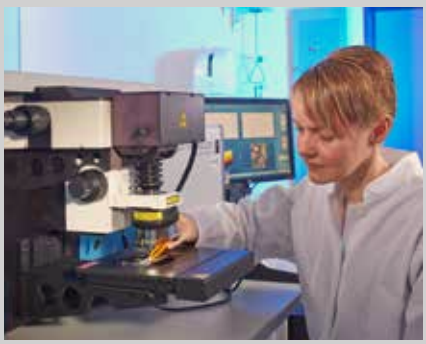
Fraunhofer
ICT

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

ANNUAL REPORT 2018/2019

60 YEARS ICT



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GENERAL INFORMATION

A STABLE ENVIRONMENT FOR COOPERATION

The positive economic situation in Germany and Baden-Württemberg has enabled us to apply many of our ideas and competences in practice. This is reflected in the large number of projects we have carried out. In more than 500 bilateral research and development projects in 2018 we generated almost 10 million euros through contractual research for our industrial customers. A further 11.2 million euros came from collaborative projects between industry and research institutes, co-financed by the federal government, the state and the EU. The higher defense budget in Germany has also increased demand for the institute's explosives experts.

This stable environment has enabled us to further expand our areas of competence. In early 2019, following the establishment of the Karlsruhe Research Factory, we started work on a development and demonstration center for factories of the future. The aim of this collaborative project between the Karlsruhe Institute of Technology KIT and the Fraunhofer institutes IOSB and ICT is to make pre-commercial processes productive using artificial intelligence, after only a short development period.

By the way, this year we are also celebrating our 60th anniversary! In 1959, Fraunhofer ICT was founded as the seventh institute of the then ten-year old Fraunhofer-Gesellschaft. When our institute was founded, it was called the "Fraunhofer Institute for Chemical Propellants". It emerged from the Institute for Chemical Technology at the Technical University of Karlsruhe, today's KIT.

Even 60 years later, we still work on the chemistry of propellants: both military propellants and explosives, and fuels for combustion engines. Over the past six decades, however, many more competences have been developed at the institute. These can be summarized under our five current core competences. We are active in the following areas:

- Chemical processes
- Energy systems
- Explosives technology
- Drive systems
- Polymer engineering and composite materials

This annual report includes more details about our research topics. We would be very pleased to hear from you, for example at our open day on Saturday 13th July, 2019. A constant exchange of information is essential to help us keep our focus on the right topics.

With best wishes,
Peter Elsner

INSTITUTE PROFILE

Fraunhofer Institute for Chemical Technology ICT

In our research we place great emphasis on the scalability of processes, and on the transfer of research results from laboratory to pilot plant scale and in some cases to pre-series application.

In 2018, around 550 people were employed at Fraunhofer ICT. Our main campus, with over 100 laboratories, multiple technical centers and 3 test centers on 21 hectares of land, is located on the Hummelberg in Pfinztal, near Karlsruhe. The New Drive Systems Department, and its various engine and exhaust test benches, are located on the East Campus of the Karlsruhe Institute of Technology (KIT).

Our customers and project partners are chemical and process engineering companies, automotive manufacturers and their suppliers, the plastics processing industry, material manufacturers, recycling companies, companies in the field of energy and environment, customers concerned with safety-related issues, the construction industry and the aviation sector. We are also the only explosives research institute in Germany to offer the entire spectrum from laboratory testing and technical processing through to fully developed systems.

Our core competences

The core competence **"Chemical Processes"** comprises the ability to design and implement innovative, resource-saving chemical processes from the laboratory through to the technical scale. We cover the entire process chain from raw material processing, chemical reaction engineering and downstream processing (e.g. purification and separation techniques) through to subsequent processes such as product refinement (e.g. crystallization and particle technology) and shaping (e.g. formulation and compounding).

Since 1994 Fraunhofer ICT has been researching technical plastics for practical use within its core competence of **"Polymer Engineering and Composite Materials"**. Our work ranges from polymer synthesis, materials technology, plastics processing, component development and production through to recycling.

Sustainable and affordable energy supply and efficient energy management are the focus of current research policy. Within the core competence **"Energy Systems"** we work on electrical energy storage devices for mobile and stationary systems, with fuel cells and electrolysis as well as heat and material energy storage systems and their applications. Within this core competence, our institute has accumulated more than 30 years of electrochemical and chemical know-how, laying the foundations for the development of efficient and cost-effective storage devices and converters.

Based on many years of experience, Fraunhofer ICT is the only German research institute that covers the entire development chain from the raw product to the prototype in the field of **"Explosives Technology"**. The institute offers its long-standing experience to the German Federal Ministry of Defence, the public sector and industrial customers, carrying out investigations into current challenges concerning national and international security.

Our core competence **"Drive Systems"** comprises solutions for electric and internal combustion drive systems. The systems are designed, constructed, simulated, and validated through testing at Fraunhofer ICT. In addition, we work on the development and validation of mobile and stationary accumulators, batteries, fuel cells and thermal storage systems.

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In memory of the long-standing Chairman of our Advisory Board Dr.-Ing. Axel Homburg

In October 2018 we received the sad news of the death of the long-standing Chairman of our Advisory Board and Honorary Curator Dr. Axel Homburg.
Dr. Homburg was Chairman of the Advisory Board from 1994 until 2008. He then served as Honorary Curator until his death. Dr. Homburg was actively involved in the reorientation and further development of our institute. His economic and technological expertise and his precise analyses played a decisive role in shaping the direction of our research.
We are very grateful to him for all his support, and will honor his memory. He will be very much missed.

ECONOMIC DEVELOPMENT

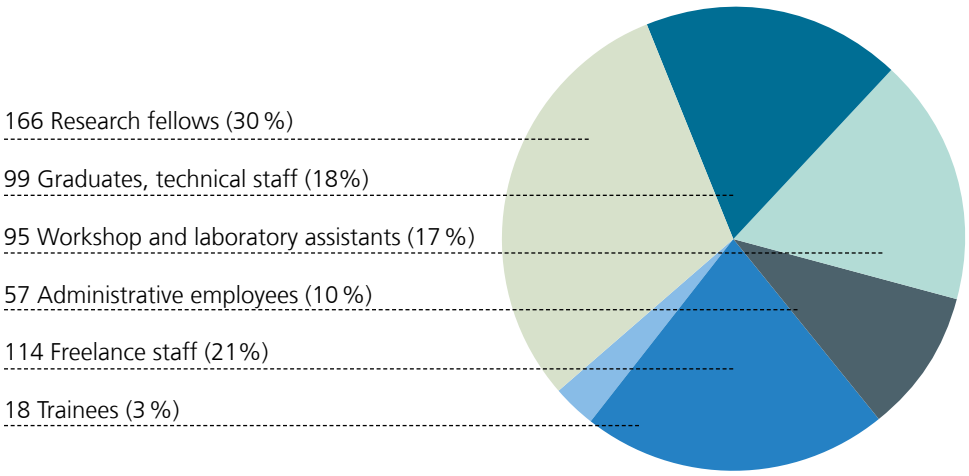
Our total budget has risen by approximately 8 percent compared to the previous year, and is currently 40.3 million euros. A third of our activities are carried out in cooperation with the German Federal Ministry of Defence and the related authorities. Thanks to the very good economic situation in Germany, we have again achieved a large increase in our industrial collaborations – so-called contractual research – of over 1 million euros compared to the previous year.

In 2018, we generated 9.97 million euros of revenue in more than 500 industrial projects, 155 of which had a volume of over 25,000€ euros. Our industrial revenues reached 39.5 percent of our total budget, improving on the previous year's figure, which was already high, by a further 2.5 percentage points.
11.2 million euros of our revenue last year came from collaborative projects between industry and research institutions, funded by the federal government, the state and the EU. We are using our institutional funding of approximately 7.4 million euros, which is calculated based on our activities and on financial data from the previous year, to work on scientific and technical approaches that will be implemented in industry within the next 5 years.

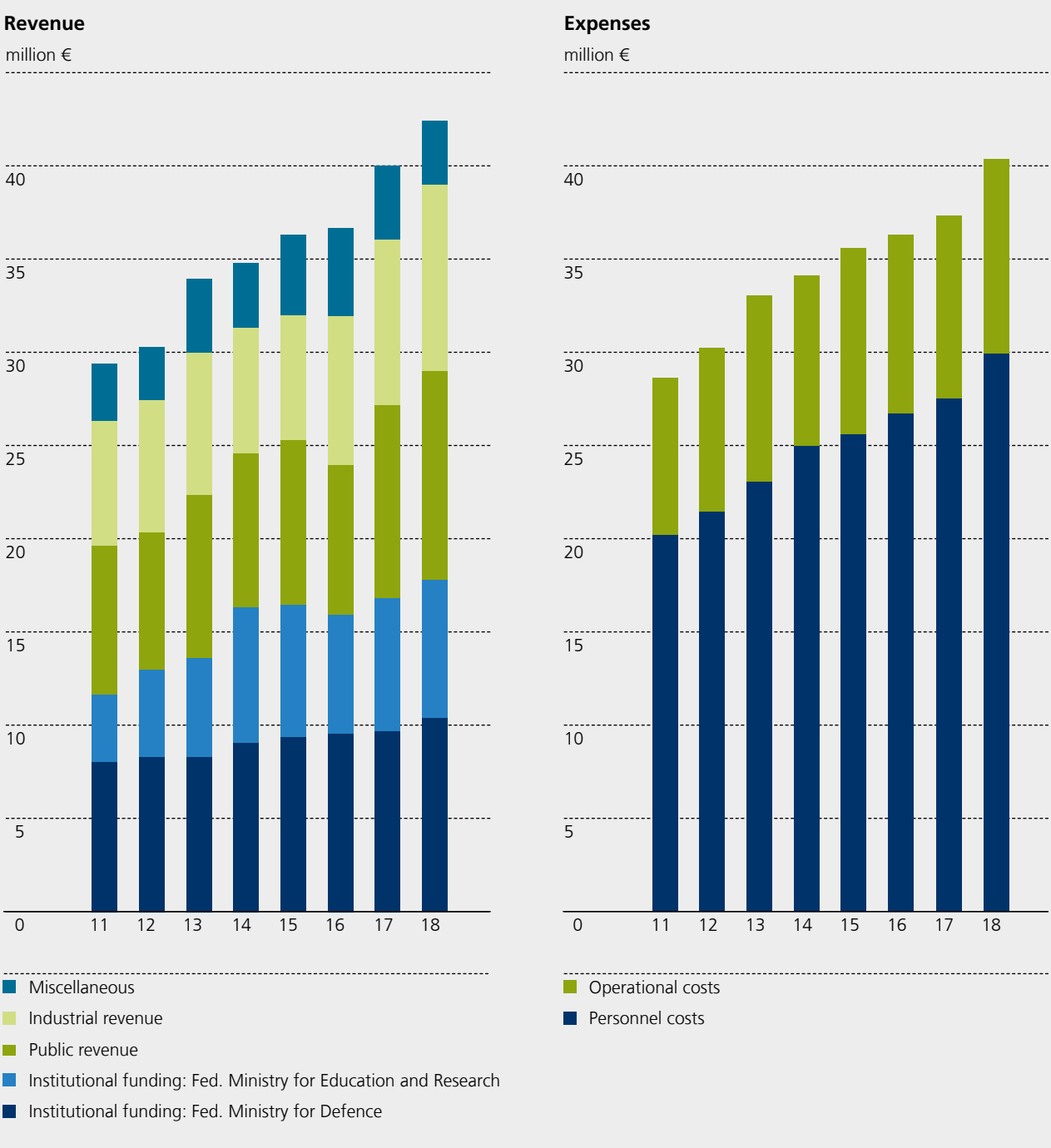
Thanks to our good economic performance, we were again able to build up reserves from unspent institutional funding in 2018. We will invest this to keep ourselves at the cutting edge of technology, and to enable our employees to participate in the institute's success through research bonuses.

