Fraunhofer ICT

Fraunhofer Institute for Chemical Technology ICT

Annual Report 2020/2021

Contents

Preface

An addition to our management team

In April 2021, Prof. Dr.-Ing. Frank Henning was appointed co-director of Fraunhofer ICT. Together with Prof. Dr.-Ing. Peter Elsner, he will now shape the future of the institute. Since he has already been working as Fraunhofer ICT's deputy director since 2009, this is not a major change in the management of the institute from an organizational point of view. We can therefore ensure continuity for our employees, for the authorities and government agencies that work with us, and for our project partners and industrial customers. Due to the size of the institute – which has more than 500 employees – there are also numerous tasks that can be better managed with two institute directors. Such tasks include, for example, shaping our core competences in collaboration with the department heads, or supporting the Fraunhofer Clusters of Excellence in the fields of programmable materials, the circular plastics economy and integrated energy systems.

In January 2021, the lead-market-oriented alliance **"Chemical Industry"** was launched, with Fraunhofer ICT as the leading partner. Fraunhofer's instrument of lead-market-oriented alliances addresses sectors with high relevance to the innovative capacity of Germany and Europe. Building on the research and development services of individual institutes, lead-market-oriented alliances generate system solutions for these lead markets, and service offers spanning multiple institutes. We are also deeply involved in two Fraunhofer lighthouse projects, with the topics **"Green Chemistry"** and **"Urban Air Mobility"**, which were launched at the beginning of the year.

Besides the chemical industry, the energy industry and, of course, our extensive work for the Ministry of Defense in explosives technology, the mechanical engineering and automotive industries are a key driver of our research and development tasks. These sectors were severely affected by the corona pandemic in 2020 due to shrinking markets, increased raw material prices and disrupted supply chains, and are also still undergoing a major technological transformation. The difficult business situation in these industries also resulted in significantly fewer commissions and smaller project volumes for us. After years of pronounced growth, the 2020 financial year was therefore a challenge, but one that Fraunhofer ICT was ultimately able to overcome thanks to the significant commitment of its employees and the generous support of its donors.

Additional research funding

The German Federal Ministry of Education and Research (BMBF) has launched programs to overcome the COVID-19 crisis so that Germany can retain its pioneering role in the development of key technologies. Within the Fraunhofer-Gesellschaft, large networks have emerged with many new connections between individual institutes. This process has shown that our strategy of thematic diversity and competence-oriented market positioning is sustainable in a crisis. The broad and consistent positioning of our topics enabled us to contribute to several of the Fraunhofer-Gesellschaft's major cutting-edge activities. In this annual report we have presented some of these new topics in the fields of hydrogen, mobility, energy supply and health, and we hope you will find some useful ideas for your own field of work. We would very much welcome your feedback, to help us consider different perspectives, dive deeper and further sharpen our research strategy. It would also be good to meet again in person in the near future.

We wish you an enjoyable read and continued successful cooperations with Fraunhofer ICT!

With best wishes

Peter Elsner Frank Henning

Institute profile

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, with its various engine and exhaust test benches, is based on the East Campus of the Karlsruhe Institute of Technology (KIT).

Fraunhofer ICT currently has 540 employees.

Fraunhofer Institute for Chemical Technology ICT

The use of wind energy, and soon also photovoltaics, allows us to operate our main campus with a decreasing carbon footprint. This campus comprises over 100 laboratories, pilot plants and test centers on 21 hectares of land. Our research orientation enables us to combine research and development work in this sector with large-scale demonstrators on our campus.

Fraunhofer ICT's wind turbine.

In our research we focus 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.

Around 540 people are currently employed at Fraunhofer ICT. Our main campus is located on the Hummelberg in Pfinztal near Karlsruhe. The **"New Drive Systems Department"**, with its various engine and exhaust test benches, is 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 working on safety and security 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 and technical processes from the laboratory up to the technical scale. The core competence comprises the entire processing chain, from raw material processing, chemical reaction control, purification and separation technology through to downstream processes such as product refinement and shaping.

In the core competence **"polymer engineering and composite materials"**, we have spent the past 30 years researching engineering plastics for practical application. Starting with polymer synthesis, we also work intensively on materials engineering and plastics processing. We support component development and manufacturing, and have many competences in recycling and waste management.

Fraunhofer ICT's site and wind turbine.

Fraunhofer ICT supports its project partners from the initial idea up to small series development."

Dr. Stefan Tröster,
PR Spokesman, Fraunhofer ICT

A sustainable and affordable energy supply and efficient energy use are the focal points of current research policy, which aims to complete the energy transition and phase out fossil fuels. Within the core competence **"energy systems"** we work on electrical energy storage devices for mobile and stationary systems, and on fuel cells, electrolysis and heat and material energy storage systems and their applications, as well as the operational safety of these systems. Within this core competence, our institute has accumulated more than 30 years of scientific know-how, laying the foundations for the development of efficient and cost-effective storage devices and converters.

Based on decades of experience within its core competence **"explosives technology, safety and security"**, Fraunhofer ICT is the only German research institute that covers the entire development chain from the raw product through to the system prototype in the development of propellants and high explosives. The institute supports the German Federal Ministry of Defence, the public sector and industrial customers in investigating current challenges concerning national and international security.

Our core competence **"drive systems"** comprises solutions for electric and hybrid drive trains and internal combustion engines. 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 and fuel cells, as well as thermal storage systems. For internal combustion engines we are researching synthetic fuels and additives in our research engines.

The institute at a glance

In our research we focus 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.

Organization chart

Peter Elsner
Director

Prof. Dr.-Ing. Peter Elsner
Phone +49 721 4640-401
peter.elsner@ict.fraunhofer.de

Frank Henning
Director
Head of Polymer Engineering Department

Prof. Dr.-Ing. Frank Henning
Phone +49 721 4640-420
frank.henning@ict.fraunhofer.de

Wilhelm Eckl
Deputy Director
Head of Energetic Systems Department

Dipl.-Phys. Wilhelm Eckl
Phone +49 721 4640-355
wilhelm.eckl@ict.fraunhofer.de

Bernd Hefer
Administration

Dr. Bernd Hefer
Phone +49 721 4640-125
bernd.hefer@ict.fraunhofer.de

Stefan Tröster
General Management

Dr.-Ing. Stefan Tröster
Phone +49 721 4640-392
stefan.troester@ict.fraunhofer.de

Stefan Löbbecke
Head of Energetic Materials Department

Dr. Stefan Löbbecke
Phone +49 721 4640-230
stefan.loebbecke@ict.fraunhofer.de

Jens Tübke
Head of Applied Electrochemistry Department

Prof. Dr. Jens Tübke
Phone +49 721 4640-343
jens.tuebke@ict.fraunhofer.de

Rainer Schweppe
Head of Environmental Engineering Department

Dipl.-Chem. Rainer Schweppe
Phone +49 721 4640-173
rainer.schweppe@ict.fraunhofer.d

Hans-Peter Kollmeier
Head of New Drive Systems Department

Dr.-Ing. Hans-Peter Kollmeier
Phone +49 721 9150-3811
hans-peter.kollmeier@ict.fraunhofer.de

Advisory board

Chairman of the Advisory Board

Dipl.-Kfm. Jörg Schneider
WERIT Kunststoffwerke W. Schneider GmbH & Co.KG,
Altenkirchen (Westerwald)

Board members

Dr.-Ing. Thomas Czirwitzky
French-German Research Institute of Saint-Louis,
Weil am Rhein

Christian Dieffenbacher
DIEFFENBACHER GmbH + Co, Eppingen

Dipl.-Kfm. Michael Humbek
Dynamit Nobel Defence GmbH, Burbach

Dr.-Ing. Guido Kurth
Bayern-Chemie GmbH, Aschau a. Inn

Dr. Christian Renz
Ministry of Economic Affairs, Labor and Tourism
Baden-Württemberg, Stuttgart

Dr. Carola Richter
President Regional Division South & East
Asia, BASF SE, Hong Kong/China

Prof. Dr.-Ing. Stefan Schlechtriem
German Aerospace Center (DLR)
Hardthausen am Kocher

Dr. Simone Schwanitz
Ministry of Science, Research and the Arts
Baden-Württemberg, Stuttgart

Dr. Tobias Wirtz
Premium Aerotech GmbH, Augsburg

Dr.-Ing. Michael Zürn
Daimler AG, Sindelfingen

Guest members

Prof. Dr.-Ing. Detlef Löhe
Pfinztal

Wolf-Rüdiger Petereit
Neuwied

Dr. rer. pol. Hans-Ulrich Wiese
Gräfelfing

Economic development

The special program launched by the Federal Ministry for Education and Research (BMBF) enabled us to retain our permanent staff and our know-how.

Financial status

As a result of the COVID-19 pandemic, our revenues decreased by approximately 1.5 million euros in the fiscal year 2020. In particular our revenues from industry, which are very important for Fraunhofer, were almost 1.9 million euros below the very high level of the previous year, reaching only 8.5 million euros in 2020. Nevertheless, as these industrial revenues still made up 33.1 percent of our total revenues, we are still within the target range of 30 to 40 percent. A special program for Fraunhofer, launched by the Federal Ministry for Education and Research (BMBF), also enabled us to compensate somewhat for the decline in industrial projects. Within this program, know-how was built up within internal cooperation projects, and technologies were developed to combat the pandemic and boost industry. Some of these **"corona and stimulus projects"** are described in this annual report. A saving of around 1 million euros in non-personnel expenses also enabled Fraunhofer ICT to break even in 2020, with an operating budget of around 41.5 million euros.

Additional research funding

Thanks to our cost-cutting measures, and with the help of the economic stimulus package, we were able to retain our permanent staff and thus all our know-how. 32 percent of our staff (172 people) work in the scientific field, and about one third of these have a doctoral degree. Due to our application-oriented focus, with extensive laboratory and pilot-scale facilities, we have a large number of technical employees (100 people, 18 percent) as well as laboratory and workshop personnel (105 people, 19 percent). 11 percent of our employees (60 people), work in our administration. Compared to other Fraunhofer institutes, we thus have a comparatively low overhead.

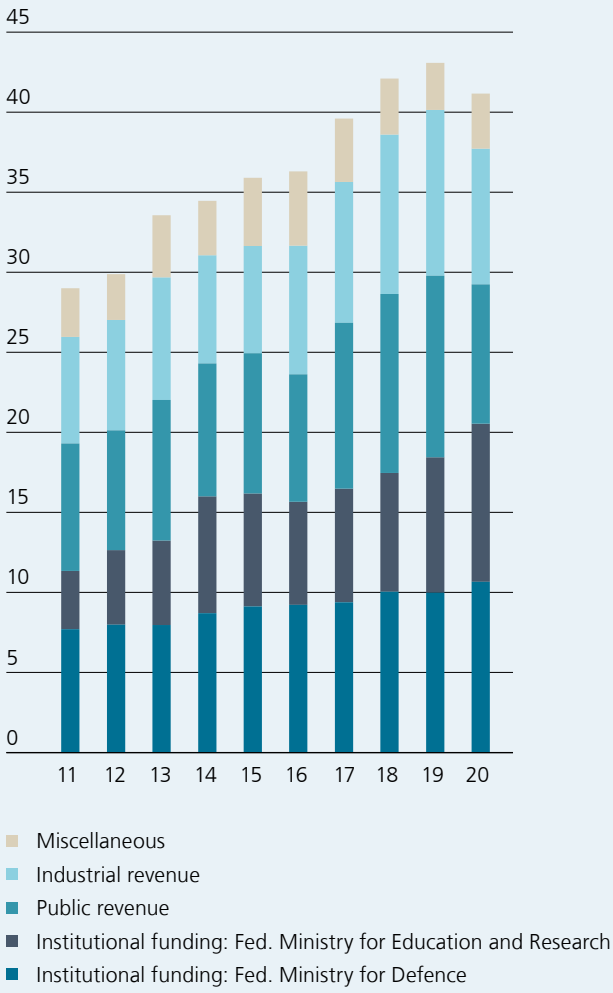
Even during the pandemic we continue to be a major training provider, with currently 22 apprentices training to become chemical laboratory technicians, industrial mechanics, process mechanics in plastics technology and materials testers. As regards our external staff, for example our scientific assistants, we have had to make some savings due to the difficult economic situation, and have reduced the number of contracts by about one third. Nevertheless, at the end of 2020 83 student assistants and interns were still working on our projects.

Outlook

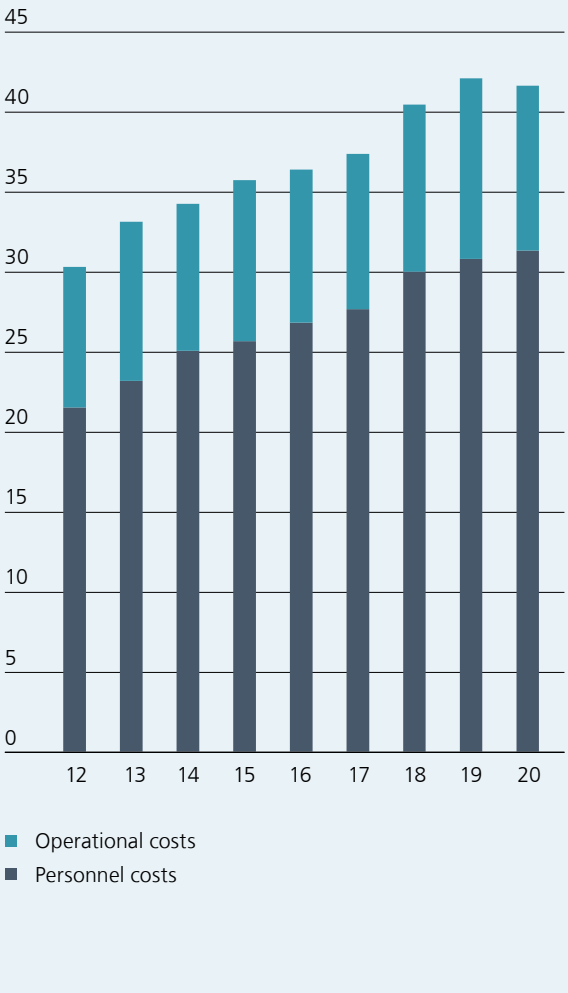
The forecast for the current fiscal year 2021 is very stable and shows a significant upturn in all areas.

