient lightweight design for large-series production processes.

In the field of FRP, the project addressed fiber-reinforced plastic components with a thermoplastic or thermosetting matrix. Thermoplastic continuous-fiber semi-finished products (unidirectional tapes) were processed in combination with long-fiber-reinforced thermoplastic molding materials (LFT), while resin transfer molding (RTM) and the wet molding process were used for the manufacture of FRP components with thermoset resins. These processing methods enable the use of novel thermoplastic semi-finished products and innovative thermoset matrix systems with short cycle times, and the realization of a significantly high level of functional integration.

**Automating the thermoset processing chain**

In the SMiLE project, solutions were developed which led to a significant increase in the cost effectiveness of the RTM processing chain, rendering it more attractive for application in the automobile industry. The key was to increase the level of automation in the preform production process. The use of established semi-finished products (non-crimp fabrics, or NCFs) combined with an innovative direct placement method for fibers and an optimized preform strategy led to a reduction of material cut-off and a component design in accordance with the load orientation. Another challenge was the optimization of the RTM infiltration process for the manufacture of large modules with a high component weight and functional integration. The existing RTM process was further developed so large components could be realized within a short cycle time and at low internal mold pressures. Using the newly developed innovative ultra-RTM process it is possible to control the cavity pressure in pressure-sensitive areas of the component. The whole process can be controlled to ensure that the pressure stability of possible core materials is not surpassed, avoiding damage. This processing variant allows the use of cost-effective polyurethane foam cores with a high pressure sensitivity. When it comes to the manufacture of structures for load application, the focus is also on cost effectiveness.

From the very beginning it was possible to consider critical aspects such as mold filling during the RTM process and the expected warpage of the component after mold ejection, ensuring optimal process design.

The interaction between the developed technologies was demonstrated in a large-scale floor module, and implemented in a process suitable for series production.

**Intelligent expansion of the thermoplastic process chain**

Within the work package "Material and processing technology for continuous-fiber-reinforced thermoplastics", the aim of SMiLE was to implement a large-scale thermoplastic floor structure with maximum integration of functions and low cycle times. This is pioneering work toward the intelligent and economical use of FRPs in the automotive sector. SMiLE was concerned with the development, manufacture, analysis

*Hybrid thermoplastic floor structure (left) and thermoset floor structure with integrated functions (right).*

and simulation of highly resilient, fiber-reinforced, thermoplastic structures for use in a vehicle floor. Different process routes were investigated. The basic investigations helped to develop processes and obtain knowledge about material behavior, simulation and process control, which could then be used for the holistic evaluation and definition of at least one target process needed for the construction of the large-scale demonstrator. A novel LFT-D compression molding process was used, in which shell-like UD tape non-woven fabrics could be locally overmolded with LFT. This reduced the wall thickness of the components, minimizing their weight without altering their performance. Within this one-step process the demonstrator was manufactured with the required geometries and joined with the aluminum profiles and the metallic structures for load application. In parallel, idealized production planning was carried out using a digital factory. The simulation helped to determine and optimize the material flows and cycle times. This maximized the cost effectiveness and the efficiency of the processes, and enabled holistic process evaluation. Tape laying is the fundamental technology on which all development work is based. In this process unidirectional, fiber-reinforced thermoplastic tapes (UD tapes) are stacked, forming multiaxial fabrics.

As the fibers are oriented so that their properties are not altered by undulation effects, UD tapes offer significant benefits compared to semi-finished textile products such as composite laminates. The fiber orientations in these semi-finished products lie between 0° and 90° as a result of the manufacturing process. Tape laying, on the other hand, makes it possible to select a variety of fiber orientations for every layer placed. The semi-finished product can therefore be adjusted according to the load profile, creating tailored blanks. In addition, the semi-finished products can be manufactured with near net shape, minimizing material waste. The implementation of complex geometries such as ribs or functional elements like snap couplings made of UD tapes is not possible due to the limited draping properties. Nevertheless, the shell-like UD tape structures can be functionalized using LFT molding materials.

**Lighthouse project**

SMiLE started in September 2014 and was completed on August 30, 2017. The German federal government chose SMiLE as one of the seven lighthouse projects of the national Platform for Electromobility. Projects which make a significant contribution to technological progress and cost reduction in the field of electromobility are designated as electromobility lighthouse projects. The Federal Ministry for Education and Research (BMBF) has provided 18 million euros of funding for SMiLE. Approximately 16 million euros are provided by industrial partners.

**Project partners**

The partners are: AUDI AG, Volkswagen AG, Volkswagen AG Group Research Division, Porsche AG, Voith Composites GmbH & Co. KG, BASF Polyurethanes GmbH, BASF SE, F.W. Brökelmann Aluminiumwerk GmbH + Co. KG, Clean-Laser-systeme GmbH, Dieffenbacher GmbH, Fraunhofer ICT, Fraunhofer IWM, Frimo Group GmbH, Institute for Metal Forming Technology of the University of Stuttgart, TU Bergakademie Freiberg – Institute of Metal Forming, Institute for Connecting and Welding Technologies at TU Braunschweig, KIT Fast, KIT IAM, KIT WBK, MgF Magnesium GmbH and Novelis Germany GmbH

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# FACILITIES AND EQUIPMENT

- Twin-screw extruders with screw diameters ranging from 18 mm to 32 mm
- Dosing systems for liquid and highly viscous media and gravimetric dosing systems for pellets, powders, fibers etc.
- Laboratory for reactive extrusion, including safety equipment for work with hazardous substances
- Parallel-running hydraulic compression molding machines for the processing of plastics with 6,300 and 36,000 kN clamping force
- Direct LFT plant
- Injection molding units with clamping forces between 350 and 7,000 kN
- Advanced injection molding processes for injection embossing, multicomponent injection molding, thermoplastic foam injection molding, expansion foaming and thermoset injection molding
- Injection molding compounder with 40 mm twin-screw extruder and 7,000 kN clamping force
- Automated thermoplastic tape-laying process for non-woven fabrics with a 2 m diameter
- Technologies for the radiation-induced vacuum consolidation of thermoplastic non-woven fabrics (up to 0.94 x 1.74 m²).
- Automatic winding technology for the manufacture of complex loop structures
- 3D printing technologies for the processing of functionalized polymers – filament-based and AKF technology
- Particle foam technology with twin-screw extruder, underwater pelletizing, prefoamers and steam chest molding machines
- Tandem foam extruder for foamed semi-finished products
- SMC-production line and BMC kneader
- Polyurethane processing PU-RIM and PU fiber spraying technology
- Thermoplastic RIM/RTM processing
- RIM/RTM technologies for the processing of thermoset and thermoplastic materials within the high-pressure injection and high-pressure compression RTM process
- Automated preform center for the manufacture of textile preforms
- Microwave generators with an output of 60 kW at 915 MHz, 12 to 60 kW at 2.45 GHz, 0.8 kW at 5.8 GHz and 0.8 kW at a variable frequency between 5.8 GHz and 7.0 GHz
- Microwave-based sensor technology for process monitoring
- Low pressure area plasma (500 x 1.000 mm application area, 8 x 2 kW power output)
- Low-pressure-plasma system with 8 gas channels, ECR-plasma and 1000 mm plasma length
- Universal testing machines with fixtures for bending, tensile, peel and compression testing
- Impact pendulum and falling dart test
- HDT/Vicat device
- High-pressure capillary viscometer with pVT measurement technology
- Rheotens® device for measurement of the extensional viscosity
- Plate-plate viscosimeter
- Contact angle measurement device
- Differential scanning calorimetry (DSC)
- TG-MS, pyrolysis-GC-MS
- Gel permeation chromatography (GPC)
- Light microscopy (incident light and transmitted light), polarization
- Scanning electron microscope with element analysis (SEM-EDX)
- FTIR, UV-VIS and NIR spectroscopy
- Flame retardant test stands
- Thermal conductivity measurement device
- Hydrostatic compression testing stand for the characterization of polymer foams

# CORE COMPETENCE
# ENERGY SYSTEMS

Sustainable and affordable energy supply and efficient energy management are the focus of current research policy. Fraunhofer ICT's core competence "Energy Systems" is concerned with electrical energy storage devices for mobile and stationary systems, fuel cells and electrolysis, thermal and material energy storage and their applications. Our institute's electrochemical and chemical know-how has been accumulated over more than 30 years, laying the foundations for the development of efficient and cost-effective storage devices and converters.

New, efficient storage possibilities are created for electrical energy storage, and commercially available systems are investigated. The emphasis is on lithium-ion batteries, all-solid-state batteries, redox-flow batteries and so-called post-lithium-ion systems, such as lithium-sulfur or sodium-based batteries. Cells and battery modules are both thermally and electrically characterized and simulated, and can therefore be designed for different applications. Other topics of interest are safety and abuse investigations with accompanying gas analysis, post-mortem investigations on cells and battery modules, and the development and validation of safety concepts for operation, transport and storage. In our abuse test laboratories we can conduct thermal, mechanical and electrical safety tests on Li-ion cells and on modules up to 2 kWh. These tests can be planned according to customer specifications, and the gases released can be analyzed qualitatively and quantitatively. We also conduct inorganic and organic analyses of battery electrolytes and battery electrolyte mixtures with the help of specific head space methods, gas analyses of cells after internal gas formation and post-mortem-analyses of failed cells. We characterize electrode materials, cells and modules in terms of their thermal behavior, such as reaction heat, heat capacity, thermal conductivity and heat transfer.

Electrolyzers and electrocatalysts for next-generation fuel cells are the core topic in the field of converters, and the aim is to increase the power density of systems powered with liquid fuels and, if possible, to avoid the use of platinum as a catalyst. The focus is on the development of alkaline direct-alcohol fuel cells, for example through the development of palladium non-noble metal alloy catalysts for the oxidation of alcohols, or ionomers with a high stability in alkaline alcohol solutions. We also develop anode catalysts for medium-temperature fuel cells with a high tolerance for impurities (especially sulfurous compounds), which can operate with military logistic fuels. In our research into electrode structures we are also developing new and modified carrier materials, for example for oxygen development electrodes in PEM electrolyzers or HT-PEMFC electrodes. We also have a high level of competence in the online analysis of electrochemical processes, which can be used to investigate degradation processes in automobile PEMFCs. In addition, we design systems for application in unusual environments, for instance underwater.

In the area of solid-oxide fuel cells (SOFCs), our focus is on characterizing the performance under various operating conditions, and on aging investigations into membrane materials to reveal more about the relevant mechanisms and later optimize new materials. The degradation of electrode and support materials is characterized in electrolysis mode. In cooperation with EIFER, a research institution of the French energy provider EdF, we operate multiple test stands in which cells and stacks for solid oxide electrolysis are tested. In the field of power-to-gas/ liquids/ chemicals, we investigate the influence of pressure on interconnector materials and coatings, and develop suitable coatings. Another way to use electric energy efficiently is the extraction of chemical products. We develop electrochemical reactors, including electrocatalysts and electrodes, their integration into a complete process and the connection to subsequent processes. A current example is

*Redox-flow battery stacks.*

the electrochemical extraction of hydrogen peroxide through the partial reduction of atmospheric oxygen, with subsequent use in selective oxidation.

Thermal storage devices based on phase-change materials (PCMs) or zeolites are developed and characterized. This involves basic physical and chemical characterization, including the modeling and characterization of adsorption and desorption phenomena using thermoanalytical methods. The design, construction and testing of sorption storage and sorption cooling systems, heat storage systems based on phase-change materials and latent heat storage systems, and hybrid components combining thermal mass and insulation are strongly market-oriented and complement our fundamental research activities. At Fraunhofer ICT, our work in the field of material-based storage devices includes hydrogen as an energy source. We focus on hydrogen safety, particularly the storage and transport of hydrogen, the development and performance of specific safety tests, and the evaluation, concept and design of hydrogen storage systems.

**Application Center for Stationary Energy Storage Devices**

Our Application Center for Stationary Energy Storage Devices is equipped for the characterization and development of a wide spectrum of materials, and also enables investigation of the behavior of the storage device in the electricity grid with renewable energy sources. Core components include physical and chemical laboratories for questions concerning system components, pilot plants for the development, construction and investigation of small storage devices and a small energy grid with generators and users, such as wind energy plants, photovoltaics and Europe's largest vanadium redox-flow battery in the MW range.