For our staff we continue to rely on a strong training program. We currently have 18 trainees, and mentor numerous employees who are working on their doctoral theses.

Workforce structure of Fraunhofer ICT: Status December 31, 2018



Financial development of Fraunhofer ICT, 2011 to 2018.



CORE COMPETENCES

CORE COMPETENCE CHEMICAL PROCESSES

The core competence "Chemical Processes" 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 synthesis, chemical 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. Where the processes of fine and specialty chemistry are concerned, 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.

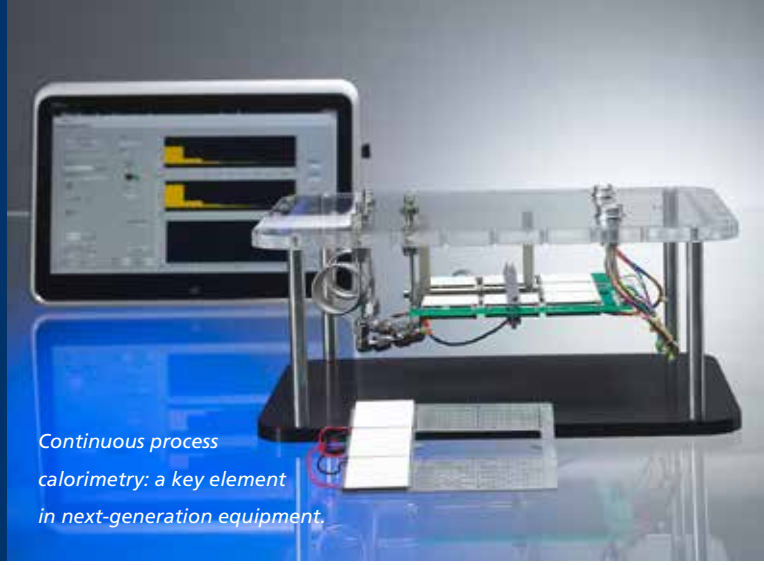
At Fraunhofer ICT we meet all these requirements through the development of modern process technologies. A considerable part of our work is exclusive, commissioned by industrial customers. A successful approach often involves a paradigm shift from discontinuous to continuous processing. For example,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

In addition, we are systematically extending continuous processes to further unit operations and new application fields. These include in particular the intensification of downstream processing (extractive purification under different pressure regimes, reactive separation, emulsion splitting), the size-controlled production of nanoparticles and microcapsules, the development of environmentally-friendly catalytic processes (also phase transfer catalysis) and electrochemical syntheses, and the intensification of multiphase reaction processes (gaseous/liquid, liquid/liquid).

An important tool in process design is cutting-edge process analysis techniques, some of which have been developed in-house. We are making significant progress in the development and adaptation of fast spectroscopic and calorimetric process analysis, which can be used to monitor the dynamics of 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 not only allows process development times to be drastically shortened, but also allows the increasing application of these data in the digitalization of chemical reaction processes - as established in the initiative "Chemistry 4.0".

The safe performance of chemical syntheses with hazard potential is based on our long-standing experience with explosives technology.

Control room for multi-stage continuous synthesis processes.



Continuous process calorimetry: a key element in next-generation equipment.

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 (explosive or toxic) processes. 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 in-house biorefinery processes and evaluate them from a bioeconomic perspective. Biogas processes for energy storage supplement the bioeconomic activities at Fraunhofer ICT. These processes include 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-chain alcohols via the PTL (power-to-liquid) process represents the latest development in reaction engineering. Hydrogen produced using regenerative energy allows the PTL process to be carried out completely independently of raw materials at the operator's site.

Biobased products enable the development of a wide variety of chemical platforms for the chemical industry. Economic assessments of downstream processes supplement the initial evaluations of the cost effectiveness, also as part of holistic life-cycle assessments (LCA). Current research topics are therefore designed for the economic intensification and energy optimization of conventional separation technologies using reactive extractions. Special salt mixtures enable selective extractions into the mobile phase. This process is more economical than a thermal separation process, especially for low-concentration product streams.

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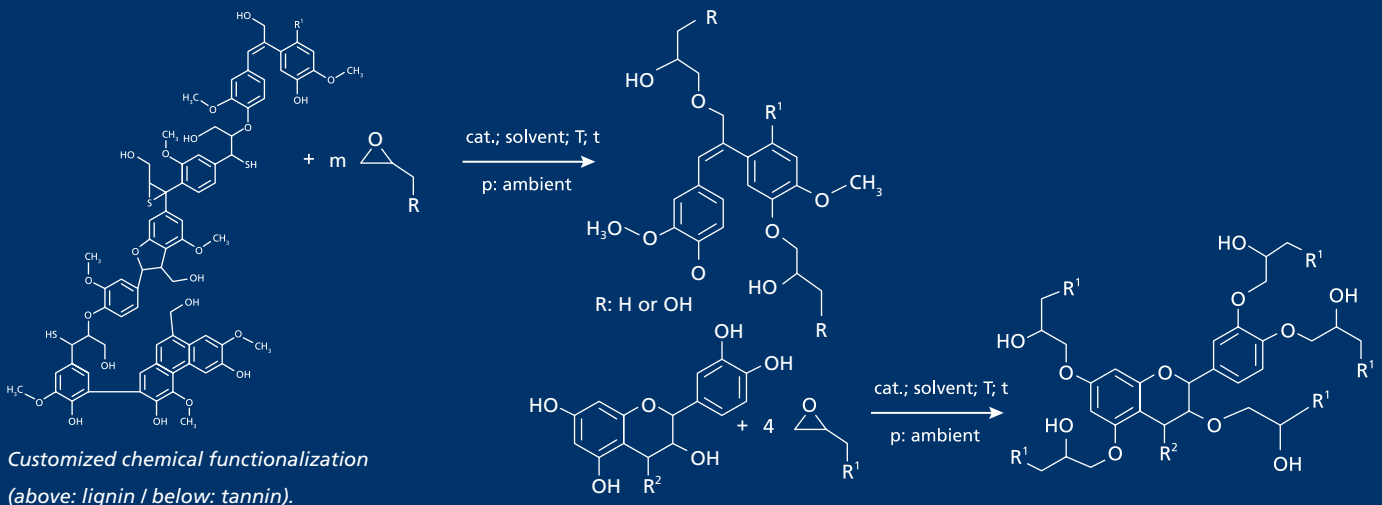

Customized chemical functionalization (above: lignin / below: tannin).

ENVIRONMENTALLY-FRIENDLY ADHESIVES MADE FROM RENEWABLE RAW MATERIALS

As part of a European collaborative project, Fraunhofer ICT is working together with associated partners on the development of alternative, formaldehyde-free wood adhesives. These new bioadhesives provide an integrative solution to the current emission problems of adhesives in wood composites.

The focus is on various chemical and biotechnological processes and modifications of the natural polyols lignin and tannin for the production of formaldehyde-free adhesive formulations. At the same time, emissions of volatile organic compounds (VOCs) generated during production and processing and later from the composite material can be eliminated. The cross-linking mechanisms, curing and co-polymerization of the bio-polyols have been investigated in detail.

New bonding technologies, bonding strength and durability as well as classification are currently the core topics in the project. By-products from major European industries (pulp industry, 2G bioethanol) are thus used for the manufacture of products to replace oil-based products with high toxicity and high environmental impact in the wood processing industry. This meets the requirements of a sustainable recycling management, and also contributes to the dissemination of new biorefinery concepts, underlining their socio-economic relevance (occupational safety and environmental protection, working conditions).

Together with the project partners, various chemical and enzymatic modifications of lignins, lignin fractions and tannins are carried out in order to adapt the chemical reactivity of these biopolymers for the production of adhesives. New approaches are under investigation for the production of lignin- and tannin-based polymeric adhesives on modified substrates. The goal is the synthesis of new, formaldehyde-free thermosets using isocyanate-free polyurethanes and polyamine building blocks. Fraunhofer ICT is developing a customized chemical functionalization of the substrates tannin and lignin as well as the fractionation or molecular sorting of different lignins as part of this conditioning. To this end, chemical modifications are implemented through grafting reactions to increase the number of chemically reactive, functional aliphatic OH groups of lignins and tannins as well as of lignin fractions up to the kilogram scale.