Financial development of Fraunhofer ICT, 2011 to 2020

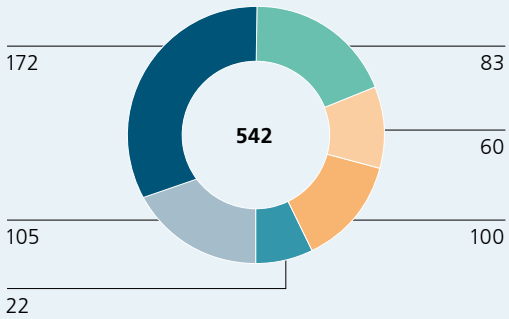
Revenue

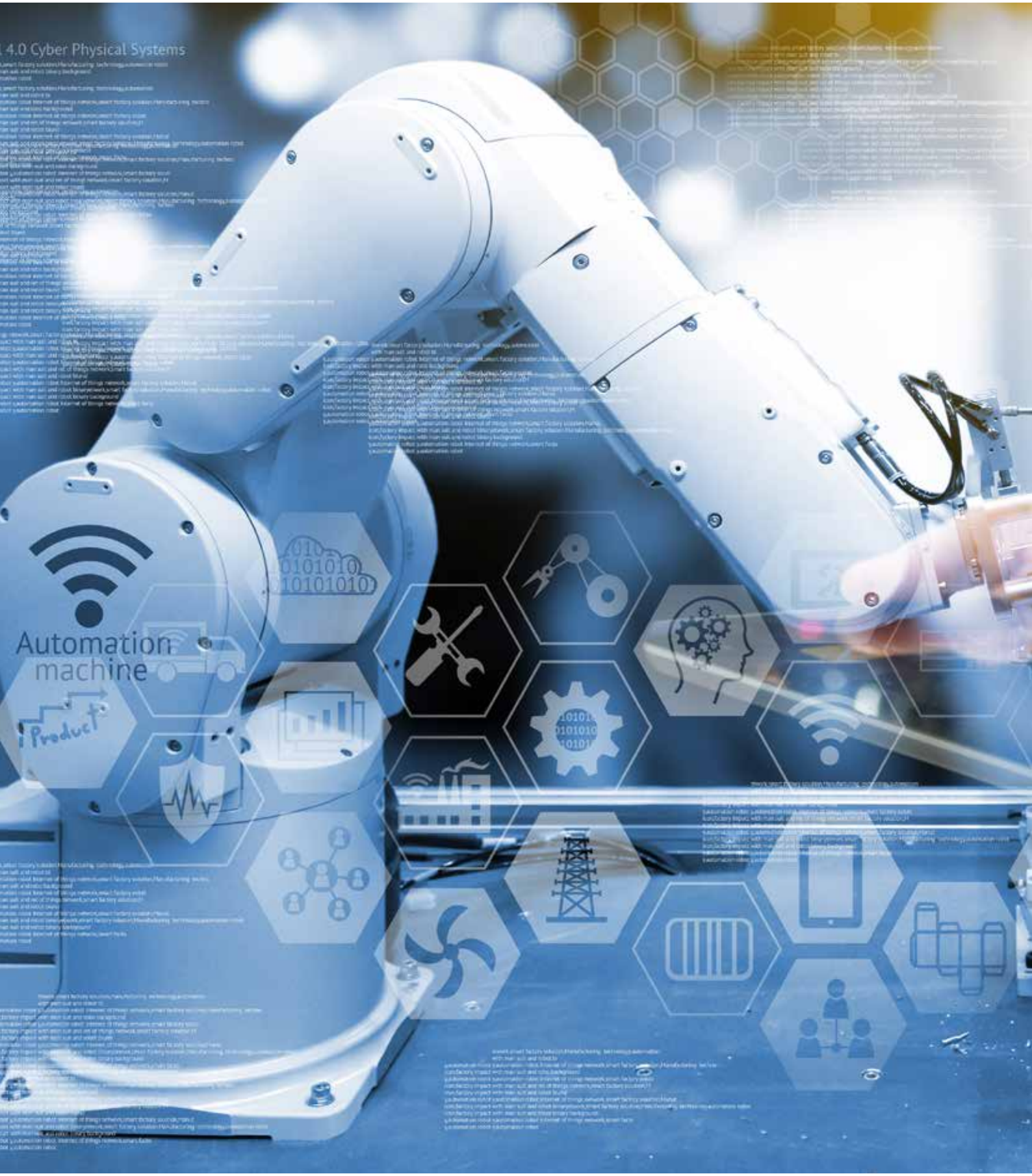


Expenses

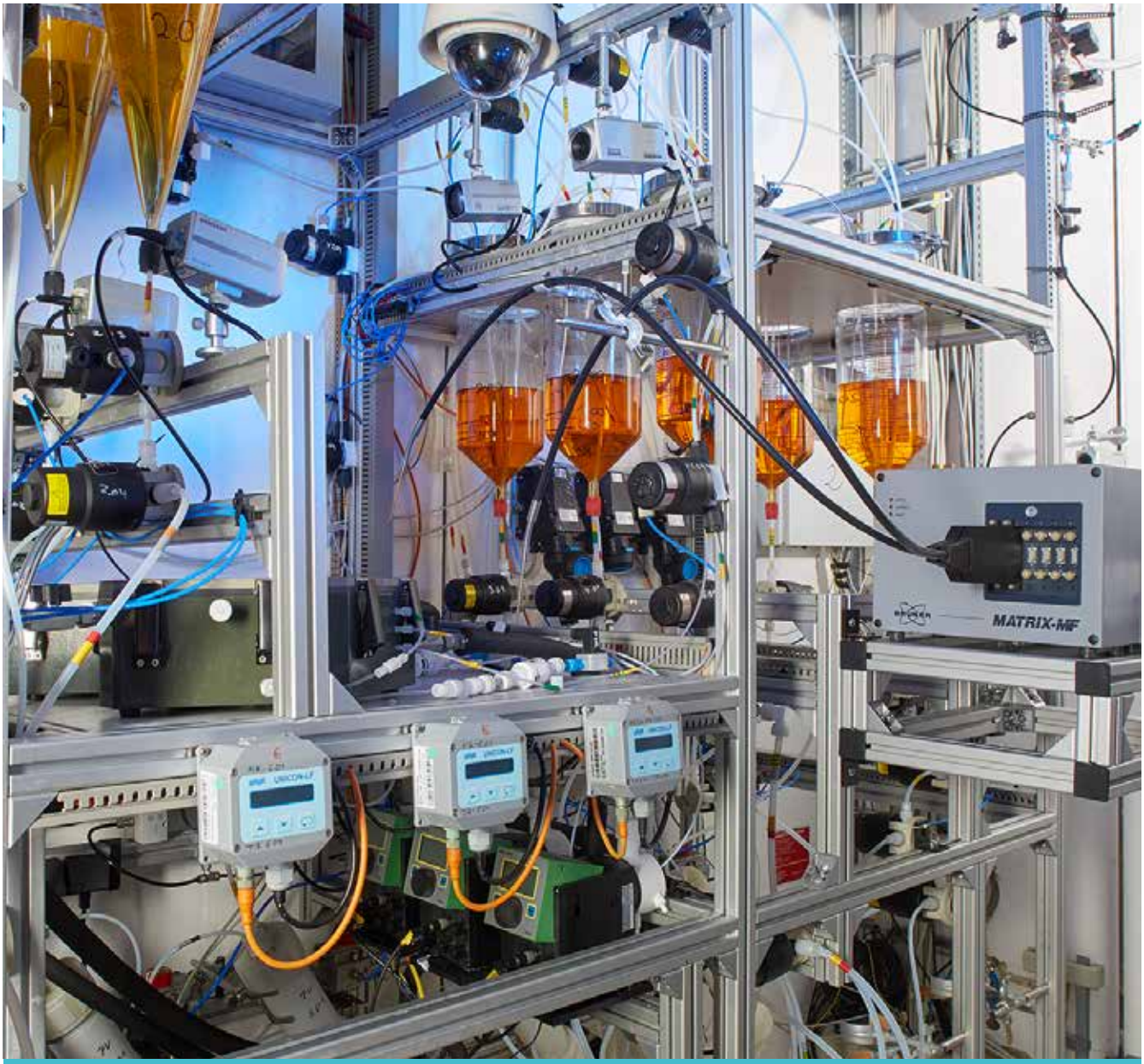


Workforce structure of Fraunhofer ICT: Status on December 31st, 2020




4.0 Cyber Physical Systems
Automation
machine
Product

Core competences



Chemical processes

Finding the right chemistry – sustainability and efficiency

Chemical processes are essential for a wide range of industrial value chains, and ensure new product developments and innovations. However, in the light of global challenges in the field of climate protection, energy and resource efficiency, chemical processes must increasingly become independent of fossil raw materials and fuels, and be integrated into concepts for circular economies and greenhouse-gas-neutral material and energy conversion. Fraunhofer ICT 's R & D tasks aim to meet these demands. A considerable part of our work is exclusive, commissioned by industrial customers. Central target parameters in the development, design and optimization of chemical processes therefore include not only product quality, safety and economic efficiency, but also sustainability. At Fraunhofer ICT, we meet these requirements by developing modern synthesis and process technologies that include energy-efficient and resource-saving process management, minimized waste streams, the recycling of material flows or the use of renewable raw material sources from the outset.

In our development work, we often complete a paradigm shift from discontinuous to continuous processing techniques. For example, continuous processing involving micro-structured equipment is a key element in process design and intensification. It enables safe processing in new processing windows (for example high temperatures, high pressures, high concentrations, short reaction times) that are difficult or even 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 process steps 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 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. Recent examples include reaction calorimetric tracking of continuous processes along the flow direction or fast infrared spectroscopic tracking of syntheses in IR-absorbing solvents using quantum cascade lasers. The techniques often yield kinetic, mechanistic and safety-related data for optimized process design. The rapid availability of comprehensive process analytical data not only enables process development times to be drastically shortened, but also allows the increasing application of these data in the digitalization of chemical reaction processes.

Chemical processes

The core competence "chemical processes" comprises the ability to design and implement innovative, resource-saving chemical and technical processes from the laboratory through to the technical scale. It covers the entire process chain from raw material processing, chemical reaction control, purification and separation technologies through to subsequent process steps such as product refinement (e.g. crystallization) and shaping.

Safe process control

Our comprehensive know-how in the field of explosive technology means that we also 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.

Above:
Continuous monitoring of the process components.

Below:
Microscopic image of a CFRP fiber for process evaluation.

Biogenic raw materials

For several years now, Fraunhofer ICT has been using renewable raw materials in process engineering. Our biorefinery processes have been specifically developed and extended from a bioeconomic perspective, to overcome obstacles in their industrial adaptation through targeted component developments, for example continuous flow reactor systems. These processes include the feed materials wood, fats and oils, carbohydrates and other biomass materials which do not compete with food production. The catalytically supported activation of CO_2 (from the air) to generate short-chain alcohols within ongoing PTL (power-to-liquid) processes is one recent development in the field of continuous process control.

We also investigate the industrial use of such lignins, especially those which are a waste product of the paper industry. Industrial applications are emerging, for example in the field of adhesives and the substitution of bitumen in road construction, which show high economic potential. Some biopolymers are hard to degrade, so recycling processes are attracting increasing attention in this field. They enable biopolymers to be reused within closed material loops. To this end, Fraunhofer ICT has developed processes for the mechanical and chemical recycling of PLA (polylactic acid) plastics.

All process developments are evaluated in economic terms, in particular downstream processes to purify the end products. Life-cycle analyses (LCA) are carried out, which take account of both cost effectiveness and resource consumption.

Contact
Dr. Stefan Löbbecke
Phone +49 721 4640-230
stefan.loebbecke@ict.fraunhofer.de

Rainer Schweppe
Phone +49 721 4640-173
rainer.schweppe@ict.fraunhofer.de

Facilities and equipment

- Various synthesis techniques for chemical and mechanical processing
- Pilot plant for synthesis upscaling into the 50 kg or 50 l range
- Safety boxes for the remote control of reactions in hazardous processes
- Flow chemistry test stands and synthesis units
- Facilities for parallel screening of synthesis approaches (also under high pressure)
- Numerous reaction calorimeters (batch and continuous)
- Cutting-edge process spectrometers for inline, online or atline process monitoring (UV/Vis, NIR, IR, Raman) in one or multiple dimensions
- Continuous and discontinuous high-pressure plants for hydrothermolysis, oxidation, hydrogenation, and reactions in subcritical and supercritical water
- High-pressure extraction units using supercritical carbon dioxide
- Pilot plants for crystallization from solutions via 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

Polymer engineering and composite materials

A focus on sustainability

Polymer engineering and composite materials

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.

"Polymer synthesis" forms the basis for our further development of classic polymers such as polyurethanes, polyesters and polyamides, with the aim of improving their functionalities, performance and range of application. Our research focuses on increased sustainability – for example plastics made from bio-based raw materials or the complete recycling of used plastics - and the synthesis of additives such as flame retardants, sustainable plasticizer systems or compatibilizers for new plastic compounds. Modern flame retardant systems no longer require halogen-containing components. Recent polymer developments aim to combine thermoplastic and thermoset functionalities for use in high-strength bonding, self-healing systems or in the manufacture of plastic actuators.

The research group for **"material development and compounding technologies"** develops new compounding processes and material formulations. Particularly important topics include extractive compounding processes to reduce emissions, the removal of impurities to facilitate recycling, and innovative reactive extrusion for polymer synthesis or polymer modification in twin-screw extruders. Innovative materials are produced using modern processing technology, for example in the field of biobased or nano-functionalized polymer compounds for high-quality injection molding materials and for 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 foaming process.

SMC production unit – small compounding pilot plant.

Besides the optimization of conventional materials, we are concerned with the foaming of biobased and technical polymers that are more resistant to increased temperatures. New sintering technologies, such as radio frequency technology, are opening up completely new areas of application, for example by enabling the production of particle foam components from materials that could not previously be sintered. The development of autoclave technology for the production of particle foam materials increases the range of materials that can be processed.

The research group for **"injection and compression molding"** focuses on standard and specialized processes in the injection molding and flow compression molding of (fiber composite) materials. The integration of local, wound or tape-laid fiber composite structures along the load path in injection molded components significantly improves the mechanical properties between load application points. Our newly installed, cutting-edge SMC line opens up new possibilities in the production of SMC semi-finished products.

Hybrid seat back made from basalt fibers.

The industrialization of process chains for the production of highly resilient, continuous-fiber-reinforced lightweight structures is our main research topic in the area of **"structural composites"**. The core technologies involved are resin transfer molding, wet compression molding, thermoplastic tape laying and pultrusion. The placement of textile and pre-impregnated semi-finished products to produce preforms, their handling and combination with polymer foams and metallic structures and subsequent resin infusion or shaping are important steps within the processing chains.

"Our group for "microwave and plasma technology" develops tailored processing units, measurement technology and methods for thermal processing and coating"

In the field of **"microwave and plasma technology"** we develop customized equipment, measurement technology and methods for thermal processing and coating. Applications include microwave-based heating of polymers, accelerated curing of adhesives and resin systems, microwave-assisted chemical reaction technology 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. Our investment in a plasma system operating at atmospheric pressure enables the integration of selected coating processes into existing industrial process chains.

Our team for **"material characterization and failure analysis"** carries out comprehensive investigations into 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 the standardized testing of standard materials, we can also test fiber composites and polymer rigid foams, and can characterize polymer compounds with regard to their acoustic damping behavior.

In the field of **"online process monitoring"**, spectral and microwave-based measurement methods are developed for process-integrated material monitoring and for process control. Our projects in the context of Industry 4.0 build on our significant experience in 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 AI algorithms enables the quicker stabilization of immature processes.

In the area of **"recycling and waste management"** we develop processes and technologies for the material recycling of polymers, aiming for a complete reintroduction into high-quality applications. The focus is on technologies for the recycling of composite materials (GFRP, CFRP). Depending on their application, some thermoplastics in the consumer sector have to undergo an extraction process before they can be reused, in order to remove associated components such as flame retardants, colorants or other additives. In the case of thermoset polymer systems, a different recycling concept is followed. This involves chemical, solvolytic cleavage into components that can be very specifically repolymerized to form plastics in this system class. As an example, aircraft seats containing polyurethane foam were processed, the separated polyurethane was depolymerized and, after purification of the resulting decomposition products, a targeted synthesis of new seat foams with intrinsic flame retardancy was carried out. An accompanying life-cycle assessment quantified the sustainability of these systems according to various impact categories.

Fraunhofer Innovation Platforms (FIPs), and the Karlsruhe Research Factory

Our cooperation with the University of Western Ontario in the form of **"FIP-Composites@Western"** combines Fraunhofer ICT's expertise in the field of fiber composites with the know-how of one of Canada's leading universities. The large-scale production plant technology of this FIP enables joint research contracts to be carried out on an industrial scale for the North American market.

The Fraunhofer Innovation Platform for Composites Research at the Ulsan National Institute for Science and Technology represents a comprehensive cooperation with a leading Korean university in the field of science and technology. Ulsan is the largest industrial location in Korea. The research focus at this FIP is the use of fiber-reinforced plastics in **lightweight applications**, particularly in the automotive sector. The work is geared toward the requirements of the Asian market. The **"FIP-Composites@UNIST"** also has innovative and cutting-edge industrial-scale processing facilities for thermoplastic and thermoset material systems.

The **"Karlsruher 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 the rapid upscaling of new, still immature production processes to series scale. The project will make an important contribution to the **"Artificial Intelligence Strategy"** of the German Federal Government.

Contact
Prof. Dr. Frank Henning
Phone +49 721 4640-420
frank.henning@ict.fraunhofer.de

Rainer Schweppe
Phone +49 721 4640-173
rainer.schweppe@ict.fraunhofer.de

Facilities and equipment

- Twin screw extruders with 18 to 32 mm screw diameter
- Dosing systems for liquid and highly viscous media and gravimetric dosing systems for pellets, powder, fibers, etc.
- Laboratory for reactive extrusion, equipped with safety devices 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 unit
- Injection molding units with clamping forces from 350 to 7,000 kN
- Advanced processing technologies for injection molding, multicomponent injection molding, thermoplastic foam injection moldi ng expansion foaming and thermoset injection molding
- Injection molding compounder with 40 mm twin-screw extruder and 7000 kN clamping force
- Automated thermoplastic tape-laying process for nonwovens with a diameter of 2 m
- Plant technology for radiation-induced vacuum consolidation for thermoplastic nonwovens up to 0.94 x 1.74 m²
- Automated winding technology to produce complex loop structures
- 3D printing technologies for processing functionalized polymers - filament-based and AKF technology
- Particle foam technology with twin-screw extruder, underwater pelletizing, prefoamer, and a (radio frequency) molding machine
- Tandem foam extrusion plant for foamed semi-finished products
- SMC production line with advanced sensor technology and BMC kneader
- Polyurethane processing PU-RIM and PU fiber spraying technology
- RIM/RTM technologies for the processing of thermoset and thermoplastic materials
- Pultrusion technology with injection technology for thermoset and thermoplastic matrix systems
- Microwave equipment with generators for a wide range of applications
- Microwave-based sensor technology for process monitoring
- Various low-pressure plasma systems
- Robot-assisted atmospheric plasma unit
- Measuring apparatus to determine the dielectric properties of materials in a wide frequency and temperature range
- Extensive and cutting-edge equipment in the field of materials testing and analysis

Energy systems

New, efficient options

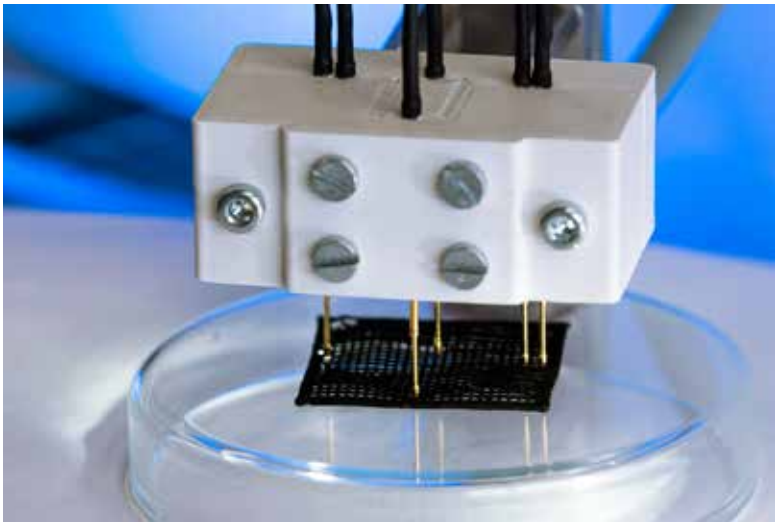
We develop new, efficient options for electrical energy storage, and investigate systems that are already available on the market. Our emphasis is on lithium-ion batteries, all-solid-state batteries, redox-flow batteries and so-called post-lithium-ion systems, such as lithium-sulfur or sodium-based batteries. Cells and battery modules are characterized and simulated thermally and electrically, to tailor them for specific 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 with an energy content of up to 2 kWh. In the field of redox-flow batteries we are investigating various cost-effective and sustainable storage materials, and are working to reduce the cost of the overall system, in particular the stack structure and materials.