In the laboratories, the materials for established technologies such as lithium-ion, lead-acid and redox-flow batteries and fuel cells - and also alternative technologies such as high-temperature batteries - can be electrochemically, chemically and physically characterized and optimized using different methods. By this means, established storage systems can be improved on the material level, or new energy storage technologies developed. It is also possible to investigate aging and the causes of failure.

Various pilot plants are available to upscale storage cells, battery components, redox-flow batteries and fuel cells to entire systems, and to investigate them electrically and thermally. Multi-channel measuring systems with DC flows of up to several hundred amperes and AC systems with a power of several kilowatts are available for electrical investigations. The storage devices can be energetically optimized and designed for specific locations through thermal simulations and electrical investigations to increase their efficiency and service life and lower the costs.

The globally unique infrastructure for developing and characterizing redox-flow batteries enables customers' components and entire systems to be investigated in parallel to the vanadium redox-flow battery, within the energy grid and in combination with renewable energy sources. Components that can be integrated into the plant and operated in parallel include cell stacks, recombination units or electrolyte regeneration and production units in virtually all required sizes. Because of the strictly modular concept of the available redox-flow battery, alternative technologies, such as organic, iron and zinc-based redox-flow batteries, can be integrated, operated in parallel, and characterized.

The small grid makes it possible to test and optimize both small storage devices, such as storage devices for houses, and larger (e.g. container-based) storage devices. Integration into the electrical grid is possible for both DC and AC, with a power of several hundred kilowatts. The storage devices can be qualified and compared according to various IEC or DIN/VDE standards, such as IEC 61427-2. In accordance with customer specifications, the storage devices can be optimized

*Battery testing.*

*Climate chamber tests on fuel cell stacks.*

for use in energy grids with wind power plants, photovoltaics and redox-flow batteries, and adjusted for operation as short-term, medium-term or long-term storage devices. Based on the data, for example concerning the performance and aging behavior, it is possible to analyze the costs of the storage devices. This enables targeted improvement of the storage devices for different locations and grid conditions. This decreases investment and storage costs (levelised cost of energy). In addition, the data can be used to determine the most cost-effective design for virtually any location in the world, using simulations, modeling, customer-specific combinations of storage devices, load profiles and sustainable energy sources.

**Networks and alliances**

Fraunhofer ICT pools its competence with other institutes of the Fraunhofer-Gesellschaft through Fraunhofer networks and alliances. Prof. Dr. Jens Tübke (Fraunhofer ICT) is the spokesperson of the Battery Alliance. With its diverse research topics, Fraunhofer ICT is also active in the alliances "Energy", "Space", "Building Innovation" and "Nanotechnology".

**Services and technology transfer**

We offer our customers a wide range of development services for electrical and thermal storage devices and electrical converters for various civil and military application fields. The design and development of (for example) range extenders or APU fuel cell systems for stationary applications and for vehicles comprises:

- Comprehensive characterization of PEMFC, HT-PEMFC and DMFC stacks
- Environmental simulation on stacks and systems, for example climate tests, effects of shock etc.
- Development of operating strategies, optimization of the interaction between the fuel cell and the battery
- Safety assessments using FMEA

We also develop electrocatalysts suitable for use with various fuels (hydrogen, alcohols) in acidic or alkaline fuel cells.

A wide variety of test cells are available to evaluate battery materials like electrodes, separators, electrolytes and conductors, including numerous special measurement cells developed in-house:

- Conductivity measurements (electrolyte, membrane, separator)
- Evaluation of electrodes (for example NCA, NCM, graphite, Si, LCO, LTO, $O_2$-cathodes, etc.)
- Tests on separators, and investigation of electrolytes (organic, inorganic, ionic liquid, solid ion conductive) to determine performance and stability
- Thermal simulation and cooling concepts for cells, modules and batteries, and the development of module and battery concepts with specific cells
- Research on next-generation systems (e.g. Li-S, air cathodes, Na-systems, solid ion conductors)

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FLOW CAMP

REDOX FLOW
BATTERY CAMPUS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłowdowska-Curie Grant Agreement no. 765289.

# GRADUATE NETWORK "FLOWCAMP" RESEARCH INTO REDOX-FLOW BATTERIES

The international graduate network "FlowCamp", which is coordinated by Fraunhofer ICT, aims to develop the next generation of redox-flow batteries and solutions for future energy storage.

Stationary energy storage devices can help compensate the supply fluctuations associated with renewable energy sources, leading to a more reliable energy supply. This enables them to make a significant contribution to network stability and frequency control. For over ten years, redox-flow batteries have been investigated and further developed as a promising energy storage method. In the project "RedoxWind", funded by the State of Baden-Württemberg, the Federal Ministry of Education and Research (BMBF) and the Fraunhofer-Gesellschaft, a Redox Flow Application Center has been established at Fraunhofer ICT, providing an infrastructure that is unique in Germany. A large-scale redox-flow storage device, based on an all-vanadium redox-flow battery, is currently under construction. Together with a wind energy plant it will supply most of the energy of the ICT campus, and thus serve as a laboratory for stationary energy storage.

This unique infrastructure provides a basis for the EU-funded FlowCamp project, which aims to develop different redox flow technologies and solutions for energy supply in the next four to ten years. Within a pan-European team, young, internationally active researchers are given the opportunity to develop new flow battery technologies that go beyond the established all-vanadium systems. The 15 PhD students are based at universities, research institutes and enterprises in France, the Czech Republic, Switzerland, the Netherlands, Hungary, Luxembourg, Israel, Great Britain and Germany, working on one joint collaborative project. The group is coordinated by Fraunhofer ICT.

Three different redox-flow battery systems are currently being investigated. Hydrogen-bromine, aqueous-organic and zinc-air flow battery systems are the three most promising systems, with the potential to significantly advance the development of flow battery technology. Initially, the young researchers are focusing on the development of suitable materials. To improve system design, and to better understand the operational behavior and thus optimize performance, the developers are supported by experts in simulation and modeling. Initial experiments are carried out on cells on a laboratory scale, then the systems are upscaled and constructed as functional models. These model batteries are then tested in the cutting-edge laboratories and facilities at Fraunhofer ICT and its project partners.

Besides the development of new energy storage systems, the FlowCamp network plays another important role: the cross-linking of battery research institutions with different areas of expertise. It is only by connecting multiple scientific disciplines that optimal battery systems can be developed. Currently, only a few researchers worldwide have the necessary overview on a systems level.

The project kick-off meeting was held in September 2017. The 15 PhD students started work at their respective locations in spring 2018.

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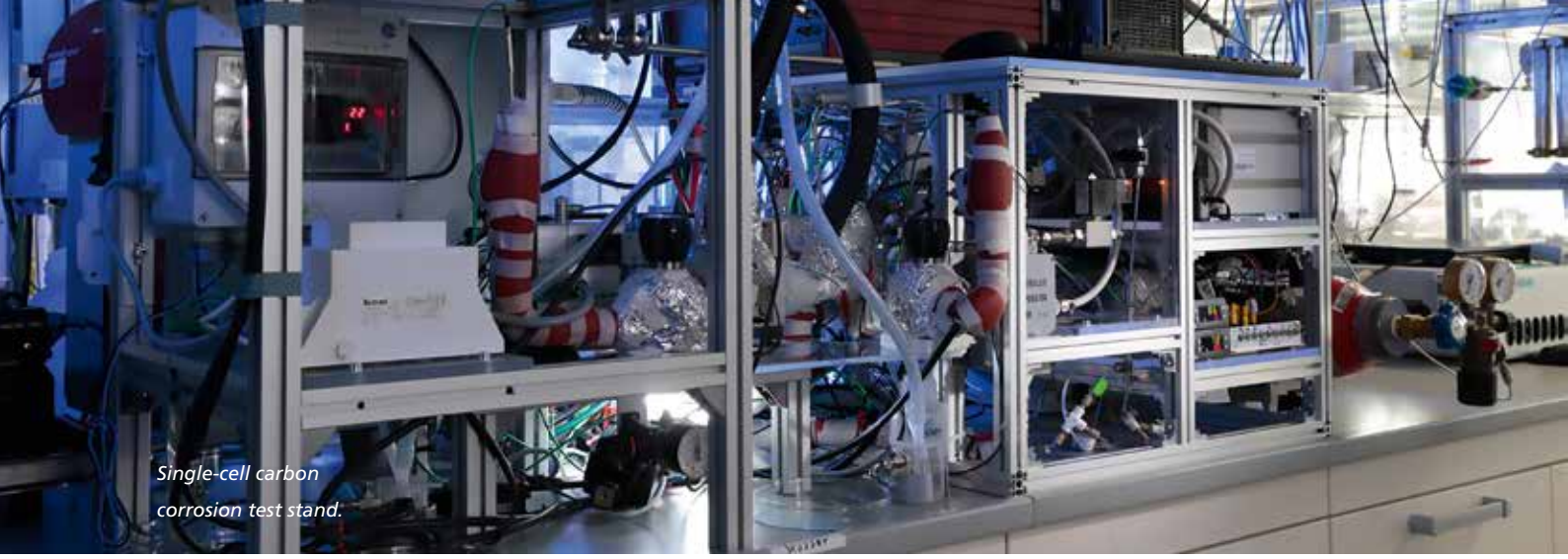

*Single-cell carbon corrosion test stand.*

# NEW APPLICATION FIELDS OF MASS SPECTROMETRY IN ELECTROCHEMISTRY

At Fraunhofer ICT, differential electrochemical mass spectrometry (DEMS) is an established method for examining reaction mechanisms, such as those occurring during alcohol oxidation. Until now, however, it has only been possible to use it for reactions in liquid electrolytes. A cell developed at Fraunhofer ICT now also enables DEMS measurements on gas diffusion electrodes. The cell was originally developed in the German-French project "EUBECELL" to investigate ethanol oxidation in the gas phase under HT-PEMFC conditions. It was successfully applied in the electromobility+ collaboration FCCF-APU, and in the projects SynKraBZ and MatModMixFuel, financed by the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB), to qualify and quantify the reactions of contaminants from fuel reformation using HT-PEMFC. In the current collaboration "DALTOCA", funded by the Federal Ministry for Education and Research (BMBF), a more advanced cell is being used to investigate parasitic reactions on direct methanol fuel cell cathodes. Further potential applications include investigations into fuel or air impurities on fuel cell catalysts and the investigation of electrosynthetic processes on gas diffusion electrodes, such as $CO_2$ reduction.

Fraunhofer ICT successfully demonstrated that the classic DEMS flow-through cell is extremely suitable for quantifying the carbon corrosion of supported fuel cell catalysts.

In the BMBF project "DEMS-BAT", analog measurements to investigate the formation of $H_2$ and $CO_2$ in zinc air cells are conducted in a modified cell. In the BMBF project "SePaLiS", online mass spectrometry is used to investigate the electrolyte degradation in lithium-sulfur cells; with the aim of identifying stable electrolytes. Using gas chromatography mass spectrometry, degradation and aging products in the electrolyte or in the gas phase of the cell can be clearly identified. A test stand developed in the German–Canadian collaboration "GECKO", funded by the BMBF, enables the quantification of carbon corrosion on single-cell level. In cooperation with Dr. Piotr Zelenay and his group from the Los Alamos National Laboratory (USA), it was demonstrated that the method is suitable for the investigation of future noble-metal-free catalysts.

Because of its very short response time, mass spectrometry can be used for the qualitative and quantitative observation of hydrogen release in fuel-cell-powered vehicles. Besides its application in the detection of leakages, the method has been shown to be suitable for quantifying hydrogen in exhaust gases in fuel cell purge cycles. Working together with a German OEM, we aim to achieve a standardization of the methods as part of the approval process for fuel-cell-powered vehicles.