After synthesis, the curing process, the bonding properties and the VOC emissions of the new adhesives are characterized in detail. The technical, economic and environmental effects of selected adhesive systems are then investigated.

The project results are used as a basis for follow-up projects, aiming for an implementation phase with commercial companies.

The European project is funded by the German Federal Ministry of Education and Research (ERACo-Bio Tech: WooBAdh Funding ref. 031B0572B).

More information about this project can be found at: www.usc.es/biogroup/woobadh

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Optical-fiber-based multiplex infrared spectroscopy in a continuous synthesis process.

Adaptation of a pushbroom imager to a microstructured reactor.

HIGH-RESOLUTION ANALYTICS FOR CONTINUOUS SYNTHESIS

The continuous operation of chemical processes is an important alternative to conventional batch process operation, and offers many advantages. For example, it helps to meet increasing demands for flexibility in chemical production processes, and significantly reduces the time-to-market. Against a background of increasingly dynamic global markets, a growing variety of products and ever shorter product cycles, continuous processes in particular enable the scaling of production capacity.

In technological terms, requirements are increasingly met through the development of modular and adaptable plant technology, for example using microstructured and miniaturized process equipment.

To improve the flexibility of processes, new concepts must also be developed and applied in the area of process control. Instead of rigid control methods, data- and knowledge-based control concepts must be implemented. At Fraunhofer ICT process analytical techniques, which provide important data on material composition, form the basis for active process control.

Another significant factor in achieving flexible production processes is rapid process development. This starts on a laboratory scale, where microreaction technology combined with spectroscopic analysis techniques enables effective process and reaction screening. At Fraunhofer ICT, micro chemical engineering processes are tracked with high temporal and spatial resolution in various spectral ranges (UV, Vis, NIR, IR, Raman).

A particularly powerful measurement technology in this context is the pushbroom imaging method, originally developed for remote sensing and satellite technology, which can simultaneously acquire spectral data in an object field. Chemical processes can thus be monitored spectroscopically in real time in a selected section of a reaction space, with high spatial resolution. The use of optical fibers also allows this imaging technique to be used simultaneously as multiplex spectroscopy at several discrete, freely selectable positions in a chemical process. This enables the tracking of chemical processes over longer reaction distances, and provides a variety of kinetic and mechanistic information.

At Fraunhofer ICT, pushbroom imaging is used, for example, for process control in the continuous production of highly explosive nitrate esters on a kilogram scale. For these esterification reactions, the correct stoichiometry of the reaction partners (mixed acid and polyalcohols) must be carefully maintained for safety reasons. Deviations lead directly to decomposition reactions, which result in an uncontrolled reaction process. A pushbroom imager is adapted with optical fibers at several positions along the reaction channel of a microstructured glass reactor. A possible decomposition reaction can thus be identified by detection of the resulting nitrous gases (NOx) with a very high time resolution (< 10 ms). Furthermore, the pushbroom imager is integrated into the process control. With the aid of closed control loops, actuators, i.e. pumps and valves, can be controlled directly in order to restore a safe operating state. This significantly increases the safety of these hazardous processes, and optimizes them through a more effective use of raw materials.

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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

CORE COMPETENCE
POLYMER ENGINEERING AND COMPOSITE MATERIALS

Since 1994 Fraunhofer ICT has been successfully researching technical plastics for practical use in its core competence of polymer engineering and composite materials. Our work ranges from polymer synthesis to materials technology, plastics processing, component development and production through to recycling.

We see polymer synthesis as a foundation for the further development of so-called classic polymers such as polyurethanes, polyesters and polyamides, with the aim of improving their functionalities, such as heat resistance, and thus opening new application fields for existing materials. Another research focus is increasing sustainability through the use of biobased raw materials or natural polymers such as cellulose. In addition to polymer synthesis, we develop and optimize syntheses of additives such as flame retardants for use in new plastic compounds. No halogen-containing components are used in modern flame retardant systems.

The research group for materials and compounding technologies develops new compounding processes and material formulations. Particularly important topics include extractive compounding processes to reduce emissions, the removal of impurities during recycling and innovative reactive extrusion for polymer synthesis or polymer modification in twin-screw extruders. More material innovations result from biobased or nano-functionalized polymer compounds for high-quality molding products and additive manufacturing processes.

In the thematic field of foam technologies we work on particle foam technology and the manufacture of foamed semi-finished products in the direct foam process. Besides the optimization of conventional materials, we also work on the foaming of biobased polymers and technical raw materials, most of which are resistant to increased temperatures. The combination of plastic foams with phase change materials enables the manufacture of hybrid lightweight construction materials with high insulation values and additional room temperature control options.

Standard and specialized injection molding and extrusion processes, together with thermoplastic fiber composite materials and their processing technologies, are our focus in the field of thermoplastic processing. The development of tape laying and tape consolidation processes and the incorporation of new plant technology has completed the process chain up to component integration.

In the area of thermoset processing we pioneer material and process development for the large-scale manufacture of long-fiber-reinforced composite parts for structural and surface applications. Our core expertise is in the material development and processing of sheet molding compounds (SMC) and thermoset injection molding. The first major projects in the field of thermoset injection molding were successfully completed with the production of thermoset-based electric motor and turbocharger housing components.

Key elements of research in the area of high-performance fiber composites are the further development and industrialization of resin transfer molding (RTM) and wet compression molding (WCM) processes with regard to the mass production of continuous-fiber-reinforced components with thermoset and thermoplastic matrices. The production of textile preforms, their handling, combination with polymer foams and metallic structures, and the subsequent resin infusion are important components of the processing chain.

In the research group for microwaves and plasmas we are developing processing units and measurement technology for thermal microwave technology and microwave-based plasmas. Applications include microwave-based heating of polymers, accelerated hard-setting of adhesives and resin systems, and coating or modification of surfaces in the plasma-enhanced chemical vapor deposition process. A particular focus is on corrosion-resistant layers and nanoporous adhesive layers.

Particle foam with a thermo-formed outer layer.

Preforming with a particle foam.

Robot-based winding process for the production of skeleton structures as local continuous reinforcements in structural injection-molded parts.

In our testing laboratory, we carry out comprehensive examinations of polymer materials along the entire processing chain, from the raw material through to the component. In the event of damage or failure, we offer systematic analysis of the causes of the damage and the influences leading to failure, using analytical and technological measurement methods. In addition to standardized testing of standard materials, we also offer testing of fiber composites and polymer rigid foams.

In the field of online process monitoring, spectral and microwave-based measurement methods are developed for plant-integrated process and material monitoring and for process control. Projects in the context of Industry 4.0 build on our significant experience in the field of probe technology, the process integration of sensors and process-specific know-how in the evaluation of the raw data obtained. The application and integration of big data and KI algorithms enable "learning/immature processes".

In the area of recycling and waste management, processes and technologies for the material recycling of polymers are developed, aiming for a complete reintroduction into high-quality applications. The focus is on technologies for the recycling of composites and composite materials (GRP, CFRP) after the fibers have been extracted (e.g. by solvolysis or microwave-assisted pyrolysis processes) and the separation of PET multilayer composites in the packaging sector. Some consumer thermoplastics have to be subjected to an extraction process before they can be reused, for example to remove flame retardants or colorants. This involves the use of conventional solvents as well as supercritical fluids such as carbon dioxide. Since 2018 we have also been working on projects for the recycling of marine plastic waste.

Fraunhofer Project Center and Alliances

The partnership between the FPC@WESTERN in London, Ontario, Canada, and Western University optimally combines the competences of Fraunhofer ICT in the field of fiber composites with the know-how in material and surface research of the Canadian university. The large-scale plant technology enables us to carry out commissioned research on an industrial scale. The research focus of the FPC@UNIST in Ulsan, South Korea, is on manufacturing processes for fiber composites, new material solutions and the transfer of lightweight construction into mass production, through close interdisciplinary cooperation between process engineering and materials science. The official opening ceremony was held in November 2018.

The "Karlsruhe Forschungsfabrik®" (Karlsruhe Research Factory) is an initiative of the Fraunhofer-Gesellschaft with its institutes ICT and IOSB as well as the Karlsruhe Institute of Technology (KIT-wbk) on the East Campus of the Karlsruhe Institute of Technology (KIT). Together with industrial partners, the aim is to quickly bring new, still immature production processes to series production scale. The project will make an important contribution to the "Artificial Intelligence Strategy" of the German Federal Government. Construction work began on the Karlsruhe Research Factory with the joint groundbreaking ceremony in December 2018.

The close thematic networking with other Fraunhofer institutes within the Fraunhofer Alliances "Construction", "Lightweight Construction" and "Nanotechnology" enables us to offer system solutions from a single source.

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Fully automated production line for the manufacture of hybrid thermoplastic structural parts.

BMBF PROJECT MOPAHYB: MODULAR – EFFICIENT – LARGE-SERIES PRODUCTION

"The right material in the right place" is a maxim of multi-material design and the key concept in lightweight construction. Intrinsic hybridization, i.e. the production of a composite of metallic and fiber-reinforced plastic components in a direct original or forming process, offers the greatest potential. However, the lack of an economically viable production method has thus far prevented market introduction for current batch sizes. To overcome this obstacle, a new modular control and production concept was successfully developed in the MoPaHyb collaborative project, funded by the BMBF (Federal Ministry for Education and Research), and demonstrated and validated at Fraunhofer ICT as a pilot system.

Together with a consortium of 14 partners, a new type of plant architecture was developed to adapt production plants to new products in a modular and flexible way. For this it was necessary to subdivide system concepts into individual plant components - so-called production modules. The modules are connected to each other and, in particular, to a higher-level basic control system via standardized interfaces developed jointly in the project. The OPC UA communication protocol is a future-oriented option for networking production plants. The production process for a product is described in a PI sheet. This sheet is generated based on the modular system developed in the project. The system allows the production modules required for a product to be selected and linked. The PI sheet is exported into AutomationML, which is a high-level language independent of the manufacturer. It serves as the basis for the line control.