Our work in the field of converters is divided into three main topics: material development, testing and system development. As regards material development, we focus on catalyst systems for water electrolysis. We address materials for oxygen evolution / (OER) catalysts for PEM electrolysis but also supported catalysts and noble metal-free OER catalysts for AEM electrolysis starting from MOF precursors. We are also developing electrocatalysts for use in HT-PEMFCs and DMFCs. In fuel cell testing, our focus is on method development for the investigation of degradation processes, in particular carbon and ionomer corrosion, using online mass spectrometry. In addition, we support the development of test methods for fuel cell components, for example the characterization of bipolar plates and the GDL. We optimize the operation of commercial fuel cell stacks for special applications in the military and civil sectors and develop the systems required for this, including the selection of suitable peripheral components and the control system.

Hydrogen is used, among other things, as a fuel to power fuel cells in mobile and stationary applications. We ensure the necessary safety, examine the hydrogen in the respective system and investigate various operating conditions - right up to the worst-case scenario. For example, we calculate possible leaks and faults, use theoretical results to direct hydrogen specifically into cavities, and test the implementation at our test site, which is designed for up to three kilograms of TNT equivalent. In addition, we deal with issues relating to the safety distance in the refueling area and the pressure protection of fuel tanks.

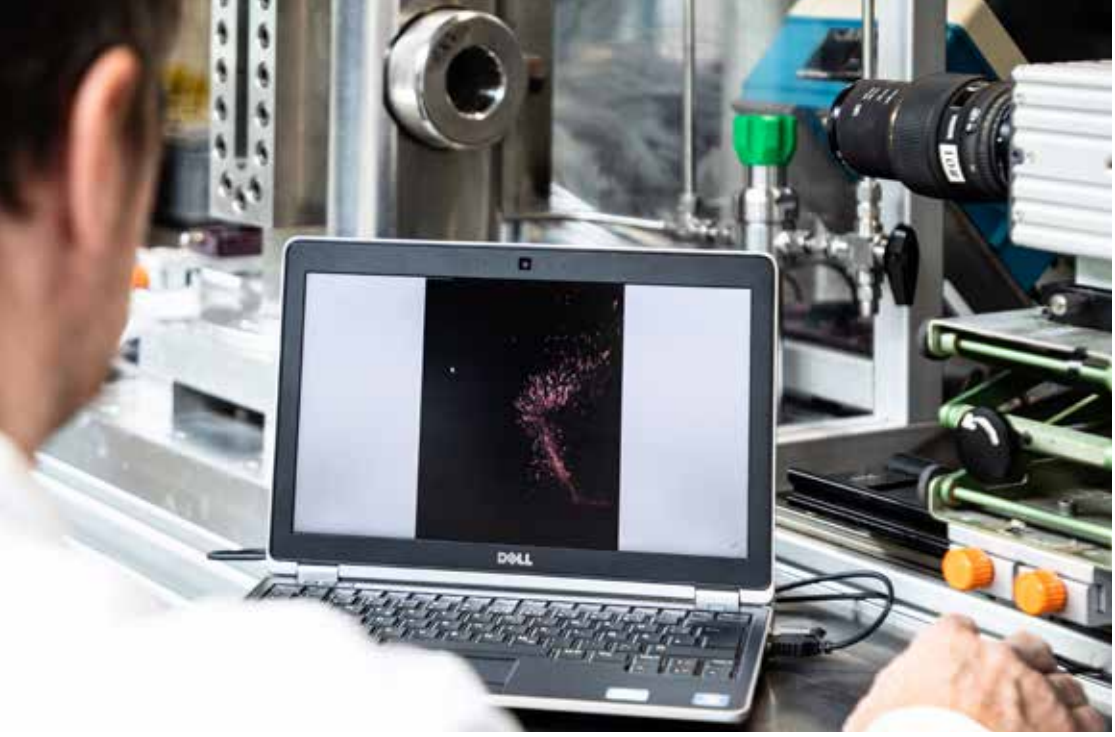
Energy systems

A sustainable and affordable energy supply and the efficient use of energy are the focal points of current research policy with the aim of completing the energy transition and phasing out fossil fuels. Within the core competence "energy systems" we work on electrical energy storage devices for mobile and stationary systems, on fuel cells and electrolysis and on heat and material energy storage systems, their applications and the functional safety of the systems. Within this core competence, our institute has accumulated more than 30 years of scientific know-how, laying the foundations for the development of efficient and cost-effective storage devices and converters.



Additively manufactured, porous transport layer for water electrolysis.

For energy supply in residential quarters with regeneratively produced hydrogen, we design the overall layout of the system including the fuel cells for reconversion, the use of the waste heat from the fuel cells, and demand-oriented distribution via local heating networks. We set up the system control and perform stress tests by simulating possible failure cases.



High-pressure autoclave to investigate the ignition and combustion of a wide variety of fuels and propellants.

One way to use electric energy efficiently is to generate chemical products. We are working on the development of electrochemical reactors, including electrocatalysts and electrodes, their integration into a complete process, and subsequent process steps. A current example is the electrochemical extraction of hydrogen peroxide by the partial reduction of atmospheric oxygen, combined with its 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 chemical 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 transport of hydrogen, the development 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.

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 includes:

- complete characterization of PEMFC, HT-PEMFC and DMFC fuel cell stacks
- environmental simulation tests on stacks and systems, e.g. climate tests, effects of shock etc.
- development of operating strategies
- optimization of the interaction between the fuel cell and the battery
- safety analyses

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, O2-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)

Facilities and equipment

- Battery charging and discharging stations incl. climatic chambers for characterization of battery cells and modules
- Argon glove boxes
- In-operando layer thickness measurements at electrode and cell level during electrochemical tests
- 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 up to 5000x magnification in 2D or 3D
- Scanning electron microscope (SEM) / spatially resolved elemental analysis by energy dispersive X-ray spectroscopy (EDS)
- RAMAN and infrared (IR) spectroscopy
- Analysis of surface size and porosity using BET gas adsorption
- Confocal microscope for surface characterization
- Ion analysis by capillary electrophoresis (CE), free-flow electrophoresis (FFE) and ion chromatography
- Thermal analysis to record physical transformations and chemical reactions with heat flow DSC
- Gas analysis using GC, MS, GC/MS and gas FTIR
- Thermal, mechanical and electrical safety testing facilities for battery cells and modules up to 2 kWh, and 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) to investigate reaction and corrosion products
- Medium-temperature cell (120 °C – 200 °C) with online mass spectrometry (HT-DEMS)
- Equipment for the production of membrane-electrode assemblies by inkjet, hot spray and electrospinning
- 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 benches for stack characterization of PEMFC and HAT-PEMFC stacks up to 5 kW with hydrogen, surrogate reformate for operating pressures up to 5 bar and with pure oxygen
- System development and investigation of components through hardware-in-the-loop method
- Environmental simulation, especially mechanical tests (vibration, impact, etc.) on fuel cell stacks and systems

Contact
Prof. Dr. Jens Tübke
Phone +49 721 4640-343
jens.tuebke@ict.fraunhofer.de

Wilhelm Eckl
Phone +49 721 4640-355
wilhelm.eckl@ict.fraunhofer.de

Prof. Dr. Karsten Pinkwart
Phone +49 721 4640-322
karsten.pinkwart@ict.fraunhofer.de

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 Battery Alliance, Prof. Dr. Jens Tübke, is an employee of Fraunhofer ICT.

Fraunhofer ICT is also active in the Fraunhofer lead market "energy sector", and in the alliances "Energy", "Space" and "Building Innovation" in relation to this topic.

Explosives technology, safety and security

From raw products to prototypes

12
working groups contribute to the core competence of explosives technology, safety and security.

Fraunhofer ICT researches and develops new energetic materials 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). Research is focused on the design, development, production and characterization of new materials and components for rocket propellants, gun propellants, explosives, pyrotechnics and new ignition and initiation systems. The portfolio is supplemented by safety and protective systems based on gas generators, decoys, fire protection coatings and filter materials for protective applications.

In the development of propellant and explosive systems, performance characteristics are adjusted and optimized for individual application profiles and requirements. To this end, new energetic materials are synthesized and modified in Fraunhofer ICT's laboratories, new processing techniques are developed and the energetic products are formulated and fabricated in the institute's pilot plants. Besides the application-specific performance properties of propellant and explosive systems, their insensitivity and stability are also important research and development challenges, as are the increasing demands for technologies and products that conserve resources, are environmentally friendly and pose no health risks. The research groups for interior ballistics and detonics then characterize and evaluate the combustion and reaction behavior, sensitivity and performance data of the products in the laboratory, detonation chamber or on open-air testing ranges, up to the kilogram scale. In addition, modern simulation software is available, which can be used to analyze and evaluate the performance and safety of new energetic materials from the molecular level up to the system.

Current research topics include performance-enhanced, environmentally compatible and low-signature solid rocket propellants for defense and civilian applications, insensitive high-performance explosives and propellants, and gel propellants that enable controlled rocket thrust phases. High-precision measurement techniques for the characterization of rocket exhaust jets and pyrotechnic decoys, new shaping techniques such as modern crystallization and coating processes, and additive manufacturing of energetic materials to realize material gradients and complex geometries are also the subject of current R&D work.

Within the framework of national and European security research, Fraunhofer ICT is involved in the development of novel sensor and measurement concepts for the standoff and trace detection of explosives, including so-called home-made explosives (HMEs) and improvised explosive devices (IEDs). The institute also operates a test center for explosives detection systems for aviation security, on behalf of the German Federal Police.

Explosives technology, safety and security

Based on decades of experience, Fraunhofer ICT is the only German research institute that covers the entire development chain from the raw product to the system prototype in the development of propellants and high explosives. The institute supports the German Federal Ministry of Defence, the public sector and industrial customers in investigating current challenges concerning national and international security.

Networks and alliances

In the field of explosives technology and security research, Fraunhofer ICT is part of the Fraunhofer Segment for Defense and Security VVS, in which eleven institutes have pooled their competences to coordinate and implement research activities in the field of defense and security. Fraunhofer ICT is also a member of the Fraunhofer Space Alliance – an association of 17 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 German Federal Ministry of Defense in the context of bilateral research agreements. Operating a Test Center for Explosives Detection Systems 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 and development 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. One focus of our R&D services is the development, design and evaluation of energetic products and systems based on the long-standing expertise of our employees and our specialized equipment and infrastructure. We develop demonstrators, prototypes and small series of new propellants and explosives as well as customized synthesis and process technologies. The experimental work is supported by thermodynamic calculations as well as quantum mechanical and molecular dynamics simulations.

Copper cylinder test – photonic doppler velocimetry (PDV) to determine the expansion work.

Software-assisted analysis and design tools, developed and applied at Fraunhofer ICT, enable the screening of new propellant and explosive formulations, for example based on their performance, safety, erosivity 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 provide support and evaluation at each stage in the development of pyrotechnic safety systems (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.

Contact
Wilhelm Eckl
Phone +49 721 4640-355
wilhelm.eckl@
ict.fraunhofer.de

Dr. Stefan Löbbecke
Phone +49 721 4640-230
stefan.loebbecke@
ict.fraunhofer.de

Facilities and equipment

Pilot plants and test stands

- Chemical pilot plants and synthesis laboratories for explosives
- Pilot plants for the manufacturing and processing of explosive products
- Safety boxes and testing site for explosion and safety/security investigations
- Test Center for Explosives Detection
- Detonation chamber (up to 2 kg TNT)
- Detonation tank (up to 100 g TNT)
- Test stands for guns up to 20 mm caliber
- Gas pressure measuring systems for 5.56 mm to 12.7 mm and 20 mm
- 100 m shooting range
- Combustion test stand for rocket engines and flares
- Flow test stand for investigation of pyrotechnic systems

Equipment

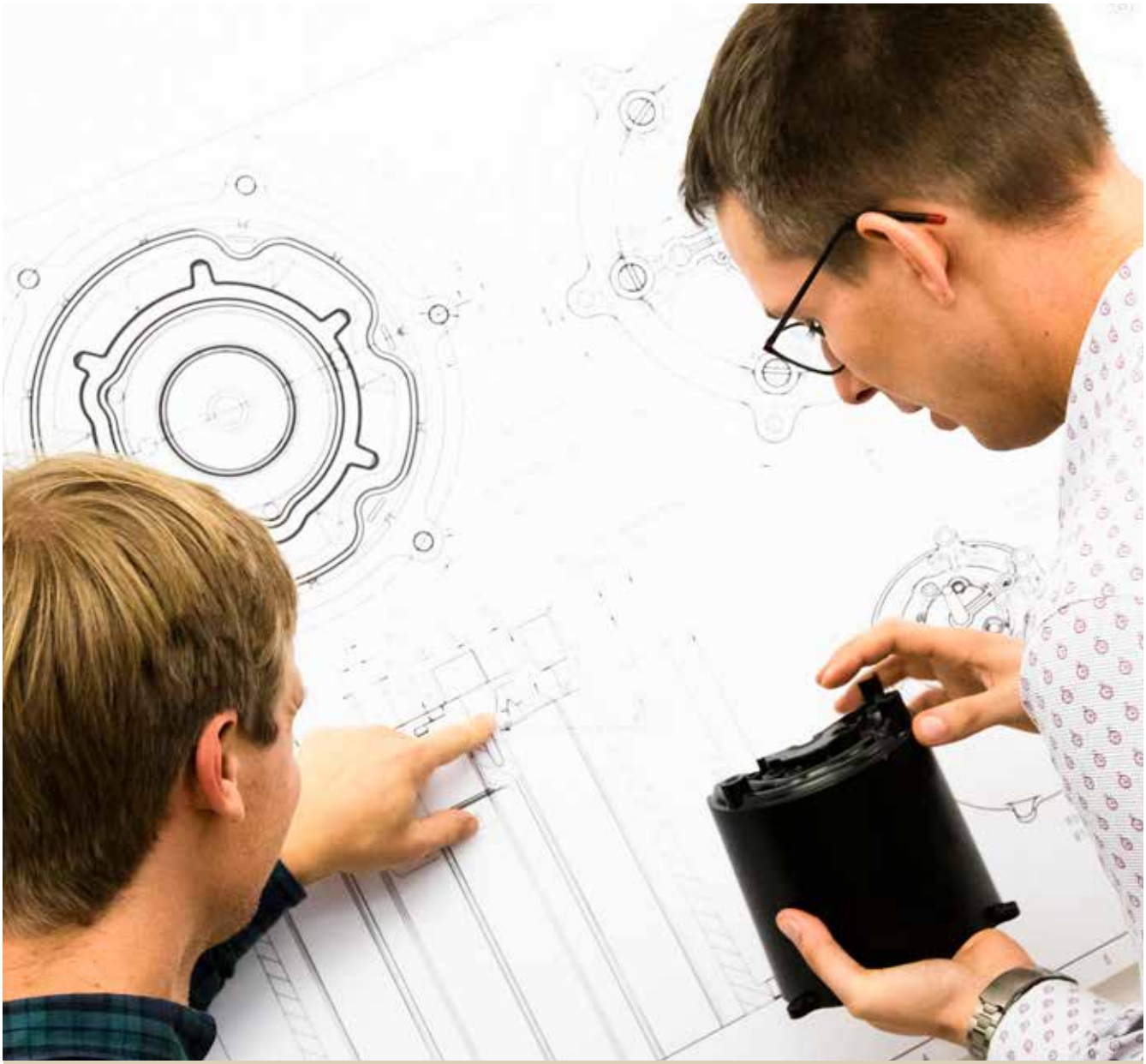
- Pilot plants for the production of explosive particles
- Flow chemistry test stands and synthesis units
- Fluidized-bed coater
- Spray crystallization unit
- High-pressure plant for isostatic compression molding
- Special kneaders, mixers, pelletizers and presses with explosion protection

Software tools

- Thermochemical codes for the thermodynamic evaluation of propellants, RFTS, SS and pyrotechnics. Examples: ICT Thermodynamic Code, EKVI code, Cheetah 2.0., EXPLO5
- ICT thermodynamics database with over 14000 substances
- Computational fluid dynamic (CFD) codes, such as SPEED, Ansys Fluent, Ansys Autodyn, Ansys Mechanical,...
- ICT-BAM for spectroscopic temperature measurement
- Interior ballistic codes such as SimIB-0D, FNGun-1D, ballistic analysis and evaluation tool BAA (ICT), software tool for powder burn-off (ICT), software tool for 3D form function (ICT)
- Quantum mechanical and molecular dynamic simulation tools

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 nanocomputer 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; hyperspectral cameras
- Ballistic bombs for all propellant powder types including evaluation software
- Optical and Crawford bomb for solid rocket propellants
- Blast measurement technology, QSP and temperature for detonation chamber and detonation tank
- Manganin pressure probes for measurements up to 400 kbar
- 4-channel photonic doppler velocimeter for transient velocity measurement up to 5 km/s
- Detonation velocity measurement
- Various safety test setups, for example Koenen test, 21 mm and 50 mm GAP test



Drive systems

Application-oriented research

Drive systems

Our core competence "drive systems" comprises solutions for electric drive trains and internal combustion engines. The systems are designed, constructed, simulated and validated through testing at Fraunhofer ICT. In addition, we validate mobile and stationary energy and thermal storage devices. In the field of internal combustion engines we are investigating synthetic fuels and additives in our research engines.