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# FACILITIES AND EQUIPMENT

- Charging and discharging stations for battery cells and module characterization
- Argon protective gas box
- High-speed and infrared cameras
- Cryostats and climate chambers from –70 °C to 250 °C
- Scanning tunneling microscope (STM) / atomic force microscope (AFM) with 3D imaging in the atom / nano range
- Digital microscopy with magnification factor up to 5,000 in two- or three-dimensional image
- Scanning electron microscope (SEM) / X-ray diffractometer (XRD)
- RAMAN and infrared (IR) spectroscopy
- Thermal, mechanical and electrical safety testing facility for battery cells and modules up to 6 kWh, fuel cell modules
- Synthesis options for supported electrocatalysts up to gram scale
- Measuring stations for electrochemical catalyst characterization and aging tests on membrane-electrode assemblies
- Differential electrochemical mass spectrometry (DEMS) for the investigation of reaction and corrosion products
- Medium-temperature cell (120 °C to 200 °C) with online mass spectrometry (HT-DEMS)
- Spraying devices for the production of membrane electrode units
- Multiple individual test stands to characterize membrane electrode units for hydrogen PEMFCs, PEM- and AEM-, and HT-PEMC-based direct-alcohol fuel cells, HT-PEMFCs operated on reformate, and PEM electrolysis
- Measuring stand for time-resolved online mass spectrometry measurements to investigate transient processes in automobile PEMFCs, such as corrosion during gear shifting processes or gas exchange of inert gases
- Test stand for the investigation of short stacks (PEMFC, DAFC and HT-PEMFC) up to 500 W
- Test stand for the stack characterization of hydrogen-air and hydrogen-oxygen PEMFCs with operating pressures up to 5 bar
- System development and investigation of components through hardware-in-the-loop method
- Environmental simulation, in particular mechanical tests (vibration, impact etc.) on fuel cell stacks and systems
- Online mass spectrometer with membrane flow unit for analysis of the liquid phase
- Sputtering unit for coating with metals
- Test stand for differential electrochemical mass spectrometry (DEMS)
- Various high-temperature ovens with the possibility to simulate $H_2$-, CO-, $CO_2$- or $SO_2$-containing atmospheres up to 800 °C, and under pressures up to 50 bar

# CORE COMPETENCE
# EXPLOSIVES TECHNOLOGY

As the only German research institution covering the entire system development chain for explosives, from the raw product through to the prototype, Fraunhofer ICT offers its long-standing expertise to the German Federal Ministry of Defence, the public sector and industrial customers, carrying out investigations into current challenges in the field of national and international security.

Fraunhofer ICT draws on the competence of its employees in the research and development of improved energetic materials and systems for the German army, and thus helps to ensure the strong analysis and decision-making capabilities of the German Federal Ministry of Defence (BMVg). In addition, the institute works on current challenges in national and international security.

Research is focused on the development, synthesis, characterization, formulation and production techniques of components for rocket propellants, gas generators, gun propellants, high explosives and new ignition systems. Fraunhofer ICT is the only German research institute covering the whole development chain from the raw product through to the system prototype.

Further elements in the portfolio are safety and security systems such as airbag gas generators, flame retardancy coatings and pyrotechnic decoy flares with spectral emissions similar to those of real engines, so that spectrally resolving IR seeker heads cannot distinguish between them.

In the development of propellant and explosive systems, performance, sensitivity, handling safety, functionality and environmental compatibility are adjusted and optimized for individual application profiles and requirements. To this end, components are synthesized and modified in Fraunhofer ICT's laboratories, new binder systems and formulations are developed and the energetic products are fabricated in the institute's pilot plants. The research group for interior ballistics and detonics then characterizes the reaction behavior, sensitivity and performance data of the products (up to the kilogram scale) in its laboratory, detonation chamber or open-air testing ranges, and carries out simulations using computer codes developed in-house. Current research topics include environmentally friendly, low-signature rocket propellants for military and civil applications, foamed propellant structures, insensitive high-performance explosives, gel propellants for rockets enabling controllable thrust phases, sensors in rocket engines that enable non-destructive monitoring of the state-of-aging of the propellant, and investigations into the compatibility and stability of new energetic materials, as well as the prediction of their aging behavior.

A further competence is the detection of explosives, even in trace amounts, using special molecular adsorbers. Fraunhofer ICT manufactures so-called terrorist explosives, assesses them in terms of their handling properties and detectability, and makes them available to the security authorities for testing purposes. Our work includes the development of concepts for locating the illegal fabrication of explosives, the design of civil or military security areas and checkpoints, and the standardized assessment of detection systems on an international level, such as those used for security checks at airports. We also develop protection systems against terrorist attacks.

*Equipment for investigating solid rocket propellants under high pressure.*

CORE COMPETENCE
# EXPLOSIVES TECHNOLOGY

## Groups and alliances

In the field of explosives technology and security research, Fraunhofer ICT is a member of the Fraunhofer Group for Defense and Security (VVS), in which seven Fraunhofer institutes and three guest institutes have pooled their competences and work together to coordinate and implement research activities. Fraunhofer ICT is also a member of the Fraunhofer Space Alliance, in which 15 Fraunhofer institutes cooperate to perform applied research in the field of space technology.

With its competence in explosives, the institute is also actively involved in numerous national and international projects (BMVg, EDA, NATO, EU, BMBF, BMI, BMWi). It also works with the BMVg in the context of bilateral research agreements. Operating as a test center on behalf of the German Federal Police, the institute contributes its know-how to international committees aiming to improve aviation security.

## Research and technology

We carry out research in every area of explosives technology, on behalf of the Federal Ministry of Defence and other public authorities, the defense and security industry, and the automotive and aerospace sectors. Key areas of our work are the development, design and evaluation of energetic products and systems based on our chemical know-how and our safety-related equipment. We develop tailored processing technologies for the safe manufacture of explosive components, support the search for critical substances compliant with REACh, and provide demonstrators for the testing of new energetic products. Software-assisted analysis and design tools permit the screening of new propellant and explosive formulations, for example according to their performance and environmental compatibility. Our analysis of gun propellants or ballistics includes the system characteristics of weapons and ammunition.

We are also able to develop pyrotechnic gas generators for safety equipment (such as airbags) according to application and customer specifications, and to evaluate all steps of this development. In our test center for explosive detection systems, we offer the manufacturers of airport scanners and detection devices the opportunity to carry out tests with real explosives and reference substances, in order to evaluate and optimize their systems. In addition, in collaboration with the German Federal Police, such detection systems are tested and certified for use at European airports.

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# RADIATION ANALYSIS OF MISSILES AND DECOYS

The rapid development of powertrain and seeker technologies means that modern missiles are a growing threat to military and civil aircraft, not only in crisis regions. To maintain and increase the effectiveness of existing detection and defense measures it is necessary to make use of cutting-edge characterization technologies and analysis systems.

A key prerequisite for the protection of aircraft is the early and reliable detection of threat situations. In recent years, radar technology and passive optical warning sensors in the ultraviolet and infrared ranges have proven to be effective. These optical sensor technologies mainly use the intensive radiation emission of the rocket plumes for detection. To ensure that the detection technology is reliable, and to minimize the number of false alarms, the characteristic spectral properties of different missile drive systems need to be identified and integrated into the evaluation of the detection process.

The next step is to find suitable countermeasures to avert the threat efficiently. The use of decoys is currently one of the most successful countermeasures against self-guiding missiles. Although new technologies for infrared-based seeker heads, such as laser-based blend processes, are becoming increasingly important, pyrotechnic decoys are still indispensable for the comprehensive protection of aircraft. Compared to seeking sensors used for the older and more common portable air defense systems, pyrotechnic decoys are particularly effective if their radiation signature is spectrally adjusted to the signature of the protected aircraft.

A high-quality radiation analysis of the intensive parts of the flames in the rocket plume and the pyrotechnic decoy is important for both tasks. The focus is mainly on spectral ranges with a high atmospheric transmission. The spectral, spatial and temporal resolution of the measurement data is essential to their quality, and determines the reliability of the radiation analyses.

As the necessary information cannot be collected by a single system, Fraunhofer ICT uses multiple measuring systems in parallel, with different measurement principles, and combines the results.

Besides fast cameras with imaging capability only, and integrated spectrometry systems, a hyperspectral imager, which can provide both spectral and spatial information simultaneously, is used for the relevant spectral range. By fusing the data collected by these different systems it is possible to increase our knowledge of how to evaluate the systems, the information content of which far exceeds the sum of the individual results.

## CONTACT

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**Achim Schreiber**
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*Electrochemical sensor technology in the loading head of a submarine vehicle ...*

*... used in trials in the Baltic Sea.*

# ELECTROCHEMICAL SENSOR TECHNOLOGY

**Defense engineering**

Together with the German armed forces (WTD 71), an electrochemical sensor system for the detection of explosives in sea water was developed and tested. The sensor system is designed to detect recently laid sea mines, home-made explosive devices or ammunition waste.

The project took two different approaches. One approach was constructing an electrochemical sensor system as an autonomous stand-alone system, in which the sensors are completely self-sufficient. This concept means that energy supply, communication and data analysis capabilities are included in the sensor system so that it can operate independently of the carrier vehicle. For this reason the system can be used on a variety of carrier vehicles. The data is analyzed by an internally developed and self-learning software, and the detection of an explosive for example is indicated by a flashing light.

Another approach was the implementation of an integrated concept. This means that the sensor system uses the energy supply and the communication capabilities of the carrier vehicle. The sensor system is integrated into the loading head of the carrier vehicle. An operator on board the accompanying ship controls the sensor system and evaluates the measurement data.

Both electrochemical systems were intensively tested in multiple trials in the North and Baltic Seas around Germany and Poland. Both systems were successfully used to investigate suspicious objects and check for traces of explosives.

**Projects**

Together with industrial customers, we are currently developing and optimizing sensor systems and elements for sensors in the gas and liquid phases. Here it is necessary to understand the theory of the underlying electrochemical processes, study the literature, analyze and characterize surfaces and perform clearly structured measurements to achieve statistically significant results. Our industrial customers aim to improve their own products, open up new areas of application or ensure that their portfolio remains viable by testing new and promising technologies.

Together with partners from research and industry, we carry out publicly funded projects relating to sensor systems. One example is the project LHyCon (funded by the Federal Ministry for Education and Research (BMBF) as part of its SME programme "KMU innovativ"). In collaboration with an industrial partner, we are developing a hydrogen sensor with a high level of sensitivity for leakage tests.

**Consultation days**

Many of our customers get to know us via consultation days. An interdisciplinary team consisting of at least three people with different areas of expertise (chemists, electrochemists, sensor system technicians, electricians, analysts, process engineers ...) provides answers to individual enquiries made by our customers.

## CONTACT

**Peter Rabenecker**
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# FACILITIES AND EQUIPMENT

## PILOT PLANTS AND TEST STANDS

- Chemical plants and synthesis laboratories for explosives
- Pilot plants for the manufacture and modification of explosive products
- Safety boxes and testing sites for explosion and safety/security investigations
- Test Center for Explosives Detection
- Detonation chamber (up to 2 kg TNT)
- Test stands for guns up to 20 mm caliber
- Combustion test stand for rocket engines and flares
- Flow test stand for the investigation of pyrotechnic systems

## EQUIPMENT

- Pilot plant for the production of ultrafine particles
- Microprocessing test stands and synthesis units
- Fluidized-bed coater
- Spray crystallization unit
- High-pressure plant for isostatic compression molding
- Special kneaders, mixers and presses with explosion protection

## ANALYTICAL EQUIPMENT AND LABORATORIES

- Atomic force microscope, field emission scanning electron microscope (FESEM) with variable pressure, and energy dispersive X-ray and nanoanalytics (EDX)
- Micro and nano computer tomography scanner
- Thermoanalytical laboratory, micro- and reaction calorimeter, test stand for aging behavior
- Laboratory for mechanical testing and rheology
- Ballistic and optical facilities to determine combustion speed and measure flame temperature
- Laboratory for X-ray diffractometry
- Laboratory for chromatographic and spectroscopic analysis (IR and RAMAN microscopy)
- Online spectroscopy (UV/VIS/NIR/RAMAN)
- High-speed camera and spectrometer systems


*Test series to determine actual driving emissions on the roller test stand.*

# NEW DRIVE SYSTEMS

In 2017, the New Drive Systems Department (NAS) continued its innovative R&D work to improve the efficiency of drive systems. A variety of drive systems, including both combustion engines and electric systems, were investigated. Some examples of our work are described below.