The validation was carried out on two demonstrator components using the pilot plant at Fraunhofer ICT. The aim was to demonstrate the configurability and reconfigurability on two different process routes. The focus of the first process route was on hybrid injection molding technology. The seat back structure investigated consists of a continuous-fiber-reinforced thermoplastic semi-finished product and metallic inserts, and is hybridized by LFT injection molding. The second process route involves an underbody segment made of a continuous fiber semi-finished product with LFT extrusion compression molding as the central process.

In addition, emphasis was placed on innovative lightweight construction technologies and their further development and optimization. For example, an intelligent tape laying process was integrated and developed: Dieffenbacher's Fiberforge. For the first process route, Arburg contributed a modular injection molding unit equipped with an FDC unit for direct fiber feeding and compounding. The outstanding feature of this technology is the separation of the supply unit from the injection molding unit. This makes it possible to connect the module individually to the Fraunhofer ICT inventory system, which is a 3600 t hydraulic downstroke press of Dieffenbacher GmbH. Additional focal points were the development of innovative gripper systems for FRP semi-finished products and investigations for the optimization of metal-FRP interfaces.

Conclusion: The pilot plant was used to successfully demonstrate and validate the innovative plant architecture. This showed that an economically viable production of hybrid fiber composite components is possible, even in small batch sizes.

More information about this project can be found at: www.mopahyb.de

MO·PA·HYB

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PU flexible foam made from recycled material.

CHEMICAL RECYCLING OF POST-CONSUMER POLYURETHANE FLEXIBLE FOAM

Polyurethanes (PUs) are one of the most versatile polymer types, since thermosetting, thermoplastic and elastomer properties can be obtained through specific formulations. With an annual production of 18 million tons, polyurethanes are the sixth most common polymer material in the world. The wide range of materials also results in a very broad field of application.

Almost a third of the polyurethanes produced worldwide are used in the manufacture of flexible foams such as mattresses, cushions and seat cushions for the automotive and aerospace industries. After an average lifespan of about 10 years, approximately 30 million mattresses need to be replaced each year in Europe alone. This is equivalent to around 450,000 tons per year. Currently 40% of these mattresses are burnt and 60% end up on landfills. This problem will become even more acute in the future, as in some countries, including Germany, landfilling is no longer permitted. The chemical recycling of the material can replace landfilling and burning while at the same time obtaining new raw materials for PUs.

Chemically, polyurethanes are condensation products of isocyanates and polyols. As part of the European research project URBANREC, we have developed a chemical solvolysis process for the recycling of PU foams. Various alcohol components are tested and used for solvolysis.

With the process developed in the project, it is possible to recover polyol components for new, high-value PU materials from post-consumer mattresses. Together with our project partners we have successfully produced mattresses, hot-melt adhesives and insulation foams. Starting from standardized tests, we have identified various potential uses for the secondary polyols produced by this chemical recycling process. These applications reduce the proportion of fossil-based polyols in new syntheses.

An economic and ecological evaluation of the process in comparison to the use of fossil polyols is currently being carried out.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no. 690103.

More information about this project can be found at: www.urbanrec-project.eu

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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
- Dynamic mechanical analysis (DMA)
- High-pressure capillary viscometer with pVT measurement technology
- Rheotens® device for measurement of 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 test 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. Within the core competence "Energy Systems", Fraunhofer ICT works on electrical energy storage devices for mobile and stationary systems, on fuel cells and electrolysis, and on heat and material energy storage devices and their potential 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.

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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.
To store electrical energy, we are developing new, efficient options and investigating systems already on the market. 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 thermally and electrically characterized and simulated, to tailor them 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.
Electrocatalysts for fuel cells and next-generation electrolyzers are a focus in the area of converters. The main emphasis is on the development of alkaline direct-alcohol fuel cells, for example the development of palladium non-noble metal alloy catalysts for alcohol oxidation or ionomers with high stability in alkaline alcohol solutions. We are developing anode catalysts for medium-temperature fuel cells that have a high tolerance for impurities (especially sulfurous compounds), for operation with logistic fuels available for military use.
We also have a high level of competence in the online analysis of electrochemical processes, which can also be applied to investigate degradation processes in vehicle PEMFCs. A further competence is the design of systems for use in unusual environments, for example under water.
One way to use electric energy efficiently is the generation of chemical products. We are working on the development of electrochemical reactors, including electrocatalysts and electrodes, their integration into a complete process, and coupling to subsequent process steps. A current example is the electrochemical extraction of hydrogen peroxide by the partial reduction of atmospheric oxygen, combined with use in a 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 reservoirs based on phase-change materials, and hybrid components combining thermal mass and insulation, are strongly market-oriented and complement our fundamental research activities. In the field of material storage, Fraunhofer ICT is concerned with hydrogen as an energetic material and platform chemical. A particular area of expertise is safety assessment and the design of systems, pilot plants and processes.
Important research areas are the handling and especially the storage and transportation of hydrogen, the development

2 MW wind power plant with redox flow battery and Battery Application Center.

and performance of specific safety tests and the evaluation, concept and design of hydrogen storage systems. The equipment available at our Application Center for Stationary Energy Storage Devices enables the characterization and development of a wide spectrum of materials, through to the behavior of a storage device in an electric grid with renewable energy sources.

Networks and alliances

Fraunhofer ICT pools its competence with other institutes of the Fraunhofer-Gesellschaft through Fraunhofer networks and alliances. The spokesperson of the Fraunhofer Batteries Alliance, Prof. Dr. Jens Tübke, is an employee of Fraunhofer ICT. Fraunhofer ICT is also active in the alliances "Energy", "Space" and "Building Innovation" in relation to this topic.

Services and technology transfer

We offer our customers a wide range of development services for electrical and thermal storage devices and electric converters, aimed at different applications in the civil and military sectors. The design and development of fuel cell systems for stationary applications and for vehicles include the following focal points:

- complete characterization of PEMFC, HT-PEMFC and DMFC fuel cell stacks
- environmental simulation tests on stacks and systems, such as 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. We have various test cells and self-developed measuring cells for the evaluation of battery materials such as electrodes, separators, electrolytes and charge eliminators.

- Conductivity measurements (electrolyte, membrane, separator)
- Evaluation of electrodes (e.g. 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 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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Solar panel system, consisting of 100m²
of air collectors at Fraunhofer ICT.

"STARK" – SOLAR THERMAL SYSTEM FOR AIR CONDITIONING IN BUILDINGS

More than 50 percent of Germany's gross final energy consumption relates to the provision of heat and cooling. Heat is predominantly generated from gas, but electricity, which is also partly produced from fossil fuels, is usually the preferred energy source when it comes to cooling. Considering the enormous energy consumption, it seems paradoxical that large amounts of waste heat are dissipated unused into the environment and existing solar heat is not used more effectively.

One way to improve the energy efficiency of heat generation processes, or to use waste heat and solar heat for cooling, is the use of thermally operated heat pumps. One example is the adsorption heat pump.

In the project "STARK", funded by the Federal Ministry of Education and Research, a solar thermal system for air conditioning in buildings will be conceptualized, constructed and tested in annual operation. The aim of the project is to develop a cost-effective and environmentally friendly alternative to air conditioning by combining solar air collectors with an adsorption cooling system. Energy savings of approximately 50% compared to the requirements for energy efficiency class A, a ratio of cooling performance to operating heat of at least 0.3, and supplementary heating during the transition period will be achieved.

A novel solar air collector, produced in the predecessor project "Solintro", will form the basis for these developments. This air collector is characterized by its particularly low weight and low flow resistance. The increased desire for comfort, especially in commercial buildings such as industrial warehouses, can be met using this collector.

Our project partner Nordluft set up a 100 square meter collector field on the Fraunhofer ICT energy campus. This collector array, which is equipped with measuring technology, supplies the operating heat for the adsorption cooling system and serves as a demonstration plant in which other technologies, such as latent heat storage devices, can also be tested. In the course of the project, data will also be collected on the efficiency of the collector system in real operation. The energy yield of the solar collectors under different environmental and processing conditions can be calculated from the obtained data using simulation calculations.

The project is funded by the Federal Ministry of Education and Research and supervised by the Project Executive Agency of the German Aerospace Center (DLR). Funding ref.: 01LY1619B.

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Electrolysis cell for the cathodic conversion of vanillin.

Divanillin as an educt for the production of polyvanillin, oligomeric Schiff bases and polyimines.

"INTELEK-TO" – PROCESS AND BIOPOLYMER DEVELOPMENT

The Kraft process is used to produce approximately 160 million tons of lignin-containing lyes worldwide, which at present are mostly used for energy production and the recovery of fractionation chemicals. Due to their multifunctional, aromatic structure, Kraft lignins are potential precursor materials for the production of fine chemicals, intermediate products and biobased high-performance polymers. Their complex molecular structure means that thermal catalytic degradation processes result in a large number of monomeric compounds, but electrochemically Kraft lignins can be oxidatively cleaved into a few monomeric compounds (vanillin, syringaldehyde, derivatives) in a highly selective manner. This is the starting point for the collaborative project "IntEleK-to", which is funded by the Federal Ministry of Food and Agriculture (BMEL) and the Agency for Renewable Resources (FNR).

Fraunhofer ICT coordinates the consortium of this collaborative project, which consists of the University of Mainz and the reactor manufacturer HiTec Zang GmbH. The aim is to develop a highly integrated electrochemical continuous process and reactor system to convert lignins into the above-mentioned aromatic platform chemicals and new oligomers. The monomer compounds are used to build drop-in chemicals and intermediate products for material applications. These are interesting because they can be processed into products already available on the market, such as polymer additives, high-performance polymers, pharmaceuticals, aromatic substances and odorants.