Our mobility is in transition: increasingly, battery electric and hybrid vehicles are entering the market. Until this process is complete, however, combustion engines are still in demand, especially in combination with synthetic fuels. We cover the entire spectrum of drive systems for the mobility transition.

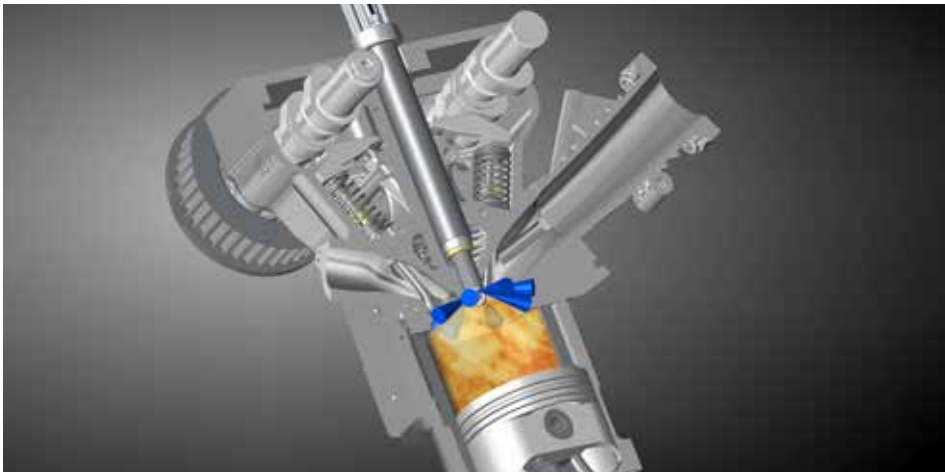
Electric drive train concepts

In the field of electromotive drive train concepts, we research and develop electric engines and drive systems for battery electric vehicles. We focus on technologies with a high weight-specific power density and high efficiency. In the field of traction battery system development, our research focuses on safe, lightweight solutions with integrated functions, which meet future demands for high energy and power densities and safety requirements during fast charging and discharging.

"Both electric and internal combustion drive systems are designed, constructed, simulated and validated through testing at Fraunhofer ICT."

Combustion engine powertrain concepts

Our R&D activities address technical solutions for increasing the efficiency of the entire powertrain (mobile and stationary applications) and consequently also for the cross-sectoral reduction of pollutant and greenhouse gas emissions. The internal combustion engine is researched and developed both as a sole propulsion unit and in combination with an electric motor as a hybrid powertrain system. The overriding objective is to minimize fuel consumption and primary energy demand as well as emissions from the powertrain (well-to-wheel). At the same time, the powertrain systems should be designed to be safe, flexible, easily available and compatible with affordable mobility.



3D CAD sectional model of the Fraunhofer ICT 1-cylinder research engine.

Above:
Lightweight camshaft module made of high-strength, fiber-reinforced plastic.

Below:
Electric motor with internal cooling and a lightweight plastic housing.

Design, simulation and testing

With our competence in the field of design we carry out complex projects for industrial and research partners. For example, we design and manufacture prototypes to validate new operating principles for electric traction components, up to complete internal combustion engines and waste heat recovery expansion devices. To verify and model new design concepts, our research group for simulation analyzes complex components and systems, starting in the concept phase. To assess the behavior of individual components within the system, we use simulation tools for the transfer of heat, material and information. The tool "IPG-CarMaker", which simulates the entire vehicle, enables vehicles to be split into different modular components, in order to assess their efficiency during driving. For flow, multi-body and structure simulation we also use professional tools according to current industrial standards. Our research group for testing and validation operates cutting-edge 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. Our hybrid test stand is used to investigate the entire electrical system within the drive train. The hot gas test stand is used to investigate waste heat recovery systems, thermoelectric generators, heat exchangers, turbo generators, exhaust-gas turbochargers and exhaust aftertreatment systems.

Batteries, accumulators and fuel cells

Our research and development in the area of batteries and accumulators includes the selection of an energy storage device for specific applications, the electrochemical characterization of materials and cells, identification of the physical parameters of materials for simulations, and causal investigations in the event of cell failure. We work on promising next-generation systems, and conduct safety tests with time-resolved gas analysis on cells and modules. The high efficiency of fuel cells means that they will play an important role in electrical energy generation in the future. Currently, hydrogen, methanol and natural gas are most often used for electricity generation in fuel cells.

Residual heat utilization and energy recovery: testing of the residual heat recovery system in the hot gas test bench.

Developments in this area relate in particular to the optimization of systems in terms of their operating conditions and the components used. Current research emphasizes the integration of fuel cells into mobile and stationary applications, and material development for the systems.

Environmental simulation and product qualification

In special technical units at Fraunhofer ICT, environmental influences on products are simulated and tailored tests are developed. Within the research group for environmental simulation and product qualification, our simulations for the mobility sector include corrosion, pollutant gas, salt spray and splash water, vibration, mechanical shock, pressure, pressure change, climate, temperature and thermal shock. For the electronics sector we simulate dust, water and IP protection class, and in the field of materials research we simulate chemical or UV resistance and aging.

Contact
Dr.-Ing. Hans-Peter Kollmeier
Phone +49 721 9150-3811
hans-peter.kollmeier@ict.fraunhofer.de

Prof. Dr. Jens Tübke
Phone +49 721 4640-343
jens.tuebke@ict.fraunhofer.de

Facilities and equipment

Engine test stands
- Single cylinder tests
- Testing of synthetic fuels
- Hydrogen combustion

Emission measurement technology
- AVL M.O.V.E Gas & Particle Counter
- AVL Particle Counter APC 489
- TSI EEPS (particle spectrometer)
- Cambustion Fast Gas Analyser (NOX,HC, CO)

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

High-frequency pulsator
- Electromagnetic drive
- Dynamic and static testing machine
- Test forces of up to 100 kN
- Test frequencies of up to 285 Hz

Test methodology and vehicle simulation
- Virtual testing
- IPG CarMaker
- AVL InMotion
- Derivation of load spectra

Data logger
- Individually configurable
- OBD, GPS, temperatures
- Humidity, pressure, vibration

Battery testing facility
- Cell characterization
- Safety tests

Service Center Environmental Simulation
- Corrosion testing
- Chemical stability
- Climate / temperature / thermal shock
- IP protection category
- Vibration / mechanical shock
- Natural weathering / solar simulation / UV stability / virtual product qualification
- Tailored environmental qualification

Clusters of Excellence

The Fraunhofer Clusters of Excellence promote the joint definition and development of system-relevant topics within a cross-institutional research structure. These research clusters operate as a virtual organization spread across multiple locations in Germany. The research clusters do not just aim to implement individual projects, but rather to pursue a roadmap for the long-term development of a complex technology trend.

Fraunhofer Cluster of Excellence "Integrated Energy Systems"

The central technological and economic challenge in the next phase of the global energy transition is the integration of a high percentage of variable renewable energies into the energy system and market. The Fraunhofer research cluster **"Integrated Energy Systems"** is therefore working on the large-scale integration of renewable energies into the German and European energy system.

A thorough, 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 infrastructure management
- Electrolysis as the basic technology for system-relevant, large-scale storage

Contact

Prof. Dr. Karsten Pinkwart
Phone +49 721 4640-322
karsten.pinkwart@ict.fraunhofer.de

"CINES offers broad collaboration opportunities that can be customized to meet specific company needs."

Fraunhofer Cluster of Excellence Integrated Energy Systems "CINES"

The "Integrated Energy Systems" research cluster is driven by the shared vision of developing Fraunhofer into the leading address for applied energy research. To achieve this, the cluster addresses the central technological and economic challenge in the next phase of the global energy transition: the system and market integration of high proportions of variable renewable energies into the energy system. This requires a massive flexibilization and integration of supply and demand across all applications – electricity, heat and transport.

Fraunhofer Cluster of Excellence “Circular Plastics Economy CCPE®”

Taking plastics as an example, the participating Fraunhofer institutes show how the energy and material flows in a value 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 goods 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 a genuine 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 economies, 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

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

Fraunhofer Cluster of Excellence “Programmable Materials”

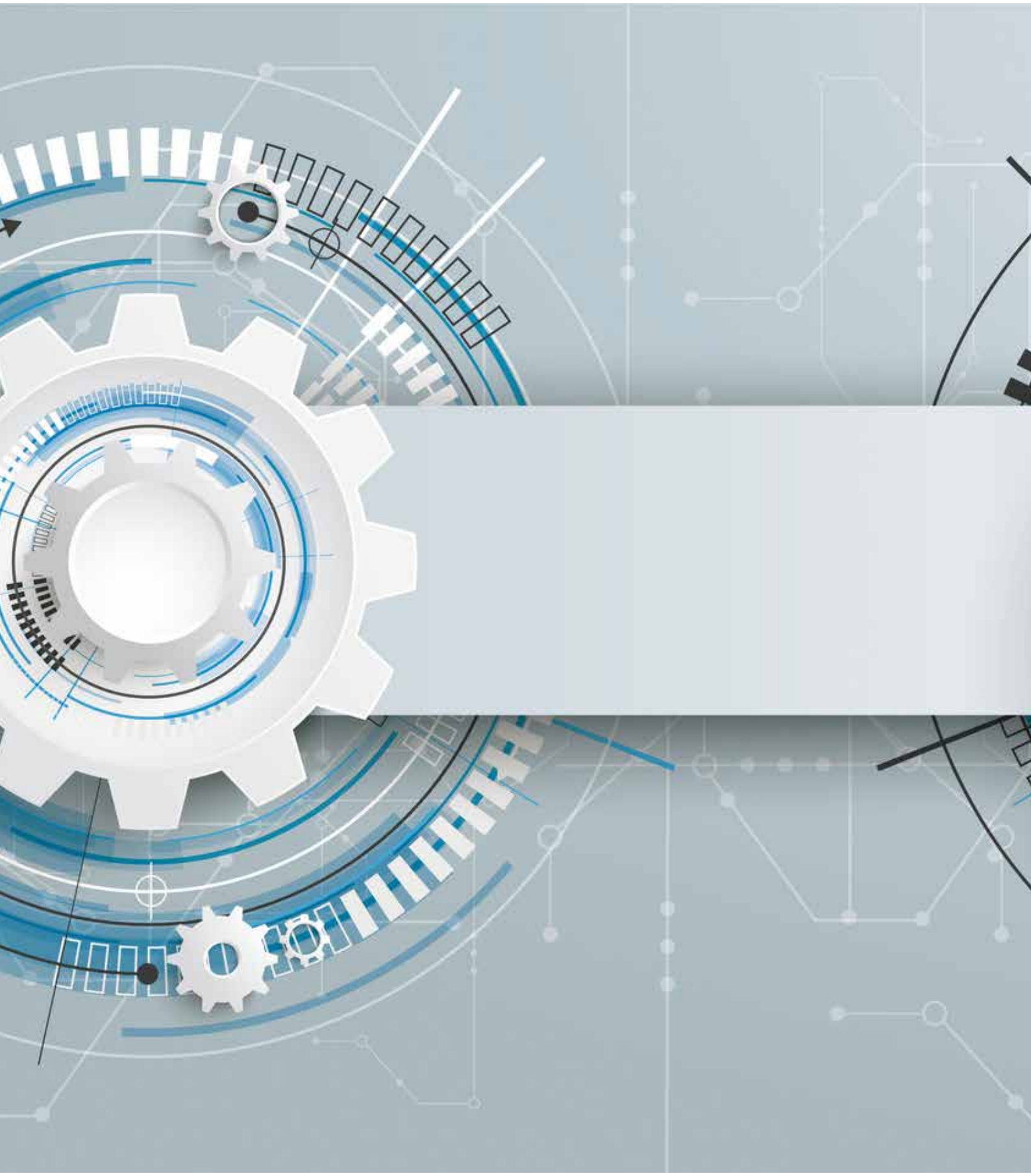
Programmable materials are causing a paradigm shift in the use of materials, as they can replace complete systems of sensors, controllers and actuators. The goal is to reduce the complexity of systems and reduce resource use by integrating functions into the material.

The Fraunhofer research cluster develops materials or material systems with an internal structure designed and manufactured to enable the material properties in the component to be reversibly adjusted, following a trigger from a defined program. This allows the integration of new complex and locally varied functions. The vision of the research cluster is to further develop the possibility to locally tailor materials and their properties for component development.

The following topics are covered:

- Programmable transport properties (mass and heat transport)
- Mechanically programmable materials (mechanical and tribo properties)
- Manufacturing and upscaling
- Product development

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



Projects

Sustainable lightweight construction: Light Materials 4 Mobility

Biobased materials make a valuable contribution to achieving national and European climate protection and sustainability targets in transport technology.

Hybrid seat back made of basalt fiber.

Light Materials 4 Mobility

In this project, new, sustainable lightweight solutions were developed in material and process technology, with the aim of maximizing resource efficiency. In the **"Bio Tape"** subproject, the focus was on the development and demonstration of a fiber-reinforced biopolymer system for lightweight structures based on:

- optimized and recyclable PLA formulations,
- cellulose regenerate fiber-reinforced injection molding material and
- basalt-fiber-reinforced UD tapes with a PLA matrix.

In addition, to demonstrate recyclability, the recycling of the materials using caustic or enzyme treatment was investigated. The recycling method allows the recovery of the basalt fibers and the monomeric lactic acid. The PLA formulations developed show heat distortion temperatures of up to 140 °C, optimized crystallizability and higher degrees of crystallization, increased ductility, and improved hydrolytic stability.

By pretreating chemical pulp with caustic soda to optimize the molecular weight distribution or the degree of polymerization, and by adjusting the solution spinning process, the stable production of regenerated cellulose fibers was possible. The orientation of the cellulose crystallites in the fiber direction resulted in an E-modulus up to 1.8 times higher than that of regenerated cellulose fibers available on the market. Injection molding material with a PLA matrix and 20 percent fiber reinforcement was produced in a double pultrusion process. In mechanical testing, the composite achieved a Young's modulus approximately 15 percent higher than that of comparable commercial material systems. The modified matrix systems enabled the production of basalt-fiber-reinforced UD tapes with homogeneous fiber distribution and fiber mass fractions of up to 63 percent. The mechanical composite properties were raised to a level comparable to that of the polypropylene/basalt fiber reference system.

Using the optimized fiber-reinforced biopolymer system – based on injection molding material and continuous-fiber-reinforced UD tapes – and the adaptation of the manufacturing processes, a seat structure demonstrator could be produced.

Contact

Kevin Moser
Phone +49 721 4640-533
kevin.moser@fraunhofer.de

Development of the simulation platform "H_2Digital" for hydrogen infrastructures

The second phase of the project "H_2D – A Hydrogen Economy for Germany" will combine and demonstrate Fraunhofer competences for the hydrogen economy.

Together with seven Fraunhofer institutes, Fraunhofer ICT has been researching the development of a simulation platform for hydrogen infrastructures.

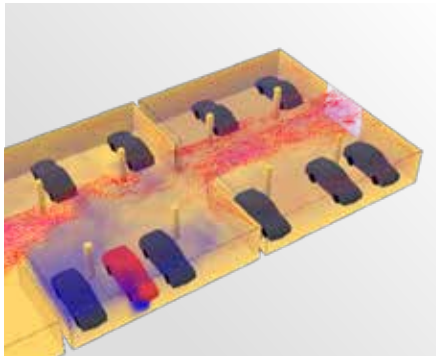
Hydrogen as a fuel

The use of green hydrogen as an environmentally friendly fuel presents some challenges. Its generation often depends on volatile energy sources, its delivery can be significantly delayed depending on the transportation method, and many application scenarios have hardly been tested in practice. Last but not least, the chemical and physical properties of hydrogen require significant safety precautions. In order to ensure efficient, failure-free operation, generators, transport infrastructure and users must be optimally coordinated.

The simulation platform H_2Digital is intended to support this coordination by enabling the modeling and simulation of complex hydrogen infrastructures, from generation, transport and storage to application. The participating Fraunhofer institutes already have highly detailed individual models of solar and wind power plants, electrolysis and fuel cell stacks, and also of material recycling processes such as ammonia synthesis. In H_2Digital, a simulation platform is now being developed that enables the coupling of these individual models and thus the simulation of interrelated systems.

Fraunhofer ICT is coordinating the development of the simulation master, i.e. the software component that serves as the interface between the individual models during their runtime.

In future work, Fraunhofer ICT will integrate individual models and analysis procedures for safety considerations into the simulation platform. CFD simulation will then be used to analyze escape scenarios and assess risks resulting from potentially explosive atmospheres. A Monte Carlo method for the automated detection of systematic failures will further enable the functional safety of the simulated infrastructures to be verified.



Simulation of a hydrogen leak in an underground parking garage.