The tasks of the New Drive Systems Department include the analysis of data generated under real driving conditions and the development of driving cycles according to customer requirements. A portable emission measurement system (PEMS) that allows measurement of the most important exhaust gas components was purchased to determine the real-driving-emission conformity (RDE) and to identify actual emissions under real operating conditions. Various measurements have since then been carried out using the NAS test vehicle on various RDE-compliant and individually defined test tracks with different height and load profiles. The focus was on further developing the measurement method using different parameters such as driver, cargo load, ambient temperature, type of fuel and other relevant influencing variables. The research work also involves investigating the cross-sensitivities of other exhaust gas components. Through the investigations we deepened our collaboration with the KIT institutes such as the Institute for Vehicle Systems Technology on the East Campus. The joint work included experiments on the four-wheel acoustic roller dynamometer.

Not only combustion engines but also electrically powered systems formed part of the R&D work. In the research project "Directly Cooled Electric Engine with Integrated Lightweight Casing", a concept for an electric traction engine for urban mobility was developed, with an integrated winding and rotor cooling system.

The internal cooling system makes it possible to use a polymer casing made of highly-filled thermosets with a high degree of functional integration. To enable later series application, only processes suitable for large-scale production are used for the manufacture, and the assembly efforts are minimized. In the next project year, a prototype based on the developed concept will be constructed, and the simulation models will be validated.

## CONTACT

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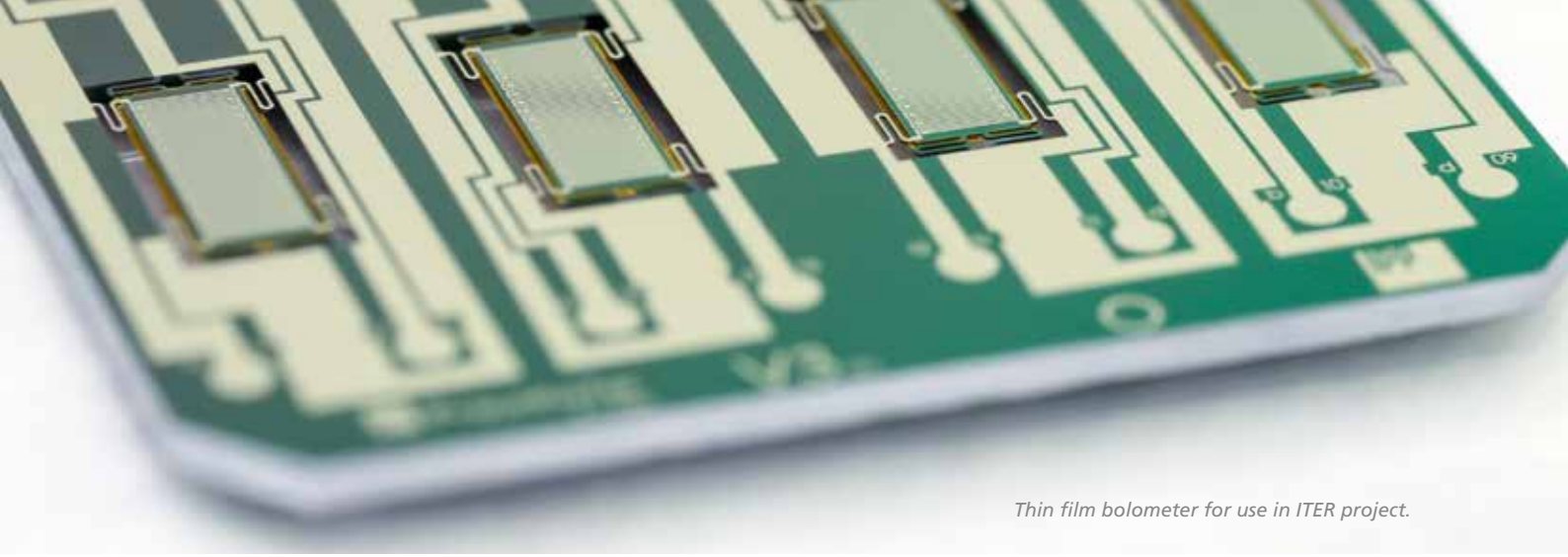


*Thin film bolometer for use in ITER project.*

# FRAUNHOFER INSTITUTE FOR MICRO-ENGINEERING AND MICROSYSTEMS IMM

Fraunhofer IMM is concerned with the two research areas of energy and chemical technology (processes, reactors, pilot plants) and analysis and sensor systems (methods, components, systems). Within this structure we prioritize energy, chemistry, raw materials, safety, health, nutrition, mobility, transport, and industry 4.0. The developments are applied in the business areas of energy and environment, chemistry, process engineering and aerospace, biomedical analytics and diagnostics, and safety and industrial analytics. With its system and technology-oriented innovations, Fraunhofer IMM contributes to the competitiveness of its customers and partners. The team is committed to the responsible handling of novel technologies and sustainable developments that directly benefit business and society.

The research area of energy and chemical technology comprises the departments Energy Technology, Chemical Technology and Nanoparticle Technologies.

The Energy Technology Department is concerned with current and future issues regarding the mobile and decentralized supply and storage of electrical energy, heat management in the automotive sector and the manufacture of synthetic (bio) fuels. The reliability and efficiency of compact material and energy conversion systems, and decentralized, mobile energy supply units are improved.

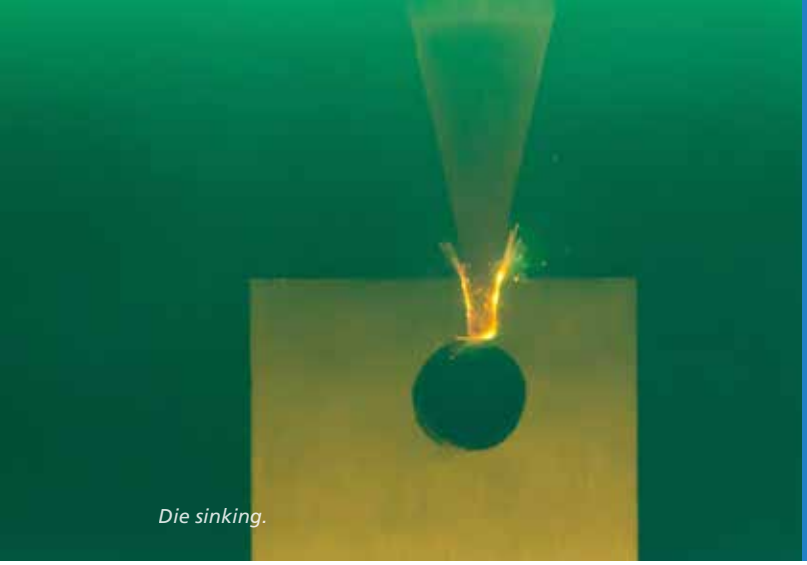
In the Chemical Technology Department, the focus is on intensifying chemical production processes by applying methods and equipment used in chemical microprocess engineering. Based on an easily scalable, modular reactor system, or using specific, often highly cross-linked models, we are developing, constructing and manufacturing milli-structured and micro-structured flow reactors on laboratory and industrial scales, which are optimally tailored to specific processes or application purposes. Chemical production processes are intensified and the availability of substances, measurement data and information regarding products and production processes is increased.

The Nanoparticle Technologies Department works on the manufacture and characterization of nanoparticles with different properties and potential applications in medicine, pharmacology and the consumer goods industry. These nanoparticles include metallic (for instance Au, Pt, Pd), metal oxidic (for instance ZnO, $SiO_2$), semiconducting (quantum dots) and polymer nanoparticles. This leads to a higher quality of nanoparticles, increased productivity during syntheses and a better efficiency and availability of chemical agents at the target location.

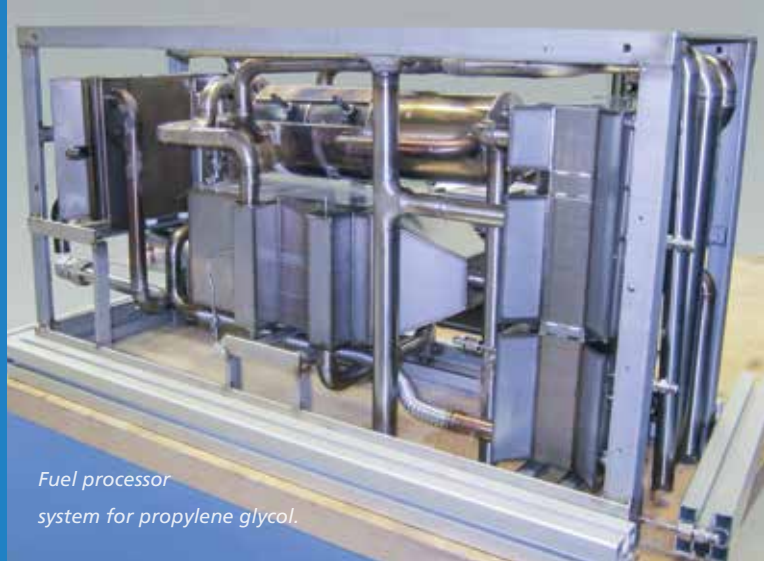
The research area of analysis and sensor systems includes the departments Microfluidic Analysis Systems, Sensor Systems and Equipment Engineering.

As one of the pioneers in microfluidics, Fraunhofer IMM has been developing fully integrated and automated microfluidic analysis systems for more than 20 years. Based on a "microfluidic kit" including a comprehensive set of all required functional elements, the team is quickly able to determine the applicability of an idea, and construct fully functional demonstrators up to pilot series level. Established analysis systems are accelerated and automated, and the compactness of established processes is improved, bringing everything together at the target location.

The Sensor Systems Department is concerned with the development of customer-specific optical, electrochemical



*Die sinking.*



*Fuel processor system for propylene glycol.*

and MEMS sensor technology. Comprehensive competences in the design of micro-structured components and their system integration, combined with a wide spectrum of micro-fabrication technologies such as mechanical precision engineering, laser material processing and silicon and thin film technology, are a unique feature of this department. The robustness of our customers' sensor systems is improved, and process monitoring efforts are minimized.

Systems Engineering at Fraunhofer IMM ranges from individual production processes through to equipment engineering. Part of the team's work is the integration of microfluidic cartridges or silicon-based sensors, for example in mechanical constructions connected functionally with the required optics, actuator technology and other electronic functional elements (heaters, engines, pumps etc.). Fluidic elements and sensors are combined and integrated into intelligent systems, creating new application possibilities.

The departments also offer a long-standing know-how in terms of mechanical precision engineering processes, spark erosion and laser material processing, and a range of clean-room-based, chemical and physical structuring processes.

## CONTACT

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# APPENDIX

# PARTICIPATION IN FRAUNHOFER GROUPS, ALLIANCES AND HIGH PERFORMANCE CENTERS

The institutes of the Fraunhofer-Gesellschaft work together, collaborating in groups and alliances or pooling different skills in flexible structures as and when needed. This secures their leading position in the development of system solutions and the implementation of comprehensive innovations. Fraunhofer ICT participates in the groups, alliances and clusters listed below.

## HIGH PERFORMANCE CENTERS

High Performance Centers are organizational structures in which university and non-university research can be conducted hand-in-hand with industry. They are characterized by well-defined, end-to-end roadmaps in which the partners attribute equal value to research and education, the promotion of young scientists, infrastructure, innovation and knowledge transfer. The Centers invite political decision-makers to modify their priorities by proving that scientific excellence can be developed with benefits to society.