The Applied Electrochemistry Department at Fraunhofer ICT works on the processing of vanillin and vanillin derivatives to higher molecular compounds by cathodic electrosynthetic conversion. For this purpose, a specialized electrochemical cell set-up was built, enabling selective electrochemical syntheses on a gram scale. Based on these results, a continuous reactor is being constructed with optimized conditions to produce vanillin-based polymers. Integrated separation technology generates biobased polymers with a uniform molecule size. The Environmental Engineering Department of Fraunhofer ICT then carries out a detailed analysis of the resulting oligomer decomposition products from the electrochemical lignin oxidation. A downstream chemical modification of the oligomer oxidation coupling products with 2,3-epoxy-1-propanol and derivatives subsequently allows variation of the chemical functionality and broadens the material application fields. In addition, the department investigates possibilities for fabricating oligomeric and polymeric Schiff's bases, which are based on vanillin and vanillin derivatives. The polyimines and bi-functional synthons produced are characterized in terms of their suitability for fabricating high-performance polymers. Cathodically produced low-molecular pinacol coupling products are converted using 2,3-epoxy-1-propanol derivatives to novel, star-shaped polyhydroxy compounds with variable functionality, and are also characterized.

Fraunhofer ICT has broken new ground in the area of organic electrosynthesis. In the 3-year collaborative project "IntEleK-to", the institute will develop renewables-based, environmentally friendly alternatives to traditional oil-based oligomers and polymers.

This project is funded by the Federal Ministry of Food and Agriculture and the FNR (Agency for Renewable Resources). Funding ref. 22409617.

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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 working with explosive materials and covering the entire development chain from the raw product through to the prototype system, Fraunhofer ICT offers its long-standing experience to the German Federal Ministry of Defence, the public sector and industrial customers, carrying out investigations into current challenges concerning national and international security.

The institute draws on the competence of its employees in the research and development of improved chemical energy sources and systems for the German army, and thus helps to ensure the strong analysis and decision-making capability of the German Federal Ministry of Defence (BMVg). In addition, current issues in the thematic fields of external and internal security are addressed. Research is focused on the development, synthesis, characterization, formulation and production techniques of components for rocket propellants, gas generators, gun propellants, explosives and new ignition systems. Fraunhofer ICT is the only German research institution to cover the entire 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 retardant coatings, and pyrotechnic flares with spectral emissions that spectrally resolving seekers cannot distinguish from those of real engines.

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 in the laboratory, detonation chamber or open-air testing ranges, up to the kilogram scale, and simulates them using in-house computer codes. Current research topics include environmentally-friendly, low-signature high-performance 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 energetic substances as well as the prediction of their aging behavior.

A further competence is the detection of explosives even in trace amounts using special sensor concepts, for example on the basis of molecular adsorbers. At Fraunhofer ICT, so-called terrorist explosives are fabricated, evaluated with regard to their handling properties and detectability, and made available to the security authorities for testing purposes. Activities extend to the development of concepts to detect illegal explosives factories, the design of civil or military security areas and checkpoints, and the standardized evaluation of detection systems on an international level, such as those used for security checks at airports. Complementary activities relate to the development of protection systems against terrorist actions.

Secondary reaction of a blast-enhanced explosive.

CORE COMPETENCE
EXPLOSIVES TECHNOLOGY

Networks and alliances

In the field of explosives technology and security research, Fraunhofer ICT is part of the Fraunhofer Group for Defence and Security VVS, in which seven institutes and three guest institutes have pooled their competences to coordinate and implement research activities. Fraunhofer ICT is also a member of the Fraunhofer Space Alliance - an association of 15 Fraunhofer institutes that conduct 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 offer research in all areas of explosives technology for the German Federal Ministry of Defence and other public authorities, the defence and security industry, and the automotive and aerospace sectors. We focus on the development, design and evaluation of energetic products and systems, drawing on our chemical know-how and safety facilities and equipment. We develop tailor-made process technologies for the safe manufacture of explosive components, support the search for REACh-compliant substances and provide demonstrators to test new energetic products.

Software-assisted analysis and design tools enable the screening of new propellant and explosive formulations, for example based on their performance and environmental compatibility. In the case of gun propellants and ballistics, this also includes the consideration of system aspects of weapons and ammunition.

We are also able to carry out and evaluate all development steps of pyrotechnic gas generators for safety equipment (e.g. airbags) according to application and customer requirements. 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. Furthermore, in cooperation with the German Federal Police, the institute tests and certifies such systems for use in European airports.

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Diver with a moored mine
©State Criminal Police Office (Landeskriminalamt) Schleswig Holstein, explosive ordnances disposal team (Kampfmittelräumungsdienst) , 2012

ROBEMM – ROBOTIC UNDERWATER SALVAGE AND DISPOSAL PROCESS

The RoBEMM project, funded by the Federal Ministry for Economic Affairs and Energy, is concerned with ammunition waste in the North and Baltic Seas. According to current estimates, there are still around 1.6 million tonnes of conventional and chemical explosive ordnance in these environments, which constitute enormous potential risks to flora and fauna, shipping and salvage personnel. Even after more than 70 years, explosives in mines, torpedoes, bombs and many other explosive devices are still intact and dangerous. As the ammunition bodies are badly corroded, in many cases toxic explosives and other ammunition components or combustible substances such as white phosphorus have already become exposed. Currents and sediment movements are distributing these substances in the sea.

The partners in the RoBEMM project have designed a methodology to map the entire process chain from ammunition salvage and dismantling through to thermal disposal directly on site. The focus of Fraunhofer ICT was on safety and minimal impact on the environment. The methodology is intended to eliminate the need for future diver operations, blasting and transportation. At the same time, the clearing capacity will need to be increased, so that the enormous quantities can be handled in bulk and thus effectively, for as long as possible.

Safety-related characterization and design

Fraunhofer ICT was chiefly concerned with the characterization of explosives samples from aged ammunition bodies with regard to their safety data, and statistical analysis of the actual explosive compositions. During the war, the availability of raw materials fluctuated greatly, and explosives were sometimes "bulked up" with fillers such as sand and sawdust. On the basis of these investigations, the safety design of the process chain from the handling of the ammunition and explosives through to their disposal was carried out as part of the RoBEMM subproject "SiMSE".

In close cooperation with the explosive ordnance disposal teams in Schleswig Holstein, Mecklenburg-West Pomerania and Lower Saxony, and with the ammunition destruction company GEKA, it was possible to take samples from various ammunition bodies. These samples were made available to Fraunhofer ICT. Most came from marine explosive ordnance, which mainly contained so-called "guncotton 39" or hexanite. This explosive formulation, often used during World War II, consisted of 2,4,6-trinitrotoluene (TNT), ammonium nitrate (AN), 2,4,6,2',4',6'-hexanitrodiphenylamine (hexyl) and aluminum (Al). The identification of these substances enabled data to be obtained on the explosive composition and toxicity according to the type of ammunition.

The main task of the safety investigations was to measure the friction and impact sensitivity of the samples, since the robotic handling, processing and disassembly of the explosive ordnance cannot be conducted without some minimal mechanical stress. According to the UN classification, an explosive substance with a value of < 40 Nm is generally considered to be sensitive to impact, and a substance with a value of < 4 Nm is considered to be very sensitive. Friction sensitivity was unproblematic for all the samples tested, but impact sensitivity was found to be decisive.

For some samples with values well below 10 Nm, impact sensitivity was in the range of the primary explosives, significantly restricting the selection and operating mode of the processes that could be used.

All results were directly incorporated into the design of the process engineering concept covering ammunition and explosives handling. Fraunhofer ICT also contributed its know-how in the physical characterization of ignition processes during detonations. For the safe application of the water-jet cutting technology developed in the project, which aims to process and dismantle the explosives contained in explosive ordnance, processing limits were calculated.

As a key step, the fastest possible separation and thus desensitization of the explosives after their extraction from the ammunition shell was identified. Various desensitizing concepts were considered in order to balance the remaining risks and optimize process reliability and fault tolerance.

For a holistic approach, all conceivable hazards in the processing and disposal of explosives were considered on the basis of risk analyses for various operating conditions, including malfunctions and maintenance, and incorporated into the safety concept.

The overall safety concept is also based on activity-specific hazard assessments, which reduced the remaining risk of spontaneous reactions of the explosives to a tolerable minimum during the disassembly and processing of explosive ordnance.

Public relations

At the Hannover Messe 2018 RoBEMM was presented at the Fraunhofer main booth, to draw attention to the project and also to the problem of contaminated sites and the associated risks, and thus stimulate a scientific approach to this broad field. The exhibits were a dummy mine provided by the project partner Heinrich Hirdes to raise awareness of the actual dimensions of marine explosive ordnance, and a miniature representation of all steps in the process, providing an overview of the project. In addition, the results of various safety investigations and analyses were presented.

Project partners

The project coordination and the engineering of the disassembly technology were carried out by the explosive ordnance clearance company Heinrich Hirdes EOD Services GmbH. Automatic Klein GmbH was concerned with linking all subcomponents and with the automation. The Institute for Infrastructure and Resource Management (IIRM) at the University of Leipzig was responsible for quality assurance in the form of guidelines and the design of a test field as a basis for certification.

Project aim:

The long-term goal of the RoBEMM project is to implement an economical procedure by which explosive ordnance can be processed semi-automatically, directly at the underwater site, and the contents desensitized. This offshore disposal will minimize environmental damage, and only the scrap metal will need to be salvaged. The dangerous use of divers will be avoided to ensure maximum safety for the clearing personnel.

The project is funded by the Federal Ministry for Economic Affairs and Energy, grant number 03SX403A.

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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

CORE COMPETENCE
DRIVE SYSTEMS

Our core competence "Drive Systems" comprises solutions for electric drive trains and internal combustion engines. The systems are designed, simulated and validated through testing at Fraunhofer ICT. In addition, we work on the development and validation of mobile and stationary accumulators, batteries, fuel cells and thermal storage systems. In the field of internal combustion engines we are investigating synthetic fuels and additives using our research combustion engines. In the area of power train system developments, we utilize our expertise in polymer engineering to develop structural power train components.