Contact

Fabian Frank
Phone +49 721 4640-268
fabian.frank@fraunhofer.de

HANNAe - CO_2 reduction through energy efficiency in light distribution transport

From 2025 onward, new commercial vehicles registered in the European Union will have to meet legally binding CO_2 fleet targets.

These targets stipulate that commercial vehicle manufacturers must reduce the average specific CO_2 emissions of their vehicles by at least 15 percent by 2025, and at least 30 percent by 2030, with reference to the emissions of a comparable fleet in 2019/20. More efficient powertrains are required for a climate-friendly and economical use of commercial vehicles. These are being conceptually developed as part of this research project.

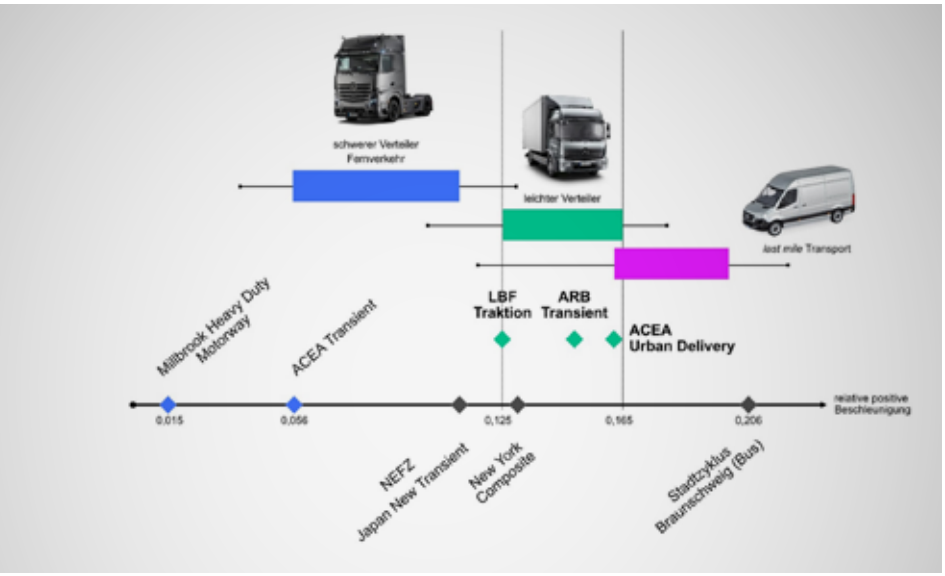
Serial hybrid powertrain with renewable methane for a 12-ton truck

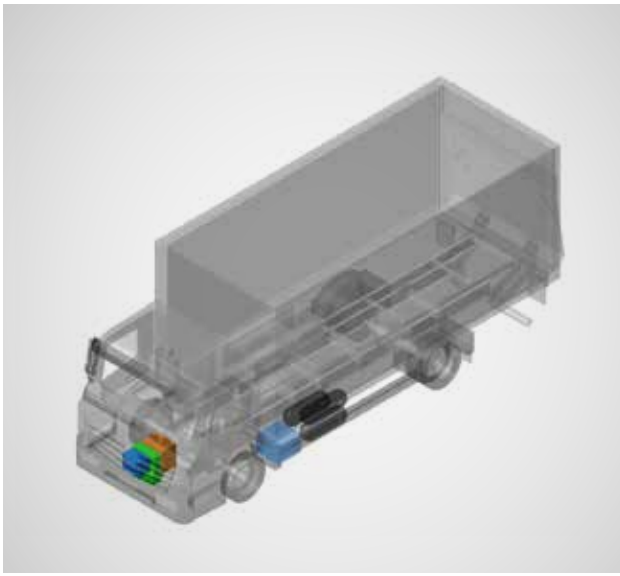
Medium-duty commercial vehicles form the backbone of today's road distribution transport for a wide range of goods. This transport is mainly local and regional and includes supplies to retail companies, deliveries directly to private individuals and the distribution of letters and parcels. Typical driving routes include large proportions of urban and extra-urban traffic with frequent idling and acceleration phases. Urban and regional distribution transport mainly involves vans and medium-heavy commercial vehicles up to 12 tons. Particularly in terms of the volumes transported, these vehicles make comparatively little use of their payload capacity. Depending on the transportation task and the traffic situation, the vehicles used in this process can have specific emissions of up to 300 grams of CO_2 per ton-kilometer.

Right: Logistics, A8 freeway, Stuttgart.

Bottom left: Relative positive acceleration as a metric for identifying relevant driving cycles and operating conditions. Source: LBF.

Bottom right: Digital mock-up of the defined powertrain and traction storage systems: Investigation of design space in the virtual 3D CAD vehicle environment.





To determine the energy and power requirements of a drive train for 12-ton commercial vehicles, this subproject simulated a variety of route and speed scenarios. Based on the analysis of driving distances, associated speed profiles and resulting driving resistances, a pure, specific traction energy requirement of 0.9 to 1.1 kWh per kilometer was calculated for the investigated vehicles. The criteria for defining and designing the drive train were significantly determined by the focus on energy-efficient, locally emission-free and climate-friendly operation in the deployment scenarios studied. A serial hybrid powertrain, in which the combustion engine is operated with regenerative synthetic methane, was defined as a suitable concept for this purpose.

Mobility is a basic social need as well as a prerequisite of our economic system."

Project goals and partners

The gas engine enables the new hybrid vehicle to achieve the driving performance of conventional vehicles while benefiting from the fuel availability of the established infrastructure. Because of its favorable carbon-to-hydrogen ratio, even fossil methane releases about 25 percent less CO_2 during combustion than currently used liquid fossil fuels. Until renewable fuels penetrate the market, even hybrid vehicles fueled with fossil methane can therefore contribute to climate protection as a bridging technology in the transport sector. Its electric traction also enables low-noise and locally emission-free propulsion as well as the recovery of kinetic energy through regenerative braking. Further advantages of combining an electric motor and combustion engine into a hybrid powertrain result from the different dynamic behavior and operating efficiency profiles of the two systems. Accordingly, the research priorities in the subproject were the fuel supply chain in the production of biogas (Fraunhofer IMM), the concept of an efficient combustion engine (Fraunhofer ICT) with an exhaust gas aftertreatment system (Fraunhofer ISE) and a battery-electric energy storage system (Fraunhofer LBF) for the complete integration of traction and recovered energy.

These research results were achieved in the project HANNAe **("Highly efficient powertrain for commercial vehicles taking into account the national mobility and hydrogen strategy")**. The project aimed to provide an effective innovation stimulus, as part of the economic recovery and crisis management plan to counter the impact of the corona pandemic, secure prosperity and strengthen future viability, which was implemented by the German government from August to December 2020.

Contact

Ivica Kraljevic
Phone +49 721 9150-3818
ivica.kraljevic@
ict.fraunhofer.de

Haiko Kowarik
Phone +49 721 9150-3824
haiko.kowarik@
ict.fraunhofer.de

Tobias Burgert
Phone +49 721 9150-3829
tobias.burgert@
ict.fraunhofer.de

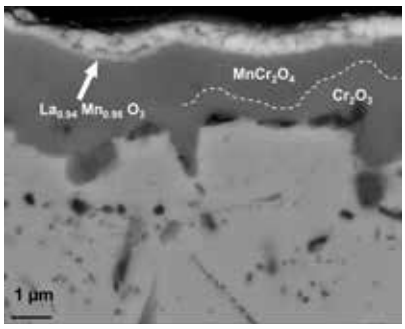
High-temperature material concepts for sustainable, decarbonized energy technology

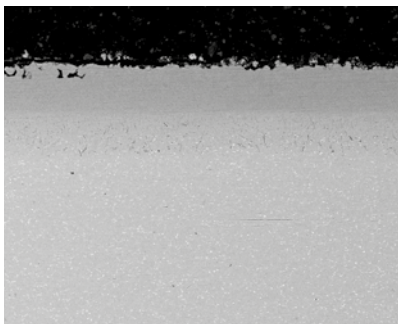
Increasing efficiency through higher operating temperatures in innovative and sustainable energy conversion processes is a key task in improving resource efficiency. It places new demands on materials, requiring the development of new material and manufacturing concepts.

Reliable, sustainable energy conversion processes using high-performance, high-temperature materials

The joint project aims to reduce CO_2, save resources and increase efficiency.

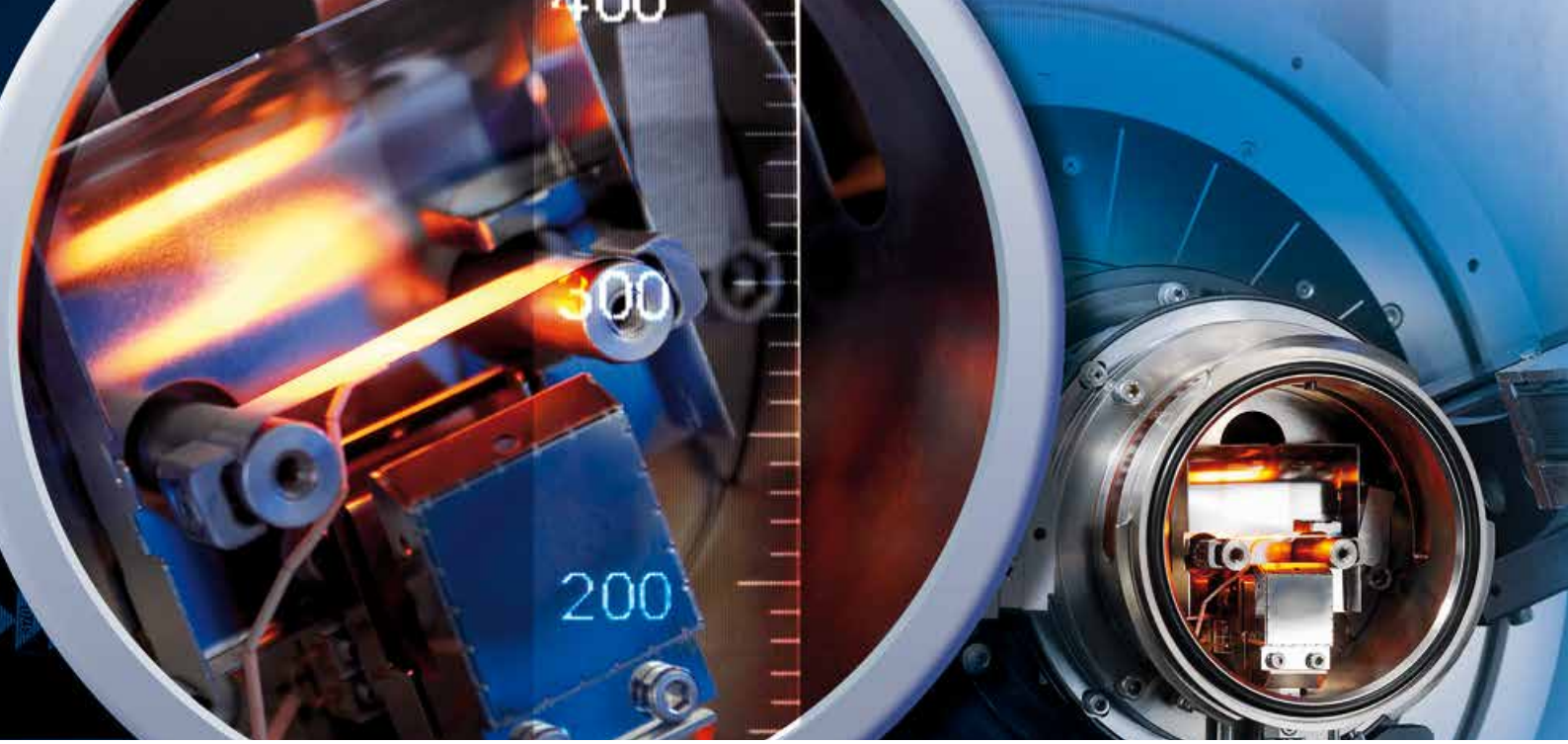
To complete the energy transition, new high-temperature material solutions and manufacturing technologies are essential for the vast majority of energy conversion technologies. The aim of the joint project is to make significant contributions to CO_2 reduction, resource conservation and the increased efficiency of production units and processes through applied materials research. Three areas are addressed: Solar thermal systems, high temperature electrolyzers and hydrogen turbines. In solar thermal energy systems, solar rays – which are focused using mirror systems - are used to heat molten salts that then transport the heat to a steam turbine. In this process, the solar receivers, piping, pumps, and storage tanks are placed under particular stress due to corrosion by the molten salts at temperatures of 350 °C to 550 °C. Low-cost aluminide diffusion coatings for heat storage tanks, and piping made of ferritic steels, are being investigated to provide corrosion protection as well as potential for higher operating temperatures. High-temperature electrolysis is a promising technology for the production of green hydrogen. Innovative and cost-effective coatings for interconnectors made of ferritic HT stainless steel – to protect against corrosion and the evaporation of volatile, toxic and function-disrupting chromium (VI) species - are being researched and further developed.





Left:
Lanthanum oxide based coating on stainless steel for interconnectors in high-temperature electrolysis.

Right:
Aluminide diffusion coating on steel to protect against corrosion at high temperatures.



High-temperature chamber for X-ray diffractometry.

MoSiB alloys for hydrogen turbines are being investigated for the highest application temperatures above 1300 °C. These alloys are produced using powder metallurgical processes. Both pressure-assisted sintering and SEBM are used. At the same time, the forming of molded parts with tribological and process optimization is under research.

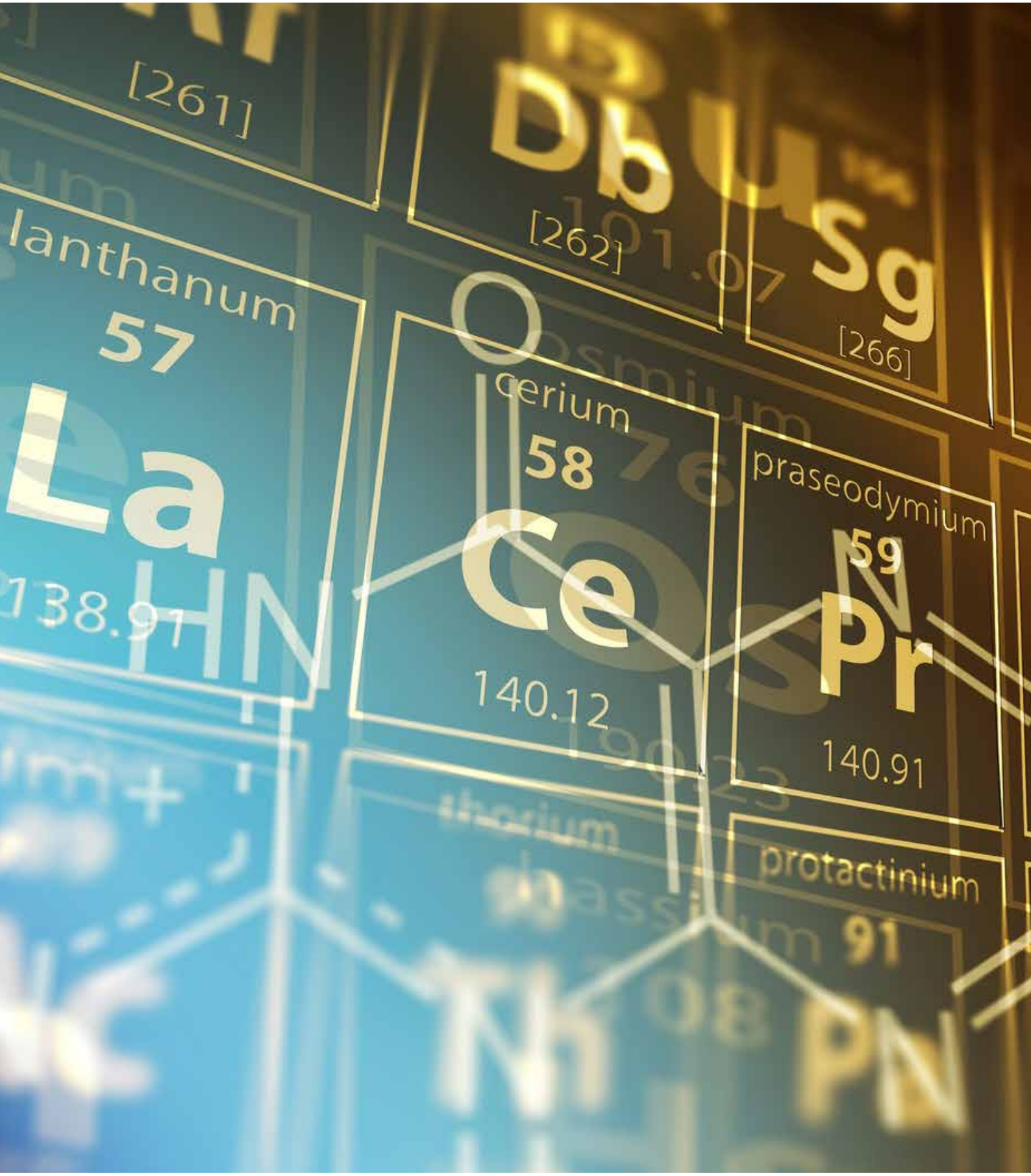
Efficient and cost-effective corrosion protection coatings for solar thermal systems and high-temperature electrolyzers.