**Regional network on mobility systems in Karlsruhe**

Within the regional network on mobility systems in Karlsruhe, the four Fraunhofer institutes ICT, IOSB, ISI and IWM, the ICT department for New Drive Systems, Karlsruhe Institute of Technology KIT, Karlsruhe University of Applied Sciences – Technology and Economics, and the FZI Research Center for Information Technology are carrying out joint research on future mobility. Seven initialization projects are concerned with the central challenges of efficient, intelligent and integrated mobility across a wide range of disciplines, and facilitate networking between stakeholders from research, applied research, and industry.

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## FRAUNHOFER GROUPS

Institutes working in related subject areas cooperate in Fraunhofer Groups and foster a joint presence on the R&D market. They help to define the Fraunhofer-Gesellschaft's business policy and act to implement the organizational and funding principles of the Fraunhofer model.

### FRAUNHOFER GROUP FOR DEFENSE AND SECURITY RESEARCH VVS

- Security research
- Protection and deterrence
- Reconnaissance and surveillance
- Explosives and safety engineering
- Decision-making support for government and industry
- Localization and communication
- Image processing

**Contact:** Prof. Dr.-Ing. Peter Elsner
Tel. +49 721 4640-401 | peter.elsner@ict.fraunhofer.de

### FRAUNHOFER GROUP FOR MATERIALS AND COMPONENTS

- Health
- Energy and environment
- Mobility
- Construction and living
- Machinery and plant engineering
- Microsystem technology
- Safety

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# FRAUNHOFER ALLIANCES

Institutes, or departments of institutes, with different competences collaborate in Fraunhofer Alliances, in order to carry out joint research work and market implementation in a specific business area.

## FRAUNHOFER BATTERY ALLIANCE

- Materials: Development, characterization, processing
- Design concepts: Mechanical design, electrical connection, thermal design, safety concepts
- Battery management: Monitoring, performance analysis, charge management, functional safety
- Production: Processes, systems engineering, process reliability, green production
- Simulation: Material-based, cell, battery, model reduction
- Testing, certification: Performance, reliability, safety and abuse, aging

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## FRAUNHOFER BUILDING INNOVATION ALLIANCE

- Product development
- Components, construction systems, buildings as integrated systems
- Software
- Construction sequence, construction planning
- Logistics, construction management, life cycle consideration of buildings
- International projects, construction work in other climatic zones

**Contact:** Prof. Dr.-Ing. Peter Elsner
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## FRAUNHOFER LIGHTWEIGHT DESIGN ALLIANCE

- New materials and material composites
- Manufacturing and joining technologies relevant to lightweight construction
- Functional integration
- Design and configuration
- Non-destructive and destructive test methods

**Contact:** Prof. Dr.-Ing. Frank Henning
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## FRAUNHOFER ENERGY ALLIANCE

- Renewable energy sources: Solar energy, biomass, windpower
- Efficiency technologies: For example combined Heat and Power (CHP) technologies, natural gas provision, storage and energy conversion technologies, fuel cells
- Buildings and components: Lowest-energy house, building energy technologies
- Digitalization of the energy industry: Collection, analysis, transport and use of energy data
- Storage and micro-energy technologies: Lithium technologies for batteries, fuel cell systems

**Contact:** Prof. Dr. rer. nat. Jens Tübke
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## FRAUNHOFER NANOTECHNOLOGY ALLIANCE

- Nanomaterials / nanochemistry
- Nano optics / electronics
- Nanobiotechnology
- Modeling / simulation
- Manufacturing technologies, handling
- Security and policy consulting

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## FRAUNHOFER SPACE ALLIANCE

- Communication and navigation
- Materials and processes
- Energy and electronics
- Surfaces and optical systems
- Protection technology and reliability
- Sensor systems and analysis

**Contact:**
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Volker Weiser
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# TEACHING ENGAGEMENT AND PUBLIC BODY MEMBERSHIP

Teaching activities and public body membership are important tasks of a research institution. In 2017 our employees held numerous lectures at the KIT and various other universities and colleges. In this way we contribute to the skills of scientists and technicians and our own future researchers. In 2015 we also participated in numerous working groups and public bodies, to help shape the future of our research fields.

## TEACHING ENGAGEMENT

### KARLSRUHE INSTITUTE OF TECHNOLOGY KIT

#### Institute for Applied Materials – Material Science and Engineering (IAM-WK)

**Elsner, Peter**
- Polymer Engineering (2 units per week, WT + ST)
- Working techniques for mechanical engineering (2 units per week, ST)

**Weidenmann, Kay André**
- Material processing technology (3 units per week, WT)
- Internship material processing technology (1 units per week, WT)
- Seminar material processing technology (2 units per week, ST)
- Materials for lightweight design (2 units per week, ST)

#### Institute for Vehicle Systems Technology FAST

**Henning, Frank**
- Lightweight vehicle construction– strategies, concepts, materials (2 units per week, WT)
- Fiber-reinforced plastics – polymers, fibers, semi-finished products, processing (2 units per week, ST)

#### Institute for Piston Machines IFKM

**Kollmeier, Hans-Peter**
- Drive systems and options for increasing efficiency (1 unit, WT)

#### Institute for Mechanical Process Engineering and Mechanics

**Tübke, Jens**
- Materials and methods for electrochemical storage devices and converters (2 unitsper week, WT + ST)

### KARLSRUHE UNIVERSITY OF APPLIED SCIENCES – TECHNOLOGY AND ECONOMICS

#### Department for Electronic and Information Technology

**Graf, Matthias**
- Sensor laboratory 1 (2 units per week, WT + ST)

**Hefer, Bernd**
- Chemistry and exercise (2 units per week, ST)
- Physical chemistry (4 units per week, ST)

**Pinkwart, Karsten**
- Bio-chemosensors III (2 units per week, ST)
- Batteries, fuel cells and super-capacitors (2 units per week, ST, WT)
- Renewable electricity generation and storage (2 units per week, ST)
- Electrochemical energy storage systems (2 units per week, WT)

**Urban, Helfried**
- Measurement technology for mechatronic students (4 units per week, ST)
- Electronics 3 for sensor system technicians (4 units per week, WT)

### BADEN-WÜRTTEMBERG COOPERATIVE STATE UNIVERSITY (DHBW), KARLSRUHE

#### Engineering Department, Mechanical Engineering Course

**Becker, Wolfgang**
- Waves and optics (4 units per week, WT)

**Kauffmann, Axel**
- Technical mechanics and mechanics of materials I (3 units per week, WT + ST)
- Technical mechanics II (3 units per week, WT + ST)
- Material sciences: plastics (2 units per week, WT)

– Plastics processing (2 units per week, ST)
– Laboratory for plastics processing (2 units per week, ST)

**Reinhard, Stefan**
– Laboratory for plastics processing (2 units per week, ST)
– Lectures on strength of materials/production machines (2 units per week, WT)

### Mechatronics Course

**Bader, Bernd**
– New materials (33 units / year)

### Safety Engineering Course

**Gräbe, Gudrun**
– Basics of environmental technology (3 units per week, WT)

## BADEN-WÜRTTEMBERG COOPERATIVE STATE UNIVERSITY (DHBW), MANNHEIM

### Mechanical Engineering Course

**Bader, Bernd**
– Properties and processing of elastomers (55 units / year)
– Construction with plastics (33 units / year, WT)

## HECTOR SCHOOL OF ENGINEERING AND MANAGEMENT

**Henning, Frank**
– Automotive lightweighting and processing of composite materials (15 units / year, WT)

## TECHNICAL UNIVERSITY NUREMBERG

### Applied Chemistry and Process Engineering Department

**Herrmann, Michael**
– Lecture on X-ray diffraction (double-unit, WT)

**Teipel, Ulrich**
– Mechanical process engineering (6 units per week, ST and 4 units per week, WT)
– Particle technology (4 units per week, WT)
– Particle engineering (4 units per week, ST)

## HELMUT-SCHMIDT UNIVERSITY – UNIVERSITY OF THE FEDERAL ARMED FORCES HAMBURG

### Electrical Engineering Department

**Pinkwart, Karsten**
– Electrochemical energy storage devices and convertors (2 units per week, WS)

## ASSOCIATED INSTITUTE OF OSTFALIA UNIVERSITY OF APPLIED SCIENCES

### Trainings- und Weiterbildungszentrum Wolfenbüttel

**Cremers, Carsten**
– Fuel cell technology (block lecture, 6 double units, ST)

**Tübke, Jens**
– Battery technology (block lecture, 6 double units, ST)

## UNIVERSITY OF WESTERN ONTARIO, CANADA

### Faculty of Mechanical Engineering, Material Science

**Henning, Frank**
– Lightweight design of vehicles (2 units per week / WT)
– Composite manufacturing (2 units per week / WT)

## PÄDAGOGISCHE HOCHSCHULE UPPER AUSTRIA, LINZ

### Institute for Training and School Development II

**Krause, Dörthe**
– Training event for teachers (2 days WT + 2 days ST)

## UNIVERSITY OF WEST BOHEMIA IN PILSEN, CZECH REPUBLIC

### Mechanical Engineering Department

**Kolarik, Vladislav**
– X-ray diffractometry as an in-situ method (guest lecture, one 2-hour session, WT)

# PUBLIC BODY MEMBERSHIP

**Böhnlein-Mauß, Jutta**
- Member of the Working Group "Interior Ballistics" of the Bundeswehr Technical Center for Weapons and Ammunition

**Bohn, Manfred**
- Member of the German Chemical Society (GDCh)
- Member of the Bunsen Society for Physical Chemistry (DBG)
- Member of the German Society for Thermal Analysis (GEFTA)
- NATO AC326 /SG1-CNG
- Member of the International Steering Committee of the International Pyrotechnics Seminar USA (IPS-USA Seminars)
- Member of the Steering Committee of the International Pyrotechnics Seminar (IPS)
- Organizing committee member of KISHEM, Korea (South)
- Scientific committee member of the NTREM, Pardubice, Czech Republic
- Member of the Committee of the HFCS-EM (Heat Flow Calorimetry Symposium on Energetic Materials)
- Member of the Committee of International NC Symposium
- Member of the International Advisory Board of the Polymer Degradation Discussion Group (PDDG)

**Bücheler, David**
- Member of the AVK Working Group SMC/BMC
- Member of the Steering Committee of the European Alliance for SMC BMC

**Cäsar, Joachim**
- DKE 131 "Environmental Simulation"
- DKE 212 "IP Protection Categories"
- Member of the German Engineers' Union VDI e. V.
- Deputy Chair of the Working Group "Effects on Products" in the Air Quality Control Commission (AQCC)
- Member of the Society for Environmental Simulation (GUS) e. V.
- Deputy Director of the Working Group "Particles – Properties and Effects" of the Society for Environmental Simulation
- Various Working Groups of the Society for Environmental Simulation (GUS)
- DAkkS Consulting Expert on Environmental Simulation

**Cremers, Carsten**
- Appointed member of the Joint Technical Committee on Fuel Cells of the Society for Energy and Environment (GEU) of the German Engineers' Union (VDI) and the Power Engineering Society (ETG) of the Association for Electrical, Electronic & Information Technologies (VDE)
- Member of the industrial network of the Working Group "Fuel Cells" in the National Federation of Machinery and Plant Construction (VDMA)
- Member of the NATO Army Armaments Group (NAAG) Land Capability Group Dismounted Soldier System (LCGDSS) Power Team of Experts
- Member of the Technical Group "Applied Electrochemistry" of the German Chemical Society (GDCh)
- Member of the Electrochemical Society ECS

**Diemert, Jan**
- Founding Member and Board Member of the European Composites, Plastics & Polymer Processing Platform (ECP4)
- Member of the Polymer Processing Society (PPS)

**Elsner, Peter**
- Chair of the Advisory Board of the Karlsruhe University of Applied Sciences, Technology and Economy
- Member of the Central Committee of the Scientific and Technical Council of the Fraunhofer-Gesellschaft
- Member of the Presidential Council of the Fraunhofer-Gesellschaft
- Chairman of the Fraunhofer Group for Materials
- Deputy Spokesman of the Fraunhofer Building Innovation Alliance
- Spokesman of the Scientific Working Group Plastics, WAK
- Member of the National Academy of Science and Engineering, acatech
- Spokesman of the Fraunhofer Sustainability Network