Electric drive train concepts

In the field of electric drive train concepts, we develop electric power trains and their components. An essential part of this work is the design and development of electric engines and transmission systems for future electric vehicles. We focus on technologies with a high weight-specific power density and high efficiency. In the case of electric engines we focus on alternative cooling concepts and winding types, as well as manufacturing technologies with the potential for use in efficient, large-scale production processes.

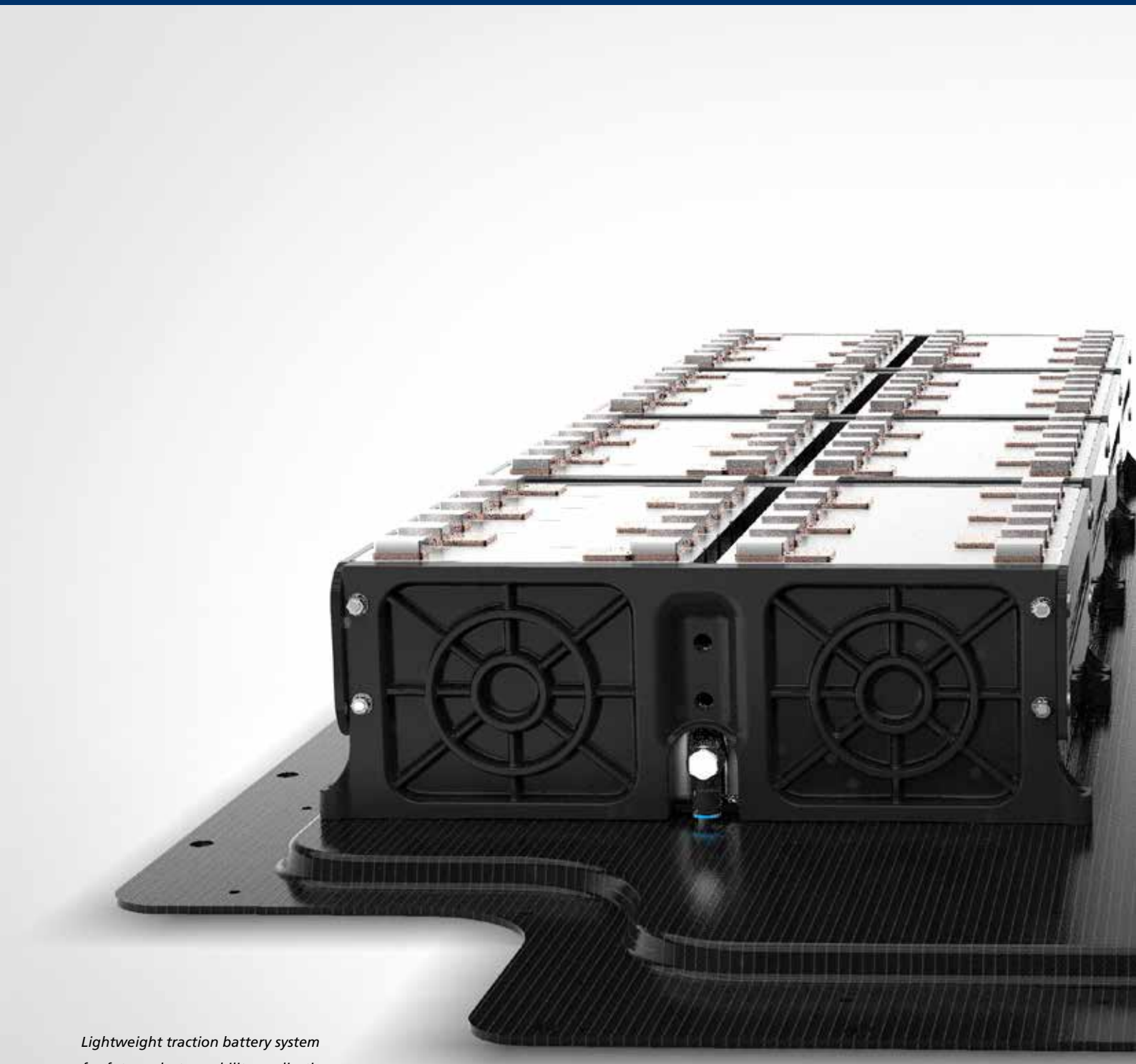
In the field of traction battery system development, our research centers focuses on the development of safe, lightweight solutions with integrated functions, which meet future demands for high energy and power densities and safety requirements during fast charging and discharging. An essential part of these developments is the conception, design and simulation of efficient thermal management systems, which are necessary for the heating or cooling of the battery systems.

Combustion engine drive concepts

Due to its very good overall efficiency (well-to-wheel) and the high gravimetric and volumetric energy densities of the fuels used, combustion engines will continue to be a dominant propulsion system in transport and individual mobility in the coming years. In the field of combustion engine concepts, we aim to develop technical solutions for the entire powertrain for mobile applications. We research and develop combustion engines both as stand-alone drive units and in combination with an electric engine, as a hybrid drive system. Our research objectives are to reduce fuel consumption and emissions from internal combustion engines, to ensure system safety and flexibility, and above all to render them compatible with affordable mobility. For this purpose we work on highly efficient combustion processes, alternative engine concepts, improved engine mechanics and waste heat recovery. Thanks to our comprehensive research expertise and the cutting-edge equipment in our pilot plants, we are setting new trends in exhaust-gas after-treatment, synthetic fuels and engine design materials. Our research staff use various simulation and optimization tools, as well as modern laboratory equipment and automated testbeds.

Design competence

Drawing on our design competence, we develop new concepts for complex systems for our industrial and project partners. For example, we design and produce prototypes to validate new operating principles or layout concepts for electric engines, up to complete thermal energy converters such as combustion engines and turbines. Our competence starts in the conventional design phase. We develop drafts and create detailed designs and drawings with a view to efficient production. As a standard we use CATIA V5 in conjunction with a CAD data management system and an extensive material database in our commissioned projects. To ensure



Lightweight traction battery system for future electromobility applications: light, safe, with integrated functions.

Generatively manufactured cylinder head during trials on the engine test stand.

the best possible collaboration with our industrial partners, we apply an MML design methodology. This generates a clear and uniform component structure.

Simulation competence

To verify and model new designs, we analyze complex components and systems, starting in the concept phase. To assess the behavior of individual components in the system, we use simulation tools for the transfer of heat, material and information, for example "Dymola" or "GT-Suite". The components are modeled physically or in a map-based system. In the field of internal combustion and electric engines, novel cooling concepts are designed and simulated using CFD and CHT modeling. The tool "IPG-CarMaker", which simulates the entire vehicle, enables vehicles to be split into different modular components, the efficiency of which can be assessed during driving. This makes it possible to calculate potential consumption advantages of the technologies in driving cycles. For flow, multi-body and structure simulation we also use professional tools according to current industrial standards, e.g. Ansys Fluent, StarCCM+, Ansys Mechanical, and SimPack.

Testing competence

We operate cutting-edge testing facilities that complement our expertise in the simulation, design, development and manufacture of components and systems in an extensive test field. Complete measurements of multi-cylinder engines (smaller passenger car size) and single-cylinder test engines can be performed on our engine test stand. On our hybrid test stand the entire electrical system within the drive train is investigated. It comprises a DC-to-DC converter, an inverter and an electric machine.

The DC-to-DC converter can be used, for example, to display changes in the battery voltage according to the state of charge. The hot gas test stand is used to investigate waste heat recovery systems, thermoelectric generators, turbo generators, exhaust-gas turbochargers and exhaust systems. An extension of this test stand developed at Fraunhofer ICT enables us to determine the damage behavior of components, or to superimpose high cycle fatigue (HCF) onto thermo-mechanical fatigue (TMF) over time. For this purpose, the hot gas test stand is combined with a high-frequency pulsator, which generates the mechanical load. Our portable exhaust gas measurement system (PEMS) and our data logger make it possible to record real driving data on emissions as well as operating and environmental conditions.

CONTACT
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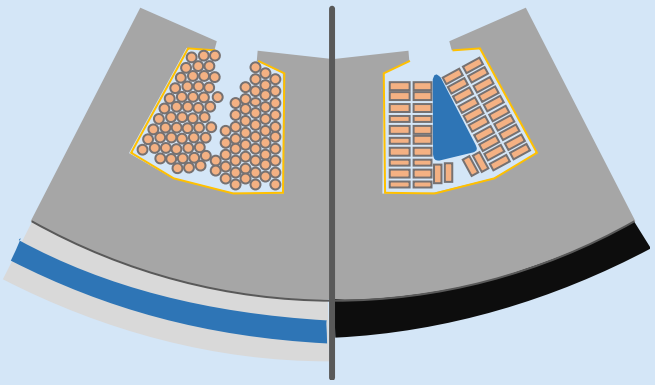
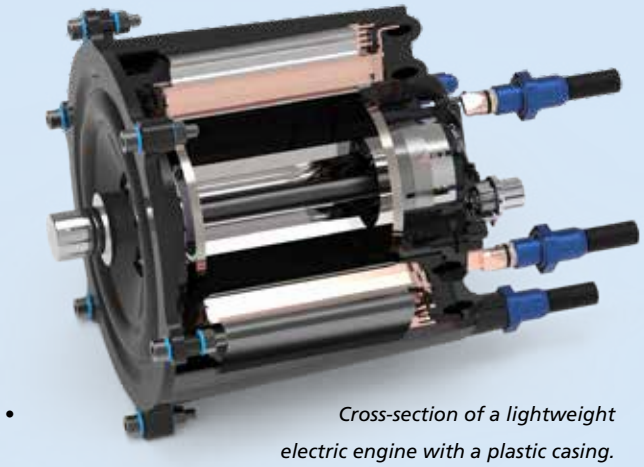


Comparison of conventional electric engine cooling (left) and a new approach with internal cooling channels (right).



Cross-section of a lightweight electric engine with a plastic casing.