In the joint project "HI-TEMP", which is funded by the German Federal Ministry of Education and Research in accordance with Guideline 3004/68 501 **"Support for application-oriented research for non-university research institutions"**, the Fraunhofer institutes IWM, IST, IKTS, ICT and IWU have joined forces to develop materials solutions for the addressed technologies in a complementary approach.

At Fraunhofer ICT an annealing process for aluminum slurry coatings is being developed as part of the joint project for solar thermal applications. The external heat creates aluminide diffusion layers that protect the steel from corrosion. The advantage of using this process rather than a furnace is that it is not necessary to subject the entire component to heat treatment, but only the component surface. For a digitized AI-supported approach to the targeted further development of diffusion layers, the entire system is parameterized in all process steps, and the data is structured in a computer-readable format. Electroplated coatings based on lanthanum oxide are being investigated to protect the interconnector in a high-temperature electrolyzer. The method is cost-effective and well suited for coating even more complex geometries, and it yields thin, nano-structured layers. To assess the potential for operating solid electrolyzers under pressure, the stability of interconnector coatings at 30 bar in relevant atmospheres is being investigated.

Contact

Dr. Vladislav Kolarik
Phone +49 721 4640-147
vladislav.kolarik@
ict.fraunhofer.de


[261]
Db
[262]
Sg
[266]
lanthanum
57
La
138.91
cerium
58
Ce
140.12
praseodymium
59
Pr
140.91
protactinium
91

Appendix

High-performance centers, networks and alliances

The institutes of the Fraunhofer-Gesellschaft work together, collaborating in networks and alliances or pooling different expertise within flexible structures according to demand. This secures their leading position in the development of system solutions and the implementation of comprehensive innovations.

"High-performance centers provide excellent infrastructure that can be used across organizations, as well as training concepts and know-how."

High-performance centers

High-performance centers organize the collaboration between university and non-university research and industry, and are characterized by reliable, consistent roadmaps for the partners involved in terms of research and teaching, support for young researchers, infrastructure, innovation and transfer.

High-performance center for mobility research in Karlsruhe
The four Fraunhofer institutes ICT (including the New Drive Systems Department), IOSB, ISI and IWM, the Karlsruhe Institute of Technology, the Karlsruhe University of Applied Sciences and the FZI Research Center for Information Technology are conducting joint research on future mobility. Seven initialization projects cover the key challenges of efficient, intelligent and integrated mobility across a wide range of topics. The projects generate a network of important players from science, applied research and industry.

Contact
Dr.-Ing. Lars-Fredrik Berg
Phone +49 721 9150-3814
lars-fredrik.berg@ict.fraunhofer.de

Ivica Kraljevic
Phone +49 721 9150-3818
ivica.kraljevic@ict.fraunhofer.de

Groups

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

Fraunhofer Segment for Defense and Security
- Safety and security research
- Protection and deterrence
- Reconnaissance and surveillance
- Explosives and safety engineering
- Decision-making support for government and industry
- Localization and communication

Contact
Prof. Dr.-Ing. Peter Elsner
Phone +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
- Microsystems technology
- Safety

Contact
Prof. Dr.-Ing. Peter Elsner
Phone +49 721 4640-401
peter.elsner@ict.fraunhofer.de

Alliances

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

Lead market – energy sector
In 2020, within its market-oriented alliances, Fraunhofer established new cooperative technology transfer platforms for so-called "lead markets". Eight lead markets have been defined so far. Within the lead markets, the Fraunhofer institutes offer their services to the entire value chain of the related industry with combined competences, research offers spanning multiple institutes, and competent, flexible project consortia. Fraunhofer ICT is involved in the lead market "energy sector" through the Energy and Batteries Alliances.

Fraunhofer Battery Alliance
The Fraunhofer Battery Alliance currently has 20 member institutes working together in the field of battery technology. The competences of the Fraunhofer Battery Alliance cover the entire value chain of battery technology, from materials, cells and cell production through to system design, system integration and the recycling of components and materials.

Simulation methods and a comprehensive range of testing and inspection services complement the material, process and manufacturing development topics.

Fraunhofer ICT is a member of the Battery Alliance and also its Head Office, as Prof. Dr. Jens Tübke is the spokesperson for the Alliance.

Contact
Prof. Dr. rer. nat. Jens Tübke
Phone +49 721 4640-343
jens.tuebke@ict.fraunhofer.de

Fraunhofer Building Innovation Alliance
- Product development
- Construction components and systems, buildings as holistic systems
- Software
- Construction sequences, construction planning, logistics, construction operations, life cycle assessments for buildings
- International projects, construction in different climate zones

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

Fraunhofer Energy Alliance

Fraunhofer ICT is one of the 19 member institutes of the Fraunhofer Energy Alliance. With its business units of Energy Renewable, Energy Storage, Energy Efficient, Energy Digital, Energy System, Energy Urban, Energy Grids, and Climate and Environment, the Fraunhofer Energy Alliance is one of the largest energy research alliances. Fraunhofer ICT contributes to Fraunhofer's energy research with its expertise in the fields of electrochemical energy storage and conversion as well as thermal storage and hydrogen.

Contact
Prof. Dr. Karsten Pinkwart
Phone +49 721 4640-344
karsten.pinkwart@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

Contact
Dr. rer. nat. Uwe Schaller
Phone +49 721 4640-676
uwe.schaller@ict.fraunhofer.de

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

Research fields

Research field of lightweight construction
The expertise of 15 Fraunhofer institutes is pooled in the research field of lightweight construction. Solutions for customers are developed from a single source, taking into account ecological and economic aspects.

- Material application and product design
- Approval and product use
- Prototype and series production of components and systems
- Further training to become a Fraunhofer composite engineer

Contact
Dr.-Ing. Philipp Rosenberg
Phone +49 721 4640-417
philipp.rosenberg@ict.fraunhofer.de

Teaching engagement and public body membership

Teaching activities and public body membership are important tasks of a research institution. In 2020 we held lectures at KIT, other universities and dual universities. In this way we contribute to the skills of scientists and technicians and our own future researchers.

Teaching engagements

Karlsruhe Institute of Technology KIT

Institute for Applied Materials – Material Sciences
Elsner, Peter
- Polymer engineering (2 units per week, WT + ST)
- Working techniques for mechanical engineering (2 units per week, ST)

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

Institute of 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

Faculty of Electrical Engineering and Information Technology
Graf, Matthias
- Sensor laboratory 1 (2 units per week, WT + ST)

Pinkwart, Karsten
- Biochemical sensors (2 units per week, ST)
- Batteries and fuel cells (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)

Baden-Württemberg Cooperative State University, Karlsruhe

Technology Department, Mechanical Engineering
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 and plastics (2 units per week, WT)
- Plastics processing (2 units per week, ST)
- Laboratories for plastics processing/ measurement technology (2 units per week, WT + ST)

Kronis, Gunnar
- Engineering design (44 units per year)

Reinhard, Stefan
- Material sciences – plastics (2 units per week, WT)
- Laboratory for plastics processing/ measurement technology (2 units per week, WT)

Mechatronics
Bader, Bernd
- Applied materials technology II "New Materials" (2 x 33 hours/year)

Safety Studies
Gräbe, Gudrun
- Basics of environmental technology (3 units per week, WT)

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

Baden-Württemberg Cooperative State University, Mannheim

Technology Department, Mechanical Engineering
Bader Bernd
- Plastics processing (57 units/year, WT)
- Construction with plastics (37 units/year, WT)

Baden-Württemberg Cooperative State University

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

Technical University Nuremberg

Faculty of Process Engineering
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)

University of Augsburg, Institute for Materials Resource Management

Weidenmann Kay
– Manufacturing technology (4 units per week, WT)
– Materials for lightweight design (3 units per week, WT)

Ulm University

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

Helmut-Schmidt University – University of the Federal Armed Forces Hamburg

Electrical Engineering Department
Pinkwart, Karsten
– Electrochemical energy storage devices and converters
(2 units per week, WT)

Mechanical Engineering Department
Cremers, Carsten
– Electrochemical power sources (2 units per week, WT)

Associated Institute of Ostfalia University of Applied Sciences

Training and Further Education 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

Mechanical Engineering Department, Material Science
– Vehicle lightweighting and composite processing
(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 unit, WT)

Public body membership

Ahlbrecht, Katharina
- Director of the Fraunhofer Battery Alliance
- Director of the Working Group "Batteries" of the Society for Environmental Simulation (GUS)

Becker, Wolfgang
- Member of the "Nano-Initiative Bavaria" in the "nanosilver" cluster

Böhnlein-Mauß, Jutta
- Member of the Working Group »Interior Ballistics« of the Bundeswehr Technical Center for Weapons and Ammunition
- Member of the Working Group »3D Printing of Propellant Powders« 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)
- Visiting fellow of NATO AC326/SG1-CNG
- Member of the German Society for Thermal Analysis (GEFTA)
- 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 the International NC Symposium"
- Member of the International Advisory Board of the Polymer Degradation Discussion Group (PDDG)

Cäsar, Joachim
- DKE 131 "Environmental Simulation"
- DKE 212 "IP Protection Categories"
- Member of the Society for Environmental Simulation (VDI e.V.)
- Deputy Chair of the Working Group »Effects on Products« of the Air Quality Control Commission (AQCC)
- Member of the Society for Environmental Simulation (GUS e.V.)
- Deputy Director of the Working Group on "Particles – Properties and Effects" within the Society for Environmental Simulation (GUS)
- 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 NATO Science & Technology Organization Panel SET-270 »Overcoming the Technical Barriers that Inhibit the Use of Fuel Cells for Dismounted Soldier Application"
- 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)

Dieterle, Michael
- Circular Economy Initiative Germany (CEID) – collaboration in the Working Group »Packaging«

Elsner, Peter
- Deputy spokesman of the Fraunhofer Building Innovation Alliance
- Member of the National Academy of Science and Engineering
- Spokesperson 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 "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 "3D Printing of Propellant Powders« of the Bundeswehr Technical Center for Weapons and Ammunition

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

Griesbaum, Patrick
- Member of the AVK Working Group SMC/BMC

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

Henning, Frank
- Director of SAMPE Deutschland e.V.
- Member of the Federation of Reinforced Plastics (AVK)
- SPE Composites Division
- 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
- Member of the Advisory Board of the Lightweight Construction Transfer Program of the Federal Ministry for Economic Affairs and Energy (BMWi)
- Member of the Society of Plastics Engineers (SPE) Composite Division and Member of the International Scientific Council of the St. Petersburg Polytechnic University, Peter the Great, St. Petersburg, Russia.

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) and the technical groups Analytical Chemistry, Chemists in Civil Service and the Association for Chemistry and Economics

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

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
- Member of the DGM Technical Committee Cellular Materials

Knapp, Sebastian
- Member of the International Pyrotechnic Society
- Member of the German Physical Society

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

Lautenschläger, Miriam
- Member of the AVK Working Group "Natural-Fiber-Reinforced Plastics"

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

Miitró, Daniel
- Member of the Working Group "3D Printing of Propellant Powders" of the Bundeswehr Technical Center for Weapons and Ammunition

Menrath, Andreas
- Seminar Spokesman in the Working Group "EATC – European Alliance for Thermoplastic Composites" of the Federation of Reinforced Plastics (AVK)

Noack, Jens
- Member IEC TC 21/ TC 82 JWG 82 "Secondary Cells and Batteries for Renewable Energy Storage and Smart Grid Structures"
- Member of IEC TC 21 / TC 105 JWG 7 "Flow Batteries"
- Member of DKE, AK 384 "Fuel Cells"
- Member of DKE, AK 371 "Fuel Cells"
- Member of DKE AK 371.0.1 "Terms and Definitions"
- Head of Working Group DKE, AK 371.0.6 "Flow Batteries"
- Member of the scientific committee of the International Flow Battery Forum (IFBF)

- Deputy Director, German-Australian Alliance for Electrochemical Technologies for Storage of Renewable Energy (CENELEST), University of New South Wales, Sydney, Australia
- Member of the International Society of Electrochemistry (ISE)
- Member of the Electrochemical Society (ECS)
- Member of the German Chemical Society (GDCh) – Expert Group Electrochemistry

Parrisius, Martina
- Board member of "learning in the laboratory", Bundesverband für Schülerlabore e.V.
- Member of "entrepreneurship at school", Federal Ministry for Economic Affairs and Energy, Berlin

Pinkwart, Karsten
- Member of the National Hydrogen Council of the German Federal Government
- 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
- Elected member of the Scientific and Technical Council of the Fraunhofer-Gesellschaft
- Member of the Scientific Board of the HybridSensorNet Symposium

Reichert, Thomas
- Managing Director of the Society for Environmental Simulation (GUS) e.V.
- Former president of the European Federation of Clean Air and Environmental Protection Associations (EFCA)
- Former 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)
- Contributor to the DIN Standardization Committee on Plastics, NA 054-01-04, Resistance Against 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)
- Member of the Quality Working Group (ECAC)

Rope, Elisa
- Circular Economy Initiative Germany (CEID) - collaboration in the Working Group »Packaging«

Schaller, Uwe
- Member of the NATO AVT-340 Program Committee
- Representative of Fraunhofer ICT in the Fraunhofer Space Alliance
- Member of the EDA CapTech Missiles and Munitions Group

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 INNONET Netzwerk; Head of the Working Group "Recycling"
- Member of the Working Group "Bioeconomy" of the Ministry of Rural Affairs and Consumer Protection of 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 "Chemie-Ingenieur-Technik" – Thematic Area: Particle technology

- Chair of the Working Group "Effects on Products" of the Clean Air Commission
- 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
- Spokesman of the R&D Advisory Board of the Bundesverband Energiespeicher (BVES) (German Energy Storage Association)
- Member of the Executive Board of 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 the International Pyrotechnic Society
- Representative of Fraunhofer ICT 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 Committee "Hybrid Materials"
- Member of the Scientific Committee of the International Conference on Composite Structures (2017, 2018)
- Member of the Scientific Committee of the Conference on Hybrid Materials and Structures
- Member of the Executive Board of the Application Center for Material and Environmental Research, Augsburg
- Member of the board of directors of the AI Production Network Augsburg

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"
- Member of the International Ballistics Society (IBS)

Events, trade fairs and exhibitions

2020 was a turbulent year for trade fairs, as the entire industry had to deal with the effects of the COVID-19 pandemic. Through numerous trade fair cancellations and postponements we lost important acquisition platforms. However, we were able to counteract this in part with a few virtual trade fairs.

Addressing customers is one of the greatest challenges in the digital space.

Learning by doing

This was the motto of the past year. New, digital trade fair formats and event series have emerged to retain existing customer networks or establish new ones. The new digital opportunities, and our attempt to maintain our presence on important platforms, have shown that personal contact cannot easily be replaced. Customer engagement is one of the greatest challenges in the digital space.

With our virtual tour of the institute, we have created the possibility for you to visit our laboratories and pilot plants virtually. Via livestream, we also provide insights into the high standard of our current research work.

Virtual room at the Fraunhofer Solution Days.