**Eyerer, Peter**
- Executive Board of the TheoPrax Foundation
- Member of Jury VIP+, Funding Program of the Federal Ministry of Education and Research, Berlin; Project Executive Agency VDI/VDE-IT
- Consulting Expert at KMU-NETC, Funding Program of the Federal Ministry of Education and Research, Berlin; Project Executive Agency VDI/VDE-IT, Berlin
- President of the "Offene Jugendwerkstatt" (youth workshop), Karlsruhe

**Fischer, Thomas**
- Member of the Working Group "Interior Ballistics" of the Bundeswehr Technical Center for Weapons and Ammunition
- Member of the Working Group "External Ballistics" of the Bundeswehr Technical Center for Weapons and Ammunition
- Member of the Task Group "Interior Ballistics Simulation"
- Member of the Working Group IPT-REACH of the Federal Office of the Bundeswehr for Equipment, Information Technology and In-Service Support Bundeswehr

**Gettwert, Volker**
- Member of the Technical Group "Construction Chemistry" of the German Chemical Society (GDCh)
- Member of the International Committee of the International Workshop High Energy Materials (HEMs)

**Gräbe, Gudrun**
- Member of the Water Chemistry Society (professional group of the GDCh)

**Heil, Moritz**
- Member of the Committee of the HFCS-EM (Heat Flow Calorimetry Symposium on Energetic Materials)

**Henning, Frank**
- Director of SAMPE Deutschland e. V.
- Member of the Federation of Reinforced Plastics (AVK)
- SPE Composites Division (Board of Directors, European Liaison)
- Adjunct Research Professor in the Department of Mechanical and Materials Engineering, Faculty of Engineering of the University of Western Ontario, Canada
- Deputy Chairman of the Executive Board of the Center for Lightweight Construction Baden-Württemberg (LBZ-BW)
- Member of the Advisory Board to the Federal Agency for Lightweight Construction BW

**Herrmann, Michael**
- Member of the German Crystallography Society (DGK)
- Member of the German Society for Thermal Analysis (GEFTA)

**Hübner, Christof**
- Elected member of the Scientific and Technical Council of Fraunhofer-Gesellschaft
- Representative of the Fraunhofer ICT in the Fraunhofer Nanotechnology Alliance

**Joppich, Tobias**
- Representative of Fraunhofer ICT in the Lightweight Construction Center in Baden-Württemberg (LBZ-BW e. V.); assistance to the Managing Board
- Representative of the Fraunhofer ICT in the Lightweight Construction Agency Baden-Württemberg
- Member and Spokesperson of the Working Group "EATC – European Alliance for Thermoplastic Composites" of the Federation of Reinforced Plastics (AVK)
- Member of the Program Committee and Chairman of the International Exhibition and Conference (ITHEC)

**Juez-Lorenzo, Mar**
- Member of the German Society for Electron Microscopy (DGE)
- Member of the European Microscopy Society (EMS)

**Kauffmann, Axel**
- Member of the Fraunhofer Building Innovation Alliance

**Knapp, Sebastian**
- Member of the International Pyrotechnic Society
- Member of the German Physical Society (Deutsche Physikalische Gemeinschaft)

**Kolarik, Vladislav**
- Member of the International Advisory Body of the Research, Development and Innovation Council of the Government of the Czech Republic
- Member of the German Society for Corrosion Protection (GfKORR) and of the Research Group on Corrosion Protection at High Temperatures (within the GfKORR)
- Session Chairman on "Coatings for Use at High Temperatures", International Conference on Metallurgical Coatings and Thin Films, San Diego, USA

**Krause, Dörthe**
- Executive Board Member of the TheoPrax Foundation

**Löbbecke, Stefan**
- ProcessNet, including Technical Groups for Microprocessing Technology, Reaction Technology, Process Analytics; Working Committee on Reaction Technology for Processes with Complex Safety Issues; Working Group for Metal-Organic Frameworks (Founding Member)
- Member of the German Chemical Society (GDCh), including Working Group "Process Analysis"
- Member of the German Catalysis Society (GECatS)

**Neutz, Jochen**
- Chair of the Program Committee AIRBAG 2000 plus

**Noack, Jens**
- Member IEC TC 21/ TC 82 JWG 82 "Secondary Cells and Batteries for Renewable Energy Storage and Smart Grid Structures"
- Member IEC TC 21 / TC 105 JWG 7 "Flow Batteries"
- Head of Working Group DKE, AK 371.0.6 "Flow Batteries"
- Member DKE, AK 384 "Brennstoffzellen" ("Fuel Cells")

**Parrisius, Martina**
- Member of the Executive Board of the Federal Association "Lernort Labore" e. V.
- Member of the Working Group "Entrepreneurial Spirit", Federal Ministry for Economic Affairs and Energy, Berlin
- Member of the Expert Advisory Board Neue Oberstufe Berlin

**Pinkwart, Karsten**
- Fraunhofer Electrochemistry Network (Coordinator)
- Executive Board Member of the Association of Electrochemical Research Institutes (AGEF)
- Member of the Working Group "Energy Technology" of the German Society for Defense Technology (DWT)
- Director of the Working Group "Batteries" of the Society for Environmental Simulation (GUS)
- Member of the Working Group "Electrochemical Processes" of DECHEMA / ProcessNet
- Member of the Technical Group "Applied Electrochemistry" and "Chemistry and Energy" of the German Chemical Society (GDCh)

**Reichert, Thomas**
- Managing Director of the Society for Environmental Simulation (GUS) e. V.
- Member of the Technical Advisory Board of the Clean Air Commission, Board III on Environmental Quality, in the German Engineers' Union (VDI) and the DIN (German Institute for Standardisation)
- Chairman of the Working Group "Effects on Materials and Environmental Simulation" of the Clean Air Commission at the VDI and DIN
- Chairman of the "European Weathering Symposia EWS"
- Chairman of the CEEES Technical Advisory Board for "Climatic and Air Pollution Effects on Materials and Equipment"
- Chairman of the Organizing Committee for the »Ultrafine Particles Symposia UFP«
- Working Member in the DIN Standard Committee "Kunststoffe" (Plastics) NA 054-01-04, "Behavior under Environmental Influences"

**Roeseling, Dirk**
- Member of the Liquid Explosive Study Group (ECAC)
- Member of the Trace Explosive Study Group (ECAC)
- Member of the EDS Cabin Baggage Explosive Study Group (ECAC) (formerly ACBS)
- Member of the Vapor Trace Explosive Study Group (ECAC)
- Member of the EDS Hold Baggage Explosive Study Group (ECAC)

**Schnürer, Frank**
- Member of the Advisory Board of the Civil Security Coordination Office (KoSi)

**Schweppe, Rainer**
- Chairman of the CleanSky Platform "Eco Design Transversal Activity", Joint Undertaking
- Member of the International Association for Sustainable Aviation (IASA)
- Member of the INNONET Network, Head of the Working Group "Recycling"
- Member of the Working Group of the Ministry of Rural Affairs, Baden-Württemberg

**Stier, Christian**
- Molecular Sorting Platform (Exchange and Acquisition Platform within the FhG)

**Teipel, Ulrich**
- Appointed member of the ProcessNet Technical Committee on Comminution and Classification
- President of the Working Group on Particles – Properties and Effects within the Society for Environmental Simulation (GUS)
- Appointed member of the ProcessNet Technical Committee on Crystallization
- Consulting Expert of the German Federation of Industrial Research Associations (AiF) and the German Research Foundation (DFG)
- Member of the Editorial Board of the journal "Chemical Engineering & Technology"
- Guest editor of the journal "Chemical Engineering and Technology", thematic area of particle technology
- Director of the Working Group for the Influence on Products, in the Commission on Air Pollution Prevention, of VDI and DIN (KRdL)
- Liaison lecturer of the DFG at the Technical University Nuremberg
- Member of the German-Russian Raw Materials Forum
- Member of the Working Group "Limits of development/ sustainability" of the Intern. Seminar on Planetary Emergencies at the World Federation of Scientists / Erice Member of the Scientific Committee of the "PARTEC 2019"
- Appointed member of the ProcessNet Technical Group "Raw Materials"
- Appointed member of the Council of Science and Humanities

**Thoma, Bernd**
- Member of the Working Group "Euro-RTM-Group" of the Federation of Reinforced Plastics (AVK)

**Tübke, Jens**
- Spokesman of the Fraunhofer Battery Alliance
- Member of the Working Group "National Platform for Electromobility" (NPE)
- Spokesperson of the R&D Advisory Board of the Bundesverband Energiespeicher BVES (German Energy Storage Association)
- Deputy Director of the fokus.energie e. V.
- Chair of the MEET Scientific Advisory Board – Münster Electrochemical Energy Technology
- Member of the Advisory Board of "Battery Research Germany" of the Federal Ministry for Education and Research (BMBF)
- Member of the Technical Group for Applied Electrochemistry of the German Chemical Society (GDCh)
- Member of the Society for Chemical Engineering and Biotechnology (DECHEMA e. V.)

**Urban, Helfried**
- Honorary professor at the Karlsruhe University of Applied Sciences

**Weiser, Volker**
- Member of the Combustion Institute
- Member of the German Fire Protection Association
- Member of International Pyrotechnic Society
- Representative in the Fraunhofer Space Alliance

**Weidenmann Kay**
- Member of the Selection Committee of the German Academic Scholarship Foundation (Studienstiftung des deutschen Volkes e. V.)
- Consulting Expert of the German Research Foundation (Deutsche Forschungsgemeinschaft)
- Member of the DGM Technical Committees "Metal Matrix Composites" and "Hybrid Materials"
- Founding member of the Karl Drais Gesellschaft zur Förderung der Wissenschaften e. V.
- Member of the Scientific Committee of the 20th International Conference on Composite Structures (2017, 2018)
- Member of the Scientific Committee of the 4th Conference Hybrid Materials and Structures (2020)

**Wurster, Sebastian**
- Member of the Working Group for Interior Ballistics
- Member of the Working Group "External Ballistics" of the Bundeswehr Technical Center for Weapons and Ammunition
- Member of the Task Group "Interior Ballistics Simulation"

# EVENTS AND PARTICIPATION IN TRADE FAIRS AND EXHIBITIONS

## EVENTS

March 22-24, 2017
**46th Annual conference of the German Society for Environmental Simulation GUS "Assessment, Simulation and Evaluation of Environmental Influences"**
Festhalle, Stutensee-Blankenloch, Germany

April 4-6, 2017
**Training opportunities offered by the Alliance "Lightweight Construction": Advanced training "Composite Engineer"**
Fraunhofer ICT, Pfinztal, Germany

April 26, 2017
**Phontonics BW e.V.: Laser Treatment of CFRPs**
Fraunhofer ICT, Pfinztal, Germany

April 27, 2017
**Girls' Day**
Fraunhofer ICT, Pfinztal, Germany

May 8-10, 2017
**9th European Symposium on Non-Lethal Weapons**
Stadthalle Ettlingen, Germany

June 21, 2017
**6th Workshop – Technology Platform Micro-Encapsulation**
Achat Plaza, Karlsruhe, Germany

June 21-22, 2017
**FIPCO: 2nd Functional Integrated Plastic Components**
Hotel Der Blaue Reiter, Karlsruhe, Germany

June 22-23, 2017
**8th Symposium - Product Design in Particle Technology**
Achat Plaza, Karlsruhe, Germany

June 27, 2017
**18th Defense Engineering Day**
Fraunhofer ICT, Pfinztal, Germany

June 27-30, 2017
**48th International Annual Conference of the Fraunhofer ICT: "Reactivity and Modelling"**
Kongresszentrum, Karlsruhe, Germany