DIRECTLY COOLED PLASTIC COMPOSITE ELECTRIC ENGINE FOR TRACTION APPLICATIONS

Motivation and objectives

Electric drive trains are considered to be a key element of sustainable and environmentally friendly mobility for the future. To increase power density, improve efficiency and simultaneously reduce costs, a new approach for a permanent magnet synchronous machine is being investigated. This machine is constructed using plastic composites and is equipped with direct cooling of the stator and rotor. The chosen cooling concept significantly increases the continuous power density of the engine compared to engines based on today's state-of-the-art technology. Plastics with increased thermal conductivity are used in the engine.

Concept

The core component of the engine is a stator consisting of twelve segmented individual teeth which are vertically wound with a flat wire. By using the flat wire, in contrast to the typically used round wire, a free space can be created with a consistent slot fill ratio, which is used to form a cooling channel. This means that waste heat can be dissipated directly in the stator and thus close to where it occurs. The distribution of the cooling water flow to the individual cooling channels takes place in bearing shields, which result from the design of ring-shaped channels. Because the rotor is cooled by a fixed water jet in the rotor shaft, the waste heat of the rotor can also be dissipated directly in the engine. The functional demonstrator with its continuous power of 50kW is designed for traction applications in electric mobility.

Material and production process

All electrically active parts of the stator assembly are overmolded in a transfer molding process with a highly filled, thermally conductive epoxy resin molding compound, in which process the cooling channels are formed by mold cores. The low viscosity during mold filling means that copper windings, sensors and electrical connections can be incorporated without damage. To ensure the structural integrity of the engine, the overmolded stator assembly is mounted in an injection-molded casing made of a structural phenolic resin molding compound, in which the rotor assembly and the sealing of the cooling circuit are also achieved. The thermoset compounds selected by our strategic industrial partner SBHPP have good mechanical properties, even at elevated operating temperatures. They are also resistant to the cooling agents used, and are characterized by high dimensional stability. Processing in transfer molding and injection molding ensures high reproducibility with short cycle times.

CONTACT
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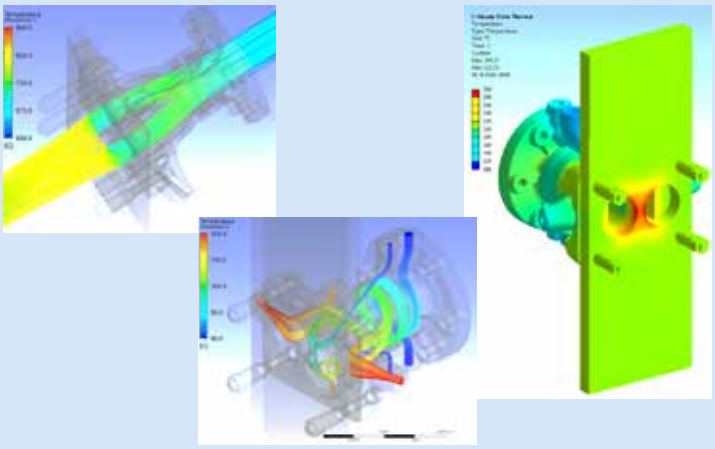
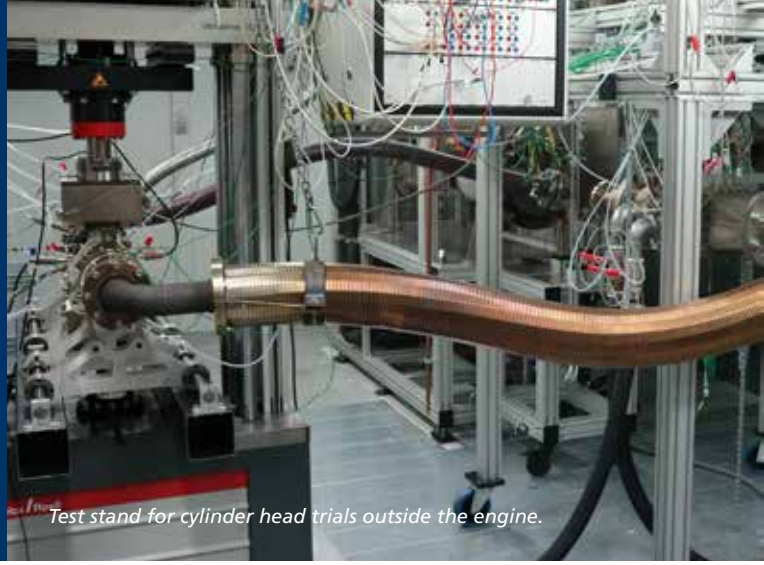


CHT simulation of the test stand components and samples.



Test stand for cylinder head trials outside the engine.

COMPONENT TESTING OUTSIDE THE ENGINE AND UNDER REALISTIC STRESS CONDITIONS

Motivation and objectives

Cylinder heads and pistons in combustion engines are exposed to significant temperature changes during operation, which cause high thermo-mechanical stress and thus thermo-mechanical fatigue (TMF). Since the thermo-mechanical stress is associated with time-dependent plastic deformations, small fatigue cracks form after relatively few thermo-cycles, and their growth limits the service life of the components. The combustion process results in additional high-frequency loads, which are superimposed onto the thermal cycles and also contribute to fatigue (HCF = high cycle fatigue).
To prevent premature failure of the components affected by TMF/HCF, these components are tested on engine test stands under tougher operating conditions, before the series production of a new combustion engine begins. However, trials on these test stands are time- and cost-intensive and allow only a very limited insight into the local stresses on the components, limiting the conclusions that can be drawn about the damage development of individual components. Within a research project, a test methodology was developed which can be used to test pistons and cylinder heads as well as different materials under realistic conditions without engine bench tests, and to track and document damage during the test.

Concept

In order to represent realistic loads, TMF and HCF loads must be superimposed. This was achieved by coupling two different test fixtures. The TMF load is applied with the natural gas burner of the hot gas test stand. For the HCF load, the test specimens are clamped in a high-frequency pulsator (HFP), which allows them to be exposed to hot gas under simultaneous mechanical loading.

Test stand development

A highly simplified geometry of the combustion chamber roof is defined for the cylinder head sample using several FEM simulations. By this means the state of loading can be simulated very realistically with an HFP in the failure-critical area of the valve crosspiece. A slightly modified series-produced commercial vehicle piston is used for the piston sample. Numerous FEM simulations provide the necessary data for realistic load application by an HFP.
The design of the test stand superstructures is based on the real thermal loads of the components to be tested. The flow of the hot gas and the cooling of the test specimens are repeatedly optimized using CHT simulation and adaptation of the design so that realistic surface temperatures and temperature gradients can be achieved.
An in-situ optical crack detection system has been developed to monitor crack formation and crack propagation. It uses water-cooled, high-temperature resistant endoscopes, camera systems and optical fibers to observe the critical area of the test specimens.

CONTACT
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FACILITIES AND EQUIPMENT

ENGINE TEST STAND

- Load equipment
- D2T automation
- 250 Nm, 120 kW, 12 000 r.p.m.
- Exhaust gas measurement technology
- Cambustion NDIR, HFR, CLD
- AVL 489 (particle counter)
- Simulation platform
- AVL InMotion

HOT GAS TEST STAND

- UTF natural gas burner
- Max. temperature 1200 °C
- Power up to 400 kW
- Hot gas mass flow up to 1800 kg/h
- Temperature gradient up to 100 K/s

MOBILE HOT AIR TEST STAND

- Hot air generator (electric)
- Max. temperature 650 °C
- Power up to 32 kW
- Hot air mass flow up to 250 kg/h

RDE MEASUREMENT EQUIPMENT GAS-PEMS

- NO/NO2, CO/CO2, O2
- Opt. FID module (THC, CH4)
- Exhaust gas volume flow
- OBD logging
- Heated channels
- Electricity supply: battery

PN-PEMS

- Real-time particle number

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 and cells: Synthesis of electrode materials, current collector and particle modifications, development of electrolytes and separation technologies
- Cell production: Electrode production, cell assembly, cell characterization, digitalized battery production, Industry 4.0
- System and integration: Packaging and cell design, battery management systems, prototype battery manufacturing, vehicle integration
- Testing and evaluation: Electrical and mechanical characterization, functional tests, transport and storage tests, safety and abuse tests
- Simulation and modeling: Supporting simulations across all stages of the value chain, from quantum chemical to structural mechanical simulations

Contact: Prof. Dr. rer. nat. Jens Tübke
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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 different climate zones

Contact: Prof. Dr.-Ing. Axel Kauffmann
Tel. +49 721 4640-425 | axel.kauffmann@ict.fraunhofer.de

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
Tel. +49 721 4640-420 | frank.henning@ict.fraunhofer.de

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: Near zero-energy buildings
- 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
Tel. +49 721 4640-343 | jens.tuebke@ict.fraunhofer.de

FRAUNHOFER SPACE ALLIANCE

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

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Volker Weiser
Tel. +49 721 4640-156 | volker.weiser@ict.fraunhofer.de

CLUSTERS OF EXCELLENCE

The Fraunhofer Clusters of Excellence promote the cooperative development and processing of system-relevant topics through an inter-institute research structure. In organizational terms, these research clusters correspond to a "virtual institute" spread over multiple locations. The aim of the research clusters is not just to temporarily implement single projects but rather to follow a roadmap for the long-term development of a complex technological trend.

FRAUNHOFER CLUSTER OF EXCELLENCE-PROGRAMMABLE MATERIALS

The development of programmable materials could transform our use of materials. A single material can replace complete systems comprising sensors, controllers and actuators. The aim of the Fraunhofer Research Cluster Programmable Materials is to reduce the complexity of systems and the consumption of resources by integrating functions into the material.
The Fraunhofer Cluster develops materials or material systems whose internal structure is designed and manufactured in such a way that the material properties in the component can be selectively modified or even reversed. In this way, novel complex and locally distinct functions can be implemented.
The vision of the Cluster is to systematically advance the possibility of local designability of materials and their properties and to utilize them in component development.