Events

May 14-15, 2020
Particle Conference
Fraunhofer ICT, Pfinztal, digital

March 24-25, 2021
49th Annual Conference of the Society for Environmental Simulation GUS "Identification, Simulation and Evaluation of Environmental Impacts"
Online conference

Trade fairs and exhibitions

March 26-28, 2020
FC Expo
Tokyo, Japan

March 26-28, 2020
Battery Expo
Tokyo, Japan

July 28-29, 2020
PIAE Europe
Digital only

October 13-15, 2020
ITHEC 2020
Digital only

October 26-29, 2020
Fraunhofer Solution Days 2020
Digital only

January 13-15, 2021
BAU 2021
Digital only

April 27-29, 2021
Battery Conference 2021
Digital only

June 01-02, 2021
JEC Composites Connect
Digital only

June 15-16, 2021
Achema Pulse
Digital only

Publications

Poppe C.; Albrecht F.; Krauß C.; Kärger L.
A 3D modelling approach for fluid progression during process simulation of wet compression moulding – motivation & approach
International Conference on Material Forming, Online
In: Procedia manufacturing, Vol. 47 (2020), pp. 85-92
Zeitschriftenaufsatz

Schweizer C.; Reichenbach R.; Butz A.; Lienhard J.; Herrmann T.; Preußner J.; Hartrott P.; Friedmann V.; Wessel A.; Thomas A.; Augenstein E.; Oesterlin H.; Tlatlik J.; Bader B.; Graf M.; Baumann S.; Grau G.; Schindler S.; Dauner M.; Bulling F.; Tiberto D.; Klotz U.; Basler C.; Bertz A.; Blug A.; Becker A.; Goranov A.; Burkhardt C.; Hartman H.; Körte F.
Abschlussbericht zu "Material Digital"
Laufzeit: 1.7.2018 - 30.6.2020
Feiburg, 2020, Bericht

Quaresma J.; Deimling L.; Campos J.; Mendes R.
Active and Passive Optical Fiber Metrology for Detonation Velocity Measurements
In: Propellants, explosives, pyrotechnics, Vol. 45 (2020), No.6, pp. 921-931
Zeitschriftenaufsatz

Wendel R.; Rosenberg P.; Wilhelm M.; Henning F.
Anionic Polymerization of ε-Caprolactam under the Influence of Water: 2. Kinetic Model
In: Journal of composites science, Vol. 4 (2020), No. 1, Art. 8, 12 pp.
Zeitschriftenaufsatz

Roznyatovskaya N.; Noack J.; Pinkwart K.; Tübke J.
Aspects of electron transfer processes in vanadium redox-flow batteries
In: Current opinion in electrochemistry, Vol. 19 (2020), pp. 42 - 48, Zeitschriftenaufsatz

Beck B.; Tawfik H.; Haas J.; Park Y.-B.; Henning F.
Automated 3D Skeleton Winding Process for Continuous-Fiber-Reinforcements in Structural Thermoplastic Components
International Symposium on Plastics Technology 2020, Aachen
In: Hopmann, C.: Advances in polymer processing 2020: Proceedings of the International Symposium on Plastics Technology, Aachen/Germany, March 2020. Berlin: Springer Vieweg, 2020, pp. 150 - 161, Konferenzbeitrag

Lichtner V.; Frey G. (Gutachter); Burkhardt C. (Gutachter); Behnisch F. (Betreuer)
Beitrag zur Entwicklung eines einstufigen Herstellungsverfahrens von Polyurethan-Sandwichbauteilen mit CFK-Decklagen
Pforzheim, Hochschule, Master Thesis, 2020, Master Thesis

Moser K.
Beitrag zur Kristallisationsoptimierung von Poly(L-Lactid) (PLLA) und Grundlagen zur Validierung einer Methode zur Inline-Charakterisierung des Kristallisationsverlaufs im Spritzgießprozess
Stuttgart: Fraunhofer Verlag, 2020 (Wissenschaftliche Schriftenreihe des Fraunhofer ICT 89)

Zugl.: Karlsruhe, Inst. für Technologie (KIT), Diss., 2019
ISBN 978-3-8396-1585-0

Saražin J.; Schmiedl D.; Pizzi A.; Sernek M.
Bio-based adhesive mixtures of pine tannin and different types of lignins
In: BioResources, Vol. 15 (2020), No. 4, pp.9401-9412, Zeitschriftenaufsatz

Piscopo C. G.; Polyzoidis A.; Werner D.; Ahlhelm M.; Richter H.-J.
Breakthrough Screening of Porous Materials: A Simple and Effective Tool for Database Generation
In: ChemistrySelect, (2020), Online First, 6 pp., Zeitschriftenaufsatz

Duan J.; Henning F. (Supervisor); Wilhelm M. (Supervisor)
Characterization of influencing parameters in the robot-based filament winding process on a skeleton structure with thermoset pre-impregnated carbon fiber tows
Karlsruhe, Inst. für Technologie (KIT), Master Thesis, 2020

Wilhelm M.; Wendel R.; Aust M.; Rosenberg P.; Henning, F.
Compensation of Water Influence on Anionic Polymerization of ε-Caprolactam: 1. Chemistry and Experiments
In: Journal of composites science, Vol. 4 (2020), No. 1, Art. 7, 19 pp. Zeitschriftenaufsatz

Pickhardt S.
Construction and initial operation of a plant for the determination of the ultimate aerobic biodegradability according to DIN EN ISO 14855-2:2018
Offenburg, Univ., Master Thesis, 2020

Schmid H.
Corona-Mechanistik, Kinetik, Modellierung, Simulation und Vorhersage des Verlaufs in Deutschland
Präsentation am Fraunhofer-Institut für Chemische Technologie ICT, März 2020, Vortrag

Schöttl L.; Kolb P.; Liebig W.V.; Weidenmann K.A.; Inal K.; Elsner P.
Crack characterization of discontinuous fiber-reinforced composites by using micro-computed tomography: Cyclic in-situ testing, crack segmentation and crack volume fraction
In: Composites communications, Vol. 21 (2020), Art. 100384, Zeitschriftenaufsatz

Lang J.; Bohn M.
Decomposition of ammonium dinitramide (ADN) elucidated by quantum chemical computations
In: University of Pardubice: 23th Seminar on New Trends in Research of Energetic Materials, NTREM 2020. Proceedings: Energetic output and effects; April 1 - 3, 2020, Pardubice, Czech Republic. Pardubice: University of Pardubice, 2020, 16 pp., Konferenzbeitrag

Lang J.; Bohn M.
Decomposition Pathways of Ammonium Dinitramide (ADN) and its HNO3-Clusters Elucidated by DFT-Calculations
In: Propellants, explosives, pyrotechnics, (2020), Online First, In Print: 2021, 46, 233–244

Pretsch T.; Chalissery D.; Schönfeld D.; Walter M.; Wafzig F.
Design for Recycling mit Formgedächtnispolymeren
Vortrag gehalten beim VDI - Arbeitskreis Kunststofftechnik, 25. November 2020

Stemmler C.
Designverifikation eines innovativen Elektromotors mit innenliegender Kühlung und integralem Kunststoffgehäuse mit Hilfe eines Funktionsprototypen
Karlsruhe, Inst. für Technologie (KIT), Master Thesis, 2020

Choi N.H; Olmo D. del; Fischer P.; Pinkwart K.; Tübke J.
Development of flow fields for zinc slurry air flow batteries
In: Batteries, Vol. 6 (2020), No.1, Art. 15, 10 pp., Zeitschriftenaufsatz

Hübinger M.; Pinkwart K. (Referent); Coenen S. (Korefe-rent); Schäffer M. (Betreuer)
Dispatch-Algorithmen für künstliche Microgrids mit hohem Anteil an erneuerbaren Energien
Karlsruhe, Hochschule f. Technik u. Wirtschaft, Master Thesis, 2020

Weisheit L.; Wenz F.; Lichti T.; Eckert M.; Baumann S.; Hübner, C.; Eberl C.; Andrä H.
Domänenübergreifende Workflows zur effizienten Entwicklung Programmierbarer Materialien
In: Zeitschrift für wirtschaftlichen Fabrikbetrieb : ZWF, Vol. 115 (2020), No. 7 - 8, pp. 470 - 475, Zeitschriftenaufsatz

Dieterle M.; Viere T.
Eco-efficiency in a circular economy from a products life cycle gap perspective
Presentation held at 2nd Life Cycle Innovation Conference, LCIC 2020, 26. - 28.8.2020, Virtual Conference, Vortrag

Just D.; Moser K.
Elastomer Devulkanisation mittels Ultraschall-Intensivierter Extrusion Schlussbericht Teil I & II: Teilvorhaben: Kontinuierliche Devulkanisation und in-situ Materialmodifikation
Laufzeit 01.07.2017 - 31.12.2019
Pfinztal: Fraunhofer ICT, 2020

Kunkel R; Schmidt Volkmar M.; Cremers C.; Müller D.; Schmiedl D.; Tübke J.
Electrochemical Polyvanillin Production: A valorization route from lignin to biobased polymers
Poster presented at 3. Internationaler Bioökonomiekongress Baden-Württemberg, 21. - 22. September 2020

Brantsch P.; Höhne C.-C.; Hanich R.
End of Life Innovation. Polyurethane Chemical Recycling (Solvolysis) Eco-statement - Preliminary results
Poster presented at Clean Sky 2, AIRFRAME ITD Workshop, 28. - 29.04.2020, Dassault, Online

Ulrich J.; Gauterin F. (Betreuer); Pfriem M. (Projektleiter); Liebertseder J. (Projektleiter)
Entwicklung eines Modells zur performanten elektrisch-thermisch gekoppelten Simulation von am Ableiter temperierten Lithium-Ionen-Batteriezellen zur Bewertung des Thermomanagements von Traktionsbatterien
Karlsruhe, Inst. für Technologie (KIT), Master Thesis, 2020

Schindele K., Sorg T., Hentschel T., Liebertseder J.
Leichtbau-Nockenwellenmodul aus hochfestem faserverstärkten Kunststoff
MTZ – Motortechnische Zeitschrift 81, 28 – 35 (2020). https://doi.org/10.1007/s35146-020-0271-3

Moser K; Holzer A.; Meijer D.
Entwicklung von maßgeschneiderten PHB-Kompositen

für technische Anwendungen PHB2MARKET
PHB2MARKET-Schlussbericht-Teile I und II; Laufzeit: 1.1.2017 - 30.4.2020, Fraunhofer ICT

Baumann N; Blankenship A.; Dorn M.; Cremers C.
Evaluating Current Distribution and Influence of Defect Sites for Graphitic Compound Bipolar Plate Materials
In: Fuel Cells, Vol.20 (2020), No.1, pp. 40 - 47, Zeitschriftenaufsatz

Seuffert J.; Rosenberg P.; Kärger L.; Henning F.; Kothmann M.H.; Deinzer G.
Experimental and numerical investigations of pressure-controlled resin transfer molding (PC-RTM)
In: Advanced manufacturing: polymer & composites science : AMPCS, Vol. 6 (2020), No. 3, pp. 154 - 163, Zeitschriftenaufsatz

Weiser V.; Kelzenberg S.; Knapp S.
Experimental Investigation of the Ignitor Plume/Probellant Interaction
In: Lutradyn-Energetic Materials Science &Technology Consulting, Kaiserslautern: 15th Workshop on Pyrotechnic Combustion Mechanisms, WPC 2020: Ignition of Energetic Materials, Web-Workshop, October 5 - October 7, 2020. Kaiserslautern: Lutradyn-Energetic Materials, 2020, pp. 182 - 226, Konferenzbeitrag

Haas J.; Bose B.
Formed Pultrusion Profiles. Wrinkle-Free Forming of Pultruded Hollow Profiles by Local Stretch Bending
In: Kunststoffe international, (2020), No. 10, pp. 40 - 43, Zeitschriftenaufsatz

Springsklee L.
Funktionalisierung aromatischer Diamine aus dem chemischen PUR-Recycling.
Heilbronn, Hochschule, Master Thesis

Haas J.; Bose B.
Geformte Pultrusionsprofile. Faltenfreie Umformung pultrudierter Hohlprofile durch lokales Streckbiegen
In: Kunststoffe, (2020), No. 12, pp.40 - 43, Zeitschriftenaufsatz

Tarkhanov E.; Lehmann A.; Menrath A.
Halfway to Technical Stereocomplex PLA Products – an Arduous Path to a Breakthrough
In: Macromolecular materials and engineering, Vol. 305 (2020), No. 12, Art. 2000417, 6 pp., Zeitschriftenaufsatz

Henning F.; Möller E.
Handbuch Leichtbau. Methoden, Werkstoffe, Fertigung
2., überarbeitete und erweiterte Auflage, München: Hanser, 2020
ISBN 978-3-446-45638-9, Sammelband

Gurieff N.; Green D.; Koskinen I.; Lipson M.; Baldry M.; Maddocks A.; Menictas C.; Noack J.; Moghtaderi B.; Doroodchi E.
Healthy power: Reimagining hospitals as sustainable energy hubs
In: Sustainability, Vol. 12 (2020), No. 20, Art. 8554, 17 pp., Zeitschriftenaufsatz

Kübler M.; Wagner S.; Jurzinsky T.; Paul S.; Weidler N.; Gomez Villa E.D.; Cremers C.; Kramm U.I.
Impact of Surface Functionalization on the Intrinsic Properties of the Resulting Fe-N-C Catalysts for Fuel Cell Applications
In: Energy technology, Vol. 8 (2020), No. 9, Art. 2000433, 13 pp., Zeitschriftenaufsatz

Dongmo S.; Stock D.; Jakob J.; Kreissl A.; Groß M.; Weixler S.; Hagen M.; Miyazaki K.; Abe T.; Schröder, D.
Implications of Testing a Zinc-Oxygen Battery with Zinc Foil Anode Revealed by Operando Gas Analysis
In: ACS omega, Vol.5 (2020), No.1, pp. 626 - 633, Zeitschriftenaufsatz

Baust T. M.
Improving the Design and Evaluation of PDV-Based Cylinder Test Experiments for JWL-Parameter Determination
In: Propellants, explosives, pyrotechnics, Vol.45 (2020), No. 9, pp. 1344 - 1356, Zeitschriftenaufsatz

Roznyatovskaya N.; Fühl M.; Roznyatovsky Vitaly A.; Noack J.; Fischer P.; Pinkwart K.; Tübke J.
The Influence of Free Acid in Vanadium RedoxFlow Battery Electrolyte on "Power Drop" Effect and Thermally Induced Degradation
In: Energy technology, Vol. 8 (2020), No. 10, Art. 2000445, 9 pp., Zeitschriftenaufsatz

Chairopoulou M. A.; Kratzer F.; Gross R.; Herrmann M.; Teipel U.
Influence of the Temperature on Coccolith-Containing Systems from Emiliania huxleyi Cultivations
In: Chemical Engineering and Technology, Vol. 43 (2020), No. 5, pp. 904 - 912, Zeitschriftenaufsatz

Griesbaum P.; Höhne C.C.; Wallat L.; Henning F.; Huber T.; Yu W.
Investigation of SMC Flame Retardants for Application in Battery electric Vehicles
In: Society for the Advancement of Material and Process Engineering -SAMPE-: SAMPE Europe Conference and Exhibition 2020: The Future Composite Footprint, Online, Amsterdam, 30. September - 1. October 2020. Red Hook, NY: Curran, 2020, pp. 258 - 265, Konferenzbeitrag

Dresel A. Teipel U.
Jet Dispersion of Multi-wall Carbon Nanotubes and Correlation with Suspension Rheology
In: Chemical Engineering and Technology, Vol. 43 (2020), No. 5, pp. 869 - 878, Zeitschriftenaufsatz

Mühlecker A.
Konsolidierungsmaßnahmen zur Verbesserung der mechanischen Eigenschaften in Lagengrenzbereichen der 3D Skelett Wickeltechnik
Karlsruhe, Inst. für Technologie (KIT), Master Thesis

Zeller T.
Konzeptionierung und Analyse eines langfaserverstärkten Getriebedeckels für ein Elektrofahrzeug
Karlsruhe, Inst. für Technologie (KIT), Master Thesis

Jongbloed B.; Villegas I. F.; Salles A.; Lätsch C.; Reichert T.; Gess A.; Pfeuffer S.
Manufacturing Innovation. Continuous ultrasonic welding of thermoplastic composites LCI Modelling for the Eco-Statement
Poster presented at Clean Sky 2, AIRFRAME ITD Workshop, 28. - 29.04.2020, Drassault, Online

Werner H.; Poppe C.; Henning F.; Kärger L.
Material modeling in forming simulation of three-dimensional fiber-metal-laminates – A parametric study
In: Procedia manufacturing, Vol.47 (2020), pp.154-161, Zeitschriftenaufsatz

Asenbauer J.; Hoefling A.; Indris S.; Tübke, J.; Passerini S.; Bresser D.
Mechanistic Insights into the Lithiation and Delithiation of Iron-Doped Zinc Oxide: The Nucleation Site Model
In: ACS applied materials & interfaces, Vol.12 (2020), No.7, pp.8206-8218, Zeitschriftenaufsatz

Tseha M.T.; Alloin F.; Iojoiu C.; Tufa R.A.; Aili D.; Fischer P.; Velizarov S.G.
Membranes for zinc-air batteries: Recent progress, challenges and perspectives
In: Journal of power sources, Vol.475 (2020), Art. 228689, 23 pp., Zeitschriftenaufsatz

Georgi T.; Troge J.; Kranz B. Diemert J.
Messtechnische Charakterisierung und dynamische Simulation von Kunststoffbauteilen
In: Deutsche Gesellschaft für Akustik -DEGA-, Berlin: DAGA 2020 - 46. Jahrestagung für Akustik: 46. Deutsche Jahrestagung für Akustik (mit Sonderteil zu "50 Jahre DAGA"), 16. - 19. März 2020, Hannover. Berlin: DEGA, 2020, pp. 1031 - 1034, Konferenzbeitrag

Piscopo C. G.; Granadeiro C. M.C.E.; Balula S.S.; Bošković D.
Metal-Organic Framework-Based Catalysts for Oxidative Desulfurization
In: ChemCatChem, Vol.12 (2020), No.19, pp.4721-4731 Zeitschriftenaufsatz

Seiler E.; Urban H.; Teipel U.
Mikrowellenpyrolyse von carbonfaserhaltigen Kunststoffen als Recyclingoption
In: Chemie Ingenieur-Technik, Vol. 92 (2020), No. 4, pp. 469 - 475, Zeitschriftenaufsatz

Schöttl L.; Dörr D.; Pinter P.; Weidenmann K. A.; Elsner P.; Kärger, L.
A novel approach for segmenting and mapping of local fiber orientation of continuous fiber-reinforced composite laminates based on volumetric images
In: NDT & E International, Vol. 110 (2020), Art. 102194, Zeitschriftenaufsatz

Li S.; Li K.; Xiao E.; Xiong R.; Zhang J.; Fischer P.
A novel model predictive control scheme based observer for working conditions and reconditioning monitoring of Zinc-Nickel single flow batteries
In: Journal of power sources, Vol. 445 (2020), Art. 227282, Zeitschriftenaufsatz

Mendl A.; Köhler M.; Bošković D.; Löbbecke S.
Novel SERS-based process analysis for label-free segmented flow screenings
In: LAB on a chip, Vol. 20 (2020), No. 13, pp. 2364 - 2371, Zeitschriftenaufsatz

Dörr D.; Gergely R.; Ivanov S.; Kärger L.; Henning F.; Hrymak A.
On the applicability of thermoforming characterization and simulation approaches to glass mat thermoplastic composites
In: Procedia manufacturing, Vol. 47 (2020), pp. 118 - 125, Zeitschriftenaufsatz