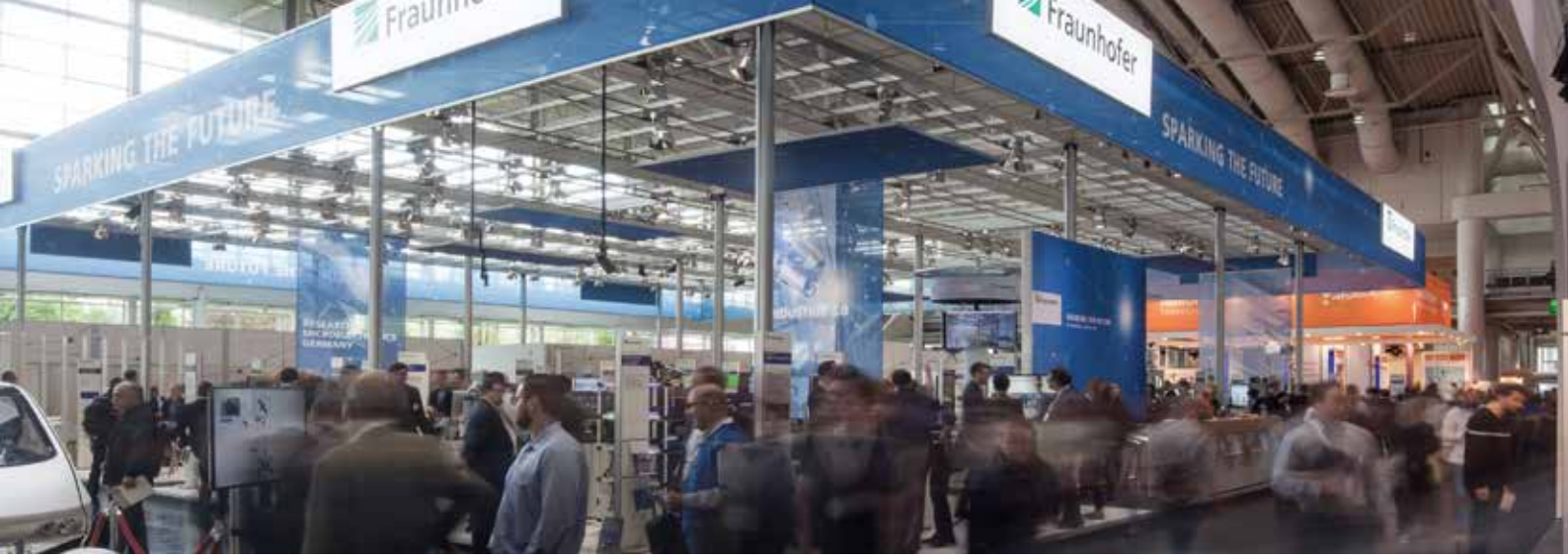
October 11, 2017
**Meeting of the Advisory Board**
Fraunhofer ICT, Pfinztal, Germany

October 19, 2017
**From the tape to the tailored lightweight solution**
LBZ Workshop, Fraunhofer ICT, Pfinztal, Germany

November 14-15, 2017
**Workshop: Propellants and Explosives / Energy Storage Devices**
Fraunhofer ICT, Pfinztal, Germany

November 21, 2017
**RETRO – Recycling of Carbon-Fiber-Reinforced Polymers: Obstacles and potentials**
Forum discussion and project workshop, Fraunhofer ICT, Pfinztal, Germany

November 28-30, 2017
**CCG Seminar: Detection of explosives**
CCG-Seminar, Fraunhofer ICT, Pfinztal, Germany




# PARTICIPATION IN TRADE FAIRS AND EXHIBITIONS

January 16-21, 2017
**BAU – World's Leading Trade Fair for Architecture, Materials and Systems**
Munich, Germany

March 14-16, 2017
**JEC Composites Paris**
Paris, France

March 14-16, 2017
**Energy Storage**
Düsseldorf, Germany

March 29-30, 2017
**VDI Conference "Polymers in the Automobile Industry"**
Mannheim, Germany

April 24-28, 2017
**H2+FC+BAT**
Hannover, Germany

June 19-25, 2017
**SIAE**
Le Bourget, France

June 28-29, 2017
**CEB & interCOGEN – 10th Energy Efficiency Fair and 2nd Co-generation Trade Fair**
Karlsruhe, Germany

September 12-14, 2017
**The Battery Show**
Novi, Michigan, USA

October 16-21, 2017
**FAKUMA**
Friedrichshafen, Germany

# PUBLICATIONS


Ahlbrecht K.
**Flexible und dichte keramische Verbundseparatoren für Na-S-Mitteltemperaturzellen.**
Dissertation, Wissenschaftliche Schriftenreihe des Fraunhofer ICT, Band 77, Fraunhofer Verlag, Stuttgart, 2017, 129 S., ISBN 978-3-8396-1259-0

Ahlbrecht K., Bucharsky C., Holzapfel M., Tübke J., Hoffmann M.J.
**Investigation of the wetting behavior of Na and Na alloys on uncoated and coated Na-β''-alumina at temperatures below 150 °C.**
Ionics 23 (2017), pp. 1319-1327, DOI: 10.1007/s11581-017-2017-x

Aladinli S., Bordet F., Ahlbrecht K., Tübke J., Holzapfel M.
**Anion intercalation into a graphite cathode from various sodium-based electrolyte mixtures for dual-ion battery applications.**
Electrochimica Acta 231 (2017) 468-478, DOI: http://dx.doi.org/10.1016/j.electacta.2017.02.041

Aladinli S., Bordet F., Ahlbrecht K., Tübke J., Holzapfel M.
**Compositional graphitic cathode investigation and structural characterization tests for Na-based dual-ion battery applications using ethylene carbonate: ethyl methyl carbonate-based electrolyte.**
Electrochimica Acta 228, 2017, pp. 503–512, DOI: http://dx.doi.org/10.1016/j.electacta.2017.01.037

Baumann N.
**Material properties of electrodes for photovoltaic-coupled polymer electrolyte membrane water electrolysis.**
Dissertation, Wissenschaftliche Schriftenreihe des Fraunhofer ICT, Band 73, Fraunhofer Verlag, Stuttgart, 2017, 188 S., ISBN 978-3-8396-1170-8

Bauman N., Cremers C., Pinkwart K., Tübke J.
**Supported IrxRu1-x$O_2$ anode catalysts for PEM-water electrolysis.**
Fuel Cells 17(2), 2017, pp. 259-267

Baumgärtner S.
**Beitrag zur Konsolidierung von thermoplastischen Hochleistungsfaserverbundwerkstoffen.**
Dissertation, Wissenschaftliche Schriftenreihe des Fraunhofer ICT, Band 75, Fraunhofer Verlag, Stuttgart, 2017, 127 S., ISBN 978-3-8396-1242-2

Baumgärtner S., Lohr C., Henning F.
**Development of a novel consolidation process for continuous-fiber-reinforced thermoplastics.**
17th European Conference on Composite Materials (ECCM17), European Society for Composite Materials (ESCM), Munich

Baumgärtner S., Jauch R., Link T., Henning F.
**Thermoplastischer Strukturleichtbau für die automobile Großserie.**
Functional Integrated Plastic Components 2017 (FIPCO), Hanser, Karlsruhe, 2017

Baumgärtner S., Huber T., Henning F.
**Structural thermoplastic lightweight design for automotive mass production - Compression molding of UD tapes and LFT.**
17th Annual SPE Automotive Composites Conference & Exhibition (ACCE), Novi Michigan, USA, 2017

Baumgärtner S., Henning F.
**Thermoplastic composites for e-mobility – tailored lightweight construction by use of UD tapes and LFT.**
3rd International Composites Congress (ICC), AVK – Industrievereinigung Verstärkte Kunststoffe e.V., Stuttgart, Germany, September 19, 2017

Becker W., Wehner H., Kölle S.
**Überwachung von Biogasprozessen.**
In: UmweltMagazin, April/Mai 2017, Special Edition Messtechnik & Analyse

Becker W., Guschin V., Mikonsaari I., Teipel U., Kölle S., Weiss P.
**Turbodimetric method for the determination of particle sizes in polypropylene/clay composites during extrusion.**
In: Analytical and Bioanalytical Chemistry, January 2017, Volume 409, Issue 3, pp. 741–751

Becker W., Sachsenheimer K., Klemenz M.
**Detection of black plastics in the middle infrared spectrum (MIR) using photon up-conversion technique for polymer recycling purposes.**
In: Polymers 2017, 9, 435; DOI: 10.3390/polym9090435

Bergmann B.
**Möglichkeiten der Verfahrensintensivierung von reaktiven Extrusionen am Beispiel der Herstellung von Polylactid.**
Dissertation, Wissenschaftliche Schriftenreihe des Fraunhofer ICT, Band 72, Fraunhofer Verlag, Stuttgart, 2017, 163 S., ISBN 978-3-8396-1148-7

Bergmann B., Buczko A., Elsner P.
**Kombinierte Prozesse für effiziente Produktion – Chemische Materialmodifikation im Doppelschneckenextruder.**
Jahresmagazin Kunststofftechnik 2017

Bermejo Sanz J., Roussel García R., Kolarik V., Juez Lorenzo M.
**Influence of the slurry thickness and heat treatment parameters on the formation of aluminium diffusion coating.**
Oxid Met (2017) 88:179–190, DOI 10.1007/s11085-017-9771-z

Blanco-Villalba J., Recio-Erquicia I., Gómez-Cordón J., Hübner C.
**Improving the processability of graphene nanoplatelets in polyamide 6 during melt compounding extrusion.**
PPS Europe Africa Conference, June 26-29, 2017, Dresden, Germany

Böhnlein-Mauß J., Kröber H.
**The REACH impact on gun propellant formulations.**
Propellants Explosives Pyrotechnics 2017, 42, pp. 54-61

Böhnlein-Mauß J., Löbbecke S.
**10 Jahre Chemikalienverordnung REACH – Eine Bestandsaufnahme.**
Symposium Ergebnisse der grundlagenfinanzierten Forschung: Explosivstoffe, Energiespeicher, Lenkflugkörper, Wirkung und Schutz, 20.-22. Februar 2017, Mannheim

Bohn M.A.
**Investigation of ageing behaviour of plasticized nitrocellulose – Accelerated ageing and real ageing.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, p. 60-1

Bohn M.A.
**The connection between wlf equation and the Arrhenius equation.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, p. 69-1

Bohn M.A.
**Following the curing of isocyanate-polyol by pressure decrease – influences of activation volume, reaction volume and change in bulk compressibility as well as diffusion control during curing.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, p. 118-1

Bohn M.A., Ferrapontoff Lemos M., Mussbach G.
**The influence of concentration, type and particle size of fillers on the dynamic mechanical behaviour of elastomeric HTPB binder.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 23-1 to 23-29

Bohn M.A., Ferrapontoff Lemos M., Mussbach G.
**Evaluation of concentration, type and particle size of fillers on the dynamic mechanical behaviour of elastomeric HTPB binder.**
In: Proceedings of the 20th Seminar on New Trends in Research of Energetic Materials NTREM, University of Pardubice, Faculty of Chemical Technology, April 26-28, 2017, Pardubice, Czech Republic, pp. 58-81, ISBN 978-80-7560-056-1

Bücheler D., Trauth A., Damm A., Böhlke T., Henning F., Kärger L., Seelig T., Weidenmann K.A.
**Processing of continuous-discontinuous-fiber-reinforced thermosets.**
SAMPE Europe Conference 2017, Stuttgart, Germany, November 15, 2017, ISBN-978-90-821727-7-5

Ciezki H.K., Kirchberger C., Stiefel A., Kröger P., Caldas Pinto P., Ramsel J., Naumann K.W., Hürttlen J., Schaller U., Imiolek A., Weiser V.
**Overview on the German gel propulsion technology activities: status 2017 and outlook.**
7th European Conference for Aeronautics and Space Sciences (EUCASS). Milano, Italy, July 3, 2017

Cremers C., Röntzsch L.
**Brennstoffzellen als Range-Extender.**
In: Neugebauer R. (Hrsg.) Fraunhofer-Forschungsfokus Ressourceneffizienz, Kap. 5.5.5, S. 85-89, 1. Auflage, Springer Vieweg, Berlin, 2017

Cristilli F., Weiser V., Maggi F., Imiolek A., Tagliabue C., Gettwert V., Dossi S.
**Burning behavior of ADN-based propellants loaded with Al-Mg mechanically activated powders.**
7th European Conference for Aeronautics and Space Sciences (EUCASS). Milano, Italy, July 3, 2017