The focus is on the following key areas:
- programmable transport properties (material and heat transport)
- mechanically programmable materials (mechanical and tribo properties)
- manufacturing and scaling, product development

Contact:
Elisa Seiler
Tel. +49 721 4640-354 | elisa.seiler@ict.fraunhofer.de

FRAUNHOFER CLUSTER OF EXCELLENCE – CIRCULAR PLASTICS ECONOMY

Taking plastics as an example, the participating Fraunhofer institutes show how the energy and material flows of a recyclable material chain can be transformed into a circular economy. To this end, special system services are being developed with and for the plastics industry, including its associated consumer and retail companies and the circular economy.

The basic idea behind the transformation from a linear to a circular economy is simple: Reduce extraction of fossil resources, avoid end-of-life losses and simultaneously facilitate real closed-loop recycling of plastics. The implementation is complex: A circular economy is about more than just increasing efficiency and recycling; it addresses not only closed-loop recirculation, but also circular product systems throughout the entire life cycle.

The following topics are covered:
- Polymers and additives suitable for a circular economy
- Material and raw material recycling
- Digital monitoring of products and processes for real-time evaluation
- Circular product design and new business models

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FRAUNHOFER CLUSTER OF EXCELLENCE – INTEGRATED ENERGY SYSTEMS

The central technological and economic challenge in the next phase of the global energy transition is the system and market integration of high proportions of variable renewable energies into the energy system.

The Fraunhofer Cluster for Integrated Energy Systems therefore works on the large-scale integration of renewable energies into the German and European energy system. A well-founded, model-based energy system analysis supports the technically and economically optimized development of an energy system in which heat, electricity and transport are connected.

The following topics are covered:
- Comprehensive, cross-sectoral system analysis
- System technology for the management of infrastructures
- Electrolysis as the basic technology for system-relevant, large-scale storage

Contact:
Karsten Pinkwart
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TEACHING ENGAGEMENT AND PUBLIC BODY MEMBERSHIP

Teaching activities and public body membership are important tasks of a research institution. In 2018 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 2018 we also participated in numerous working groups and public bodies, to help shape the future of our research fields.

TEACHING ENGAGEMENT

KARLSRUHE INSTITUTE FOR 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)
- Fiber-reinforced plastics – polymers, fibers, semi-finished products, processing (2 units per week, ST)

Institute for Mechanical Process Engineering and Mechanics

Tübke, Jens
- Materials and methods for electrochemical storage devices and converters (2 units per 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
- Computer-aided lab (4 units per week, WT)
- 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 (4 units per week, WT + ST)
- Material sciences: plastics (2 units per week, WT)
- Plastics processing (2 units per week, ST)
- Laboratory for plastics processing and measurement technology (2 units per week, WT + 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 (2 × 33 units / year)

Safety Engineering Course
Gräbe, Gudrun
– Basics of environmental technology (3 units per week, WT)

Industrial Engineering Course
Gräbe, Gudrun
– Environmental engineering and recycling (2 x 3 units per week, ST)

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)

BADEN-WÜRTTEMBERG COOPERATIVE STATE UNIVERSITY, MOSBACH

Mechatronics course
Peter Eyerer
– Polymer engineering (2 units per week, WT)

HECTOR SCHOOL OF ENGINEERING AND MANAGEMENT

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

TECHNICAL UNIVERSITY NUREMBERG

Process Engineering Department
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)

ULM UNIVERSITY

Teipel, Ulrich
– Mechanical process engineering (4 units per week, WT + ST)

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

Faculty of Electrical Engineering
Pinkwart, Karsten
– Electrochemical energy storage devices and converters (2 units per week, WS)

ASSOCIATED INSTITUTE OF OSTFALIA UNIVERSITY OF APPLIED SCIENCES

Training Center 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)

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)
- 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)

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
- Member of the National Academy of Science and Engineering, acatech
- Spokesman of the Fraunhofer Sustainability Network

Eyerer, Peter
- 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

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

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)

Hettmanczyk, Lara
- Member of the German Chemical Society (GDCh) (including membership of the technical groups Analytical Chemistry, Chemists in Civil Service and the Association for Chemistry and Economics)

Hübner, Christof
- Elected member of the Scientific and Technical Council of Fraunhofer-Gesellschaft

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 Fraunhofer ICT in the Lightweight Construction Agency Baden-Württemberg
- Representative of Fraunhofer ICT in the VDMA Working Group on Hybrid Lightweight Technologies
- 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)

Keßler, Armin
- Member of the International Association for Hydrogen Safety, IA-HySafe
- Member of the Intercontinental Association of Experts for Industrial Explosion Protection, INDEX e.V.
- Member of the CSE-Society – Society for the Promotion of Process and Plant Safety

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

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)

Rabenecker, Peter
- Member of the Scientific Board of the HybridSensorNet Symposium

Reichert, Thomas
- Managing Director of the Society for Environmental Simulation (GUS) e. V.
- Past president of the European Federation of Clean Air and Environmental Protection Associations EFCA
- Past president of the Confederation of European Environmental Engineering Societies CEEES
- 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"
- 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 Standardization)
- 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

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)
- Consulting expert of the Federal Ministry for Education and Research and DFG (German Research Foundation)
- 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 Scientific Committee of the "PARTEC 2019"
- Appointed member of the ProcessNet Technical Group "Raw Materials"
- Appointed member of the Council of Science and Humanities

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)

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)

Wittek, Michael
- Member of the Explosive Vapor Detection (EVD) Study Group of the ECAC

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 20-21, 2018
DVM working group "Structural Components made of Polymer Composites"
Fraunhofer ICT, Pfinztal, Germany

March 21-23, 2018
47th Annual Conference of the German Society for Environmental Simulation GUS: "Assessment, Simulation and Evaluation of Environmental Influences"
Festhalle, Stutensee-Blankenloch, Germany

April 16, 2018
Networking-Event: Taiwan – Grid Integration of Renewable Energies
Fraunhofer ICT, Pfinztal, Germany

April 26, 2018
Girls' Day
Fraunhofer ICT, Pfinztal, Germany

June 26, 2018
19th Defense Engineering Day
Fraunhofer ICT, Pfinztal, Germany

June 26-29, 2018
49th International Annual Conference of Fraunhofer ICT: "Synthesis, Processing, Performance"
Congress Center, Karlsruhe, Germany

October 10, 2018
Meeting of the Advisory Board
Fraunhofer ICT, Pfinztal, Germany

November 20-21, 2018
Workshop: Propellants and Explosives
Fraunhofer ICT, Pfinztal, Germany

November 21-22, 2018
Public final workshop of the project MoPaHyb
Fraunhofer ICT, Pfinztal, Germany

November 26-28, 2018
14th International Symposium and Accompanying Exhibition on Sophisticated Car Safety Systems
"Rosengarten", Mannheim, Germany

December 19-21, 2018
German-Japanese Workshop on Advanced Lithium Ion Batteries
Karlsruhe / Pfinztal, Germany

PARTICIPATION IN TRADE FAIRS AND EXHIBITIONS

February 20-22, 2018
DWT symposium: Accommodation on deployment – Energy and media connection in stationary accommodation while on deployment
Bonn, Germany

February 28 – March 2, 2018
Battery Japan
Tokyo, Japan

March 6-8, 2018
JEC Composites
Paris, France

March 13-15, 2018
Energy Storage Europe
Düsseldorf, Germany

March 14-15, 2018
PIAE Europe – Plastics in Automotive Engineering
Mannheim, Germany

April 17-18, 2018
Storage and Application
Bonn, Germany

April 23-27, 2018
Hannover Messe
Hannover, Germany

April 25-29, 2018
ILA – Innovation and Leadership in Aerospace
Berlin, Germany

June 9, 2018
Open Day of the German Army
Bildungszentrum der Bundeswehr, Mannheim, Germany

June 11-15, 2018
ACHEMA
Frankfurt, Germany

July 10-12, 2018
IFBF – The International Flow Battery Forum
Lausanne, Switzerland

July 16-22, 2018
International Airshow
Farnborough, United Kingdom

September 5-7, 2018
China Composite Expo 2018
Shanghai, China

October 16-20, 2018
FAKUMA
Friedrichshafen, Germany

PUBLICATIONS

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Analysis of gases emitted in safety events.
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Eisenlauer M., Teipel U.
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Emmerich R., Dreher R., Laux M.
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HOW TO REACH US

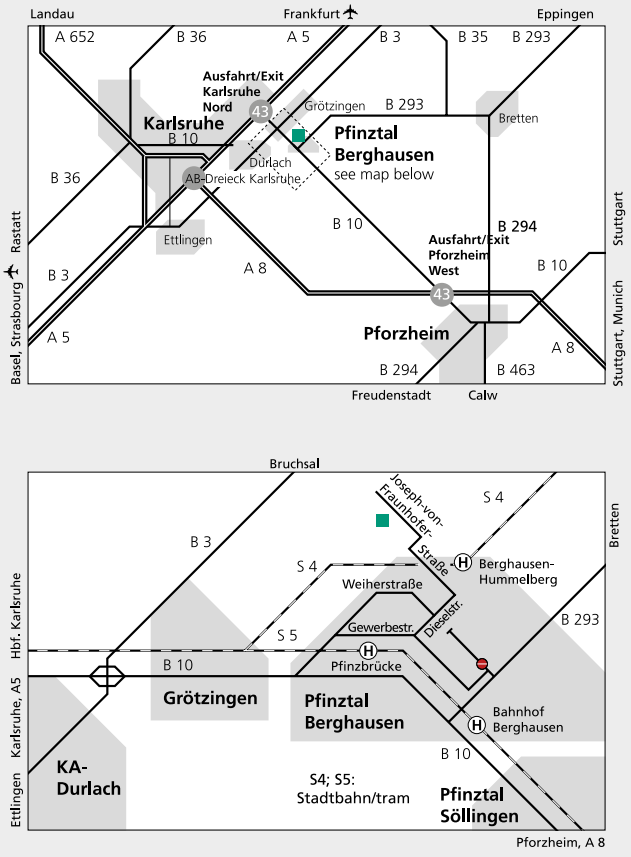
BY CAR

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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FRAUNHOFER-GESELLSCHAFT

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