Berkers W. M.; Fischer P. (Betreuer); Feiters M. (Betreuer)
Optimization of electrolyte composition for the all-iron hybrid flow battery
Nijmegen, Univ., Master Thesis, 2020

Höhne C.C.
Organische Sulfide und Disulfide von s-Triazin und s-Heptazin und deren Potential als Flammschutzmittel
Freiberg, TU Bergakademie, Diss., 2020

Gerber T.; Tübke J.; Langen, C.; Wetzel T.
Ortsaufgelöste Untersuchungen an Redox-Flow-Batterien
Stuttgart: Fraunhofer Verlag, 2020 (Wissenschaftliche Schriftenreihe des Fraunhofer ICT 88)
Zugl.: Karlsruhe, Inst. für Technologie (KIT), Diss., 2019
ISBN 978-3-8396-1576-8

Meyer N.; Saburow O.; Hohberg M.; Hrymak A.; Henning F.; Kärger L.
Parameter Identification of Fiber Orientation Models Based on Direct Fiber Simulation with Smoothed Particle Hydrodynamics
In: Journal of composites science, Vol. 4 (2020), No. 2, Art. 77, 20 pp., Zeitschriftenaufsatz

Kunkel R.; Baumann N.; Jurzinsky T.; Cremers C.
PEM-Fuel Cell Catalyst Behavior between Room Temperature and Freezing Point
In: Fuel Cells, Vol.20 (2020), No. 3, pp. 236 - 244, Zeitschriftenaufsatz

Eyerer P.; Schüle H.
Polymer Engineering 1: Einführung, Synthese, Eigenschaften, 2. Auflage
Berlin: Springer, 2020
ISBN 978-3-662-59836-8 Buch

Schüle H.; Eyerer P.
Polymer Engineering 2: Verarbeitung, Oberflächentechnologie, Gestaltung, 2. Auflage
Berlin: Springer, 2020,
ISBN 978-3-662-59840-5, Sammelband

Eyerer P.; Schüle H.; Elsner P.
Polymer Engineering 3: Werkstoff- und Bauteilprüfung, Recycling, Entwicklung, 2. Auflage
Berlin: Springer, 2020,
ISBN 978-3-662-59838-2 , Sammelband

Morais M. V.C.; Marcellan M.; Sohn N.; Hübner C.; Henning F.
Process Chain Optimization for SWCNT/Epoxy Nanocomposite Parts with Improved Electrical Properties
In: Journal of composites science, Vol. 4 (2020), No. 3, Art. 114, 11 pp., Zeitschriftenaufsatz

Schwarz A.; Liebig W.; Weidenmann K.; Elsner P.
Processing relationships of hybrid polymer-metal composites in the injection moulding process
In: Deutsche Gesellschaft für Materialkunde -DGM-: 4th International Conference "Hybrid Materials and Structures" 2020. Proceedings. Online resource: 28 - 29 April 2020, Germany, Web Conference. Frankfurt: DGM, 2020, pp. 296 - 301, Konferenzbeitrag

Ruiu A.; Bauer-Siebenlist B.; Senila M.; Jänisch T.; Foix D.; Seaudeau-Pirouley K.; Lacroix-Desmazes P.
Promising polymer-assisted extraction of palladium from supported catalysts in supercritical carbon dioxide
In: Journal of CO_2 Utilization, Vol. 41 (2020), Art. 101232, Zeitschriftenaufsatz

Schmid H.
Quo vadis, Nanosilber-Technologie?:
Beitrag zum White Paper der Nanoinitiative Bayern Cluster Nanotechnologie Netzwerk "Nanosilber" 11/2020, Vortrag

Buczko A.; Holzer A.; Kemmerling S.
Reactive Extrusion of TPU. Production of Thermoplastic Polyuerthanes with Reduced Carbon Footprint
In: Kunststoffe international, (2020), No. 8, pp. 43 - 45, Zeitschriftenaufsatz

Buczko A.; Holzer A.; Kemmerling S.
Reaktive Extrusion von TPU. Herstellung von thermoplastischen Polyurethanen mit reduziertem CO_2-Fußabdruck
In: Kunststoffe, (2020), No. 10, pp. 98 - 101, Zeitschriftenaufsatz

Chairopoulou M. A.; Schreiber A.; Kratzer F.; Wolf S.; Teipel, U.
Recycling von marinen Sekundärrohstoffen
In: Chemie- Ingenieur- Technik, Vol. 92 (2020), No. 4, pp. 405 - 413, Zeitschriftenaufsatz

Brantsch P.
Recycling von PUR-Composite durch Glykolyse
Karlsruhe, Inst. für Technologie (KIT), Master Thesis

Kunkel R.; Schmidt V.; Cremers C.; Müller D.; Schmiedl D.; Tübke J.
Reductive Electrochemical Synthesis of Polyvanillin from Biobased Vanillin
Poster prestend at GDCh Electrochemistry undercover, September 23 - 24, 2020, Online

Teipel U.; Schweppe R.
Rohstoffinnovationen und Rohstoffeffizienz. Editorial
In: Chemie- Ingenieur- Technik, Vol. 92 (2020), No. 4, pp. 311, Editorial

Walter M.; Friess F.; Krus M.; Hassan Z., Seyed M.; Grün G.; Kröber H.; Pretsch T.
Shape Memory Polymer Foam with Programmable Apertures
In: Polymers. Online resource, Vol. 12 (2020), No. 9, Art. 1914, 23 pp., Zeitschriftenaufsatz

Zieger T.; Nagel S.; Lutzmann P; Kaufmann I.; Ritter J.; Ummenhofer T.; Knödel P.; Fischer P.
Simultaneous identification of wind turbine vibrations by using seismic data, elastic modeling and laser Doppler vibrometry
In: Wind energy, Vol. 23 (2020), No. 4, pp.1145 - 1153, Zeitschriftenaufsatz

Piscopo C.G.; Löbbecke S.
Strategies to Enhance Carbon Dioxide Capture in Metal-Organic Frameworks
In: ChemPlusChem, Vol.85, No.3, pp. 538 - 547, Zeitschriftenaufsatz

Noack J.; Wernado M.; Roznyatovskaya N.; Ortner J.; Pinkwart K.
Studies on Fe/Fe Redox Flow Batteries with Recombination Cell
In: Journal of the Electrochemical Society, Vol.167 (2020), No. 16, Art. 160527, 9 pp., Zeitschriftenaufsatz

Weber L.; Weinert M.; Goedderz D.; Fuhr O.; Döring M.
Synthesis of novel bisphosphorylimides based on Staudinger reaction
In: Arkivoc, Vol.2020 (2020), Art. 20-11150ZP, 16 pp., Zeitschriftenaufsatz

Gatti F.; Amann T.; Kailer, A.; Baltes N.; Rühe J.; Gumbsch P.
Towards programmable friction: Control of lubrication with ionic liquid mixtures by automated electrical regulation
In: Scientific Reports, Vol. 10, Art. 17634, 10 pp., Zeitschriftenaufsatz

Kuchenreuther-Hummel V.; Elsner P.; Teipel U.; Heilmaier M.
Untersuchungen zum Oxidationsverhalten von TiC- und ZrC-Partikeln
Stuttgart: Fraunhofer Verlag, 2020, (Wissenschaftliche Schriftenreihe des Fraunhofer ICT 90)
Zugl.: Karlsruhe, Inst. für Technologie (KIT), Diss., 2020, ISBN 978-3-8396-1611-6

Choi N.H.; Olmo D. del; Milian D.; Kissi N. el; Fischer P. Pinkwart K.; Tübke J.
Use of carbon additives towards rechargeable zinc slurry air flow batteries
In: Energies, Vol. 13 (2020), No. 17, Art. 4482, 12 pp., Zeitschriftenaufsatz

Rohlfing J.; Diemert J.; Lüssenheide S.; Abdul Hamid Z.M.; Hohe J.; Kranz B.; Georgi T.
Vibroacoustic characterisation methods for polymer materials and components
In: Desmet, W.: ISMA 2020, International Conference on Noise and Vibration Engineering. Proceedings: In conjunction with the 8th International Conference on Uncertainty in Structural Dynamics (USD2020), 7 to 9 September 2020, CD-ROM, virtually. Leuven: KU Leuven, 2020, pp. 379 - 393, Konferenzbeitrag

Fehn T; Teipel U.
Werkstoffliche Aufbereitung von Wärmedämmverbundsystemen
In: Chemie- Ingenieur- Technik, Vol. 92 (2020), No. 4, pp. 431 - 440, Zeitschriftenaufsatz

Roznyatovskaya N., Fühl M., Roznyatovsky V. A., Noack J., Fischer P., Pinkwart K., Tübke J.,
The Influence of Free Acid in VRFB Electrolyte on "Power Drop" Effect and Thermally-Induced Degradation
Energy Technology 2020, 2000445
https://doi.org/10.1002/ente.202000445

Noack J., Skyllas-Kazacos M., Roznyatovskaya N., Menictas C.
Understanding Vanadium Redox Flow Batteries
PV-Tech Power 2020, 23

Parrisius M.
TheoPrax Projektarbeit an Schulen zur Förderung von Kompetenzen und Motivation
Springer VS, 2020, ISBN 978-3-658-25529-9, ISBN 978-3-658-25530-5 (eBook), S. 371

Lang J.; Bohn M.
Abbauwege von Ammoniumdinitramid (ADN) und seinem HNO3-Cluster durch DFT-Berechnungen aufgeklärt
In: Propellants, Explosives, Pyrotechnics, Band 46, Heft 2 Februar 2021, S. 233 - 244, Erstveröffentlichung: 14. September 2020 https://doi.org/10.1002/prep.202000165

Hanich R.; EKroke E.; Pico D.
LCA comparison of chemical recycling technologies for flexible polyurethane foam materials
Foam Expo Stuttgart, 10 - 12. Nov. 2020, Abstract for Presentation

Hanich R.; Springsklee L.; Kroke E.; Flick K.
"Functionalisation of aromatic amines coming from chemical PUR Recycling processes
Modest 2020, Abstract for Presentation, Berlin

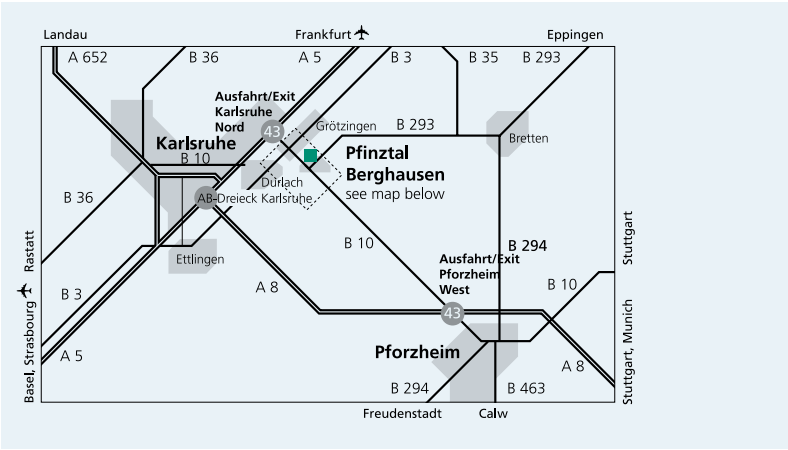
Hanich R.; Majgaonkar P.; Pico D.; Lieske A.
Upcycling of post-consumer PLA waste: A first step to connect circular and bio economy
13th EFIB conference, 5-9th October 2020

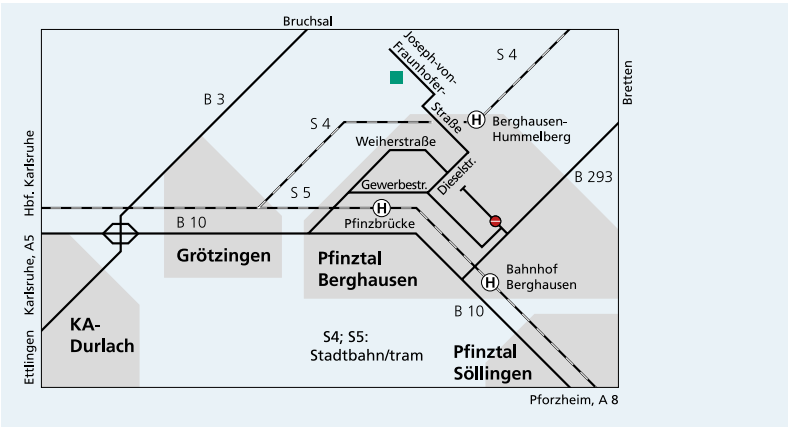
How to reach Fraunhofer ICT

By car

From the direction of Frankfurt/Main or Basel (CH):
Freeway A5, exit Karlsruhe-Nord [43], B10 direction Pforzheim, approx. 300 m after the tunnel turn left and follow the signs to Fraunhofer ICT; follow the road Joseph-von-Fraunhofer-Straße approx. 1.5 km uphill.

From the direction of Stuttgart/Munich:
Freeway A8, exit Pforzheim-West [43], B10 direction Karlsruhe, drive through Pfinztal-Berghausen and turn right after the gas station at the end of the town and follow the signs to Fraunhofer ICT; follow the road Joseph-von-Fraunhofer-Straße approx. 1.5 km uphill.





By rail

To Karlsruhe main station; from there take the S4 tram which runs every 20 or 40 minutes in the direction of Bretten/Eppingen/Heilbronn to the stop Berghausen-Hummelberg; journey time about 25 minutes, followed by a 10-minute walk up the hill (gradient 11 percent). Please do not take an "Eilzug" (express tram) and please note that the tram only stops at "Berghausen-Hummelberg" on demand, which means you have to push the button near the door in advance of the stop.

By plane

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

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft is the world's leading applied research organization. With its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry, Fraunhofer plays a central role in the innovation process. Based in Germany, Fraunhofer is an innovator and catalyst for groundbreaking developments and a model of scientific excellence. By generating inspirational ideas and spearheading sustainable scientific and technological solutions, Fraunhofer provides science and industry with a vital base and helps shape society now and in the future.

At the Fraunhofer-Gesellschaft, interdisci-plinary research teams work together with partners from industry and government in order to transform novel ideas into innovative technologies, to coordinate and realize key research projects with a systematic relevance, and to strengthen the German and the European economy with a commitment to creating value that is based on human values. International collaboration with outstanding research partners and companies from around the world brings Fraunhofer into direct contact with the key regions that drive scientific progress and economic development.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 75 institutes and research institutions. The majority of our 29,000 staff are qualified scientists and engineers who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros are generated through contract research. Around two thirds of Fraunhofer's contract research revenue is derived from contracts with industry and publicly funded research projects.

The remaining third comes from the German federal and state governments in the form of base funding. This enables the institutes to work on solutions to problems that are likely to become crucial for industry and society within the not-too-distant future.

Applied research also has a knockon effect that is felt way beyond the direct benefits experienced by the customer: Our institutes boost industry's performance and efficiency, promote the acceptance of new technologies within society and help train the future generation of scientists and engineers that the economy so urgently requires.

Our highly motivated staff, working at the cutting edge of research, are the key factor in our success as a scientific organization. Fraunhofer offers researchers the opportunity for independent, creative and, at the same time, targeted work. We therefore provide our employees with the chance to develop the professional and personal skills that will enable them to take up positions of responsibility at Fraunhofer, at universities, in industry and within society. Students who work on projects at Fraunhofer Institutes have excellent career prospects in industry by virtue of the practical training they enjoy and the early experience they acquire of dealing with contract partners.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

Last updated: January 2021

Editorial notes

Editors
Dr.-Ing. Stefan Tröster
Simone Köppel
Alexandra Linder

Picture editor
Mona Rothweiler

Production and layout
Simone Köppel

Translation
Carolyn Fisher

Editorial deadline
05/2021

Contact
Fraunhofer Institute for Chemical Technology ICT
Joseph-von-Fraunhofer-Strasse 7
76327 Pfinztal, Germany

Phone +49 721 4640-0
Fax +49 721 4640-111
info@ict.fraunhofer.de
www.ict.fraunhofer.de

Photo acknowledgements

Cover photo:	iStock
Back cover photo:	iStock
Pages 2/3:	iStock
Page 4:	Fraunhofer ICT
Pages 6/7:	Fraunhofer ICT
Pages 8/9:	Fraunhofer ICT
Page 10:	Fraunhofer ICT
Pages 14/15:	iStock
Page 16:	Fraunhofer ICT
Pages 18/19:	Fraunhofer ICT
Pages 20/21:	iStock, Fraunhofer ICT
Page 22:	Fraunhofer ICT
Pages 24/25:	iStock, Fraunhofer ICT
Page 26:	Fraunhofer ICT
Page 28:	Fraunhofer ICT
Page 30:	Fraunhofer ICT
Pages 32/33:	Fraunhofer ICT/NAS
Page 34:	Fraunhofer ICT/NAS
Pages 36/37:	iStock
Pages 38/39:	iStock
Pages 40/41:	iStock
Pages 42/43:	Fraunhofer ICT
Page 44:	Source: LBF, Fraunhofer ICT/NAS
Page 45:	iStock
Pages 46/47:	Fraunhofer ICT
Pages 48/49:	iStock
Pages 58/59:	Fraunhofer ICT

Contact

Fraunhofer Institute
for Chemical Technology ICT
Joseph-von-Fraunhofer-Strasse 7
76327 Pfinztal
Phone +49 721 4640-0
Fax +49 721 4640-111

info@ict.fraunhofer.de
www.ict.fraunhofer.de