DeLuca L.T., Bohn M.A., Gettwert V., Weiser V., Tagliabue C.
**Innovative solid rocket propellant formulations for space propulsion.**
In: Boschi Goncalves R.F., Rocco J.A.F.F., Iha K. (Eds.) Energetic Materials Research, Applications, and New Technologies. IGI Global, ISBN 9781522529033, p. 1-24

Deinzer G., Kothmann M., Rausch J., Baumgärtner S., Rosenberg P., Link T., Diebold F., Roquette D., Henning F.
**Research Project SMiLE – Manufacturing technologies for continuous fibre-reinforced lightweight automotive floor modules for cost-efficient high volume production.**
SAMPE Europe Conference, Stuttgart, Germany, 2017

Diemert J.
**Emissions- und geruchsoptimierte (Recycling-)Compounds mittels extraktiver Compoundierprozesse.**
Würzburger Compoundiertage, SKZ, Würzburg, 16-17. Mai 2017

Dieterle M., Seiler E., Viere T.
**Application of eco-efficiency analysis to assess three different recycling technologies for carbon fiber reinforced plastics (CFRPS).**
In: Herrmann A.S. (Editor) 21st Symposium on Composites. Trans Tech Publications, Switzerland, 2017, Volume 742, pp. 593-601, DOI: https://doi.org/10.4028/www.scientific.net/KEM.742.593

Dörr D., Brymerski W., Ropers S., Leutz D., Joppich T., Kärger L., Henning F.
**A benchmark study of finite element forming codes for forming simulation of thermoplastic UD-tapes.**
Paper, 1st Cirp Conference on Composite Parts Manufacturing, CIRP-CCMPM 2017, Procedia Cirp, Volume 66, 2017

Dubey S., Abhyankar H., Marchante V., Brighton J., Bergmann B., Tringh G., David C.
**Microwave energy assisted synthesis of poly lactic acid via continuous reactive extrusion: modelling of reaction kinetics.**
RSC Adv., (2017), 7, pp. 18529-18538

Eisenreich N., Kelzenberg S., Knapp S.
**Diffusion models of metal particle and wire oxidation and relation to Cabrera-Mott-theory used in thermal analysis.**
In: Koleczko A., Eisenreich N., Vorozhtsov A.B. (Eds.) Phenomena in Combustion of Propellants and Explosives. 2017, Stuttgart, Germany, Fraunhofer Verlag, pp. 73-90

Eisenreich N., Schulz O., Koleczko A., Knapp S.
**Comparison of kinetics, oxide crystal growth and diffusivities of nano- and micrometer-sized copper particles on oxidation in air.**
Thermochimica Acta 654, 2017, p. 93-100, DOI: 10.1016/j.tca.2017.05.012.

Ferrapontoff Lemos M., Bohn M.A., Schaller U.
**Mechanical properties of Desmophen-2200® based elastomer samples plasticized with energetic ionic liquids.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 92-1 to 92-12

Ferrapontoff Lemos M., Bohn M.A., Mendes L.C.
**Compatibility between azido groups containing molecules and HTPB.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 102-1 to 102-11

Fischer T., Kraus T., Kirches C., Gauterin F.
**Nonlinear model predictive control of a thermal management system for electrified vehicles using FMI.**
Proceedings of the 12th International Modelica Conference 2017, Prague, 2017, pp 255-264, https://modelica.org/events/modelica2017/proceedings/html/authors/author_71.html

Fürst T.
**Experimentelle Charakterisierung von Designvarianten überlappend gefügter Kohlenstofffaserverbundstrukturen im Kontext der Entwicklung neuartiger Drapiertechnologien.**
Dissertation, Wissenschaftliche Schriftenreihe des Fraunhofer ICT, Band 75, Fraunhofer Verlag, Stuttgart, 2017, 151 S., ISBN 978-3-8396-1221-7

Gettwert V., Franzin A., Bohn M.A., DeLuca L.T., Weiser V.
**Ammonium dinitramide/glycidyl azide polymer (ADN/GAP) composite propellants with and without metallic fuels.**
International Journal of Energetic Materials and Chemical Propulsion, 2017, Volume 16, Issue 1, pp. 61-79

Gettwert V., Schaller U., Tagliabue C., Weiser V.
**AP-free composite propellants for space applications.**
XIII International Workshop HEMs-2017, November 6, 2017, Sendai, Japan

Gettwert V., Tagliabue C., Weiser V.
**Burning behavior of aluminized adn/psan propellants.**
7th European Conference for Aeronautics and Space Science (eucass), July 3-6, 2017, Milano, Italy

Graf M., Baumgärtner S., Henning F.
**New benchmark in the tailored blank manufacturing – high volume production in an exceptional quality.**
In: SAMPE Europe Conference 2017, Leinfelden-Echterdingen, Germany, Stuttgart, November 14-16, 2017, ISBN 978-90-821727-7-5

Hafner S., Keicher T., Klapötke T.M.
**Synthesis of p(gap-co-eph) – an energetic copolyether suitable for cast-cure applications.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 126-1 to 126-8

Heil M., Müller C., Hickmann J., Bohn M.A.
**Investigation and comparison of known and new ADN stabilizers.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 43-1 to 43-13

Heil M., Wimmer K., Bohn M.A.
**Characterization of gun propellants by long-term mass loss measurements.**
Propllants, Explosives, Pyrotechnics 2017, 42, p. 706

Heintz T., Reinhard W., Leisinger K., Herrmann M., Heil M.
**ADN-prills: particle properties, stability and sensitivity.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 115-1 to 115-10

Henning F., Thoma B., Wendel R., Rosenberg P., Gresser G., Bauder H.J., Wolfrum J., Caliskan M.
**Aus einem anderen Blickwinkel. ORW-Verfahren ermöglicht multiaxiale lokale Verstärkung für RTM-Strukturbauteile.**
In: Kunststoffe 02/2017, Seite 62-64

Henning F., Baumgärtner S., Rosenberg P., Link T., Deinzer G., Kothmann M.H., Rausch, J., Diebold F., Roquette D.
**Research Project SMiLE – Manufacturing technologies for continuous fibre-reinforced lightweight automotive floor modules for cost-efficient high volume production.**
Proceedings of the Sampe Europe Conference 2017

Herrmann M., Kempa P. B., Förter-Barth U., Heintz T.
**Thermal behavior of ADN and ADN-prills – crystal and micro structure.**
25th Annual Conference of the "Deutsche Gesellschaft für Kristallographie", March 27-30, 2017, Karlsruhe, Zeitschrift für Kristallographie – Supplement 37 (2017), P63, 77, http://www.degruyter.com/view/serial/247761

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**Thermal behavior of ADN and ADN-prills – crystal and micro structure. Part I.**
In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 43-1 to 43-13

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**Aging of standard and insensitive RDX crystals investigated by means of X-ray diffraction.**
Propellants Explosives Pyrotechnics, 2017, 42, pp. 724-727

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**Comparison of methods for generating the CL-20/HMX-cocrystal.**
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In: Proceedings of the 48th International Annual Conference of the Fraunhofer ICT "Energetic Materials – Reactivity and Modelling", June 27-30, 2017, Karlsruhe, Germany, pp. 112-1 to 112-8

Hitscherich M.
**Polymerelektrolyt-Brennstoffzellensystem für ein autonomes Unterwasserfahrzeug.**
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**Rheological in-mold measurements and characterizations of sheet-molding-compound (SMC) formulations with different constitution properties by using a compressible shell model.**
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**Medium-temperature molten sodium batteries with aqueous bromine and iodine cathodes.**
Electrochimica Acta 237 (2017), 12-21. DOI: https://doi.org/10.1016/j.electacta.2017.03.152.

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**A holistic approach to use multi-scale fractions of dry carbon fibre production waste in filled bulk moulding compounds (BMC).**
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Hürttlen J., Schaller U., Weiser V.
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**Combustion behavior of a metallized ADN/GAP propellant as a function of the aluminum content and the binder/oxidizer ratio.**
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Joppich T., Menrath A., Henning F.
**Advanced molds and methods for the fundamental analysis of process induced interface properties of hybrid thermoplastic composites.**
1st CIRP Conference on Composite Parts Manufacturing, CIRP-CCMPM 2017, Procedia CIRP, volume 66, 2017

Joppich T., Menrath A., Henning F.
**Product and process development of a hybrid stiffening structure for aerospace application.**
Paper, SAMPE Europe, Stuttgart, 2017

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**Oxidation of La–Sr–Mn-coated interconnector alloys for steam electrolysis under pressure in pure oxygen and in pure steam.**
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# HOW TO REACH US

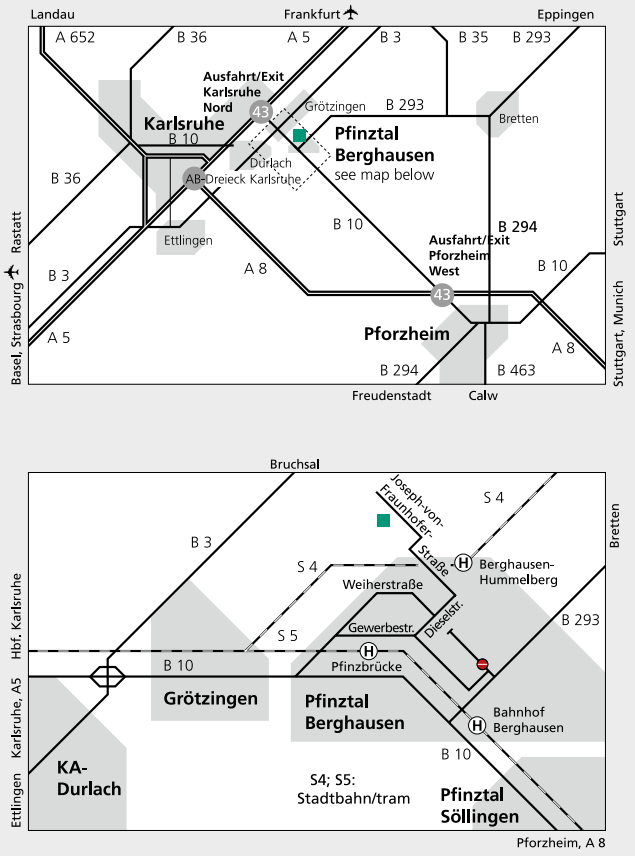
## BY CAR

**Approaching from Frankfurt/Main or Basel (CH):**
Autobahn A5, exit Karlsruhe-Nord [43], follow B10 towards Pforzheim, turn left approx. 300 m after the tunnel and follow signs to Fraunhofer ICT; follow Joseph-von-Fraunhofer Straße approx. 1.5 km uphill to reach the institute.

**Approaching from Stuttgart or Munich**
Autobahn A8, exit Pforzheim-West [43], follow B10 towards Karlsruhe, drive through Pfinztal-Berghausen, turn right after the gas station at the edge of the village and then follow signs to Fraunhofer ICT; follow Joseph-von-Fraunhofer Straße approx. 1.5 km uphill to reach the institute.

## BY TRAIN

Take the train to Karlsruhe Hauptbahnhof, change to the "Stadtbahn" (city tram) S4 which runs every 20 or 40 minutes towards Bretten/Eppingen/Heilbronn, exit at the stop Berghausen-Hummelberg. Travel time approx. 20 minutes, plus 10 minutes up the hill on foot. Please note that the S4 "Eilzug" does NOT stop at Berghausen-Hummelberg, and that the normal tram stops ONLY ON REQUEST (press the button near the door).




## BY PLANE

- Frankfurt/Main Airport (approx. 120 km)
- Straßburg Airport (France) (approx. 100 km)
- Stuttgart Airport (approx. 80 km)
- Baden Airport Karlsruhe (approx. 40 km)

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Figures are for January 2018.

# EDITORIAL NOTES

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**Printed by**
Kraft Premium GmbH, Ettlingen, Germany

**Editorial deadline**
01/2018

**Photo acknowledgements**
Title photo, page 1/2, 16, 18, 19 (right), 23, 24, 30 (right), 32, 35: Walter Mayrhofer
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