Fraunhofer ICT

Fraunhofer Institute for Chemical Technology ICT

Annual Report 2021/2022

Contents

A final goodbye

PETER ELSNER

On 19th March 2022, our long-time institute director, Prof. Peter Elsner, passed away after a serious illness.

Our institute has borne his signature for almost three decades. Peter cared deeply about the success of Fraunhofer ICT and especially the wellbeing of its employees.

His straightforward and honest approach, and his strong sense of justice, created a working culture that we will benefit from for years to come. The leadership team and every employee at Fraunhofer ICT could always rely on him and trust in his decisions. Peter will be missed, both as a person and as a wise and far-sighted institute director.

Preface

Transition to a new directorship
Following in Peter Elsner's footsteps is no easy task. However, he himself initiated a smooth and timely transition.

He will be succeeded by his longstanding colleague, Prof. Frank Henning, who was instrumental in shaping and expanding the Polymer Engineering Department that Peter Elsner established in 1994.

Frank Henning already worked alongside Peter Elsner as Deputy Director of Fraunhofer ICT, from 2009 onward. This has enabled a high degree of continuity in his transition to full directorship. Like Peter Elsner, Frank Henning has a connection to the Karlsruhe Institute of Technology KIT, as Chair of Lightweight Construction Technology at the Institute for Vehicle Systems Technology FAST.

Prof. Dr.-Ing. Frank Henning, Institute Director of Fraunhofer ICT

Dear customers, partners and colleagues, we are all deeply saddened by the loss of Peter Elsner. He has left a huge gap, both personally and professionally, and I will especially miss him as a close confidant and good friend.

I am very grateful for everything I learned by working alongside Peter Elsner for the past 25 years, and also for the creative freedom he allowed me. More than ten years ago, I was appointed as his deputy in the management of Fraunhofer ICT, and I have worked with him closely ever since. During the difficult period of his illness, which coincided with a challenging economic environment due to the COVID pandemic, our joint aim was to ensure the future viability of Fraunhofer ICT. It was always a matter of great concern to both of us that we remain a reliable and innovative partner for our public funding agencies and our industrial customers. We believe we have succeeded in this regard, especially thanks to the support of an excellent and dedicated team of employees.

I will do my best to build on Peter Elsner's great achievements, and to continue to lead the institute as he would have wished.

With best regards,

Frank Henning
Institute Director of Fraunhofer ICT

Institute profile

Our main campus, with over 100 laboratories, multiple pilot plants and 3 test centers, is located in Pfinztal, near Karlsruhe. The New Drive Systems Department, with its various engine and exhaust test stands, is based on the East Campus of the Karlsruhe Institute of Technology (KIT).

540
people are currently employed at Fraunhofer ICT.

Fraunhofer Institute for Chemical Technology ICT

The use of wind energy, and also photovoltaics in the near future, 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 in Pfinztal, near Karlsruhe. Our research strategy 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, up to pre-series application.

536 people are currently employed at Fraunhofer ICT. Our main campus is located on the Hummelberg hill in Pfinztal near Karlsruhe. The **New Drive Systems Department**, with its various engine and exhaust test stands, is located on the East Campus of the Karlsruhe Institute of Technology (KIT).

Our customers and project partners include chemical and chemical process engineering companies, automotive manufacturers and their suppliers, the aviation industry, the construction industry, the plastics processing industry, material manufacturers, recycling companies, companies in the energy and environmental sectors, and customers with safety-related issues. 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

Our core competence "Chemical Processes" comprises the ability to develop, design and implement innovative chemical processes from the laboratory through to the technical scale. It covers the entire process chain, from raw material processing, chemical synthesis, reaction control and downstream processing (especially separation processes) through to subsequent process steps such as product refinement (e.g. particle technology, shaping, formulation). Particular areas of expertise include process control, process diagnostics and process safety.

Since our partial restructuring in 1994, we have successfully conducted application-oriented research in the core competence "Polymer Engineering" with a focus on polymer and additive synthesis, material and formulation development, the further development of processing technologies for plastics, component development and service life analysis,

Fraunhofer ICT's Pfinztal site with its wind turbine.

"Our research strategy enables us to combine research and development work with large-scale demonstrators on our campus."

Dr. Stefan Tröster,
PR Spokesman, Fraunhofer ICT

lightweight construction using composites, the recycling of plastics, and the development of sustainability concepts for plastics solutions.

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 and Drive Systems" we work on electrical energy storage for mobile and stationary systems, as well as fuel cells and electrolysis, heat and material energy storage and the functional safety of the systems. In addition, we validate storage devices for mobile and stationary energy, and thermal storage devices. Within this area of expertise, 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. In the area of drive systems, we are developing solutions for both electric and internal combustion engine systems. Fraunhofer ICT designs, constructs and simulates drive systems, and validates them through testing. In the field of internal combustion engines we are investigating synthetic fuels and additives in our research engines.

In the competence area "Explosives Technology", Fraunhofer ICT covers the entire chain of expertise, starting with the synthesis and characterization of explosives, and their refinement and further processing, through to formulation, production, testing, detection, modeling and simulation. We have many years of expertise in gun propellants, rocket propellants, explosives, gas generators, pyrotechnic formulations and energetic systems. In the field of safety and security research, we focus on the detection of explosives, from the development of sensor technology to the testing of aviation security equipment and the development of materials for protection concepts.

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

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Altenkirchen (Westerwald)

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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. Dirk Tielbürger
Federal Ministry of Defense, Bonn

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

During the pandemic, Fraunhofer ICT continued to be a major training provider, with 22 trainees.

Financial situation

In the fiscal year 2021, we again achieved a positive operating result, as we have for the past 20 years. This gives us a buffer for upcoming investments and modernizations, despite the difficult economic environment. Following a weak year in 2020, our industrial revenue continued to decline from € 8.5 million to € 8.2 million. There are a number of reasons for this. Some projects were postponed due to COVID-19, and others were withdrawn as our customers struggled with the effects of the pandemic. We also noticed that our industrial partners were increasingly turning to public funding, i.e. tackling research questions in collaborative projects, in order to conserve their own development budgets. From our point of view, this is a very effective means of technology transfer. However, it has a negative effect on our industrial revenue share.

The decrease in direct industrial collaborations, and the increase in revenue generated in public projects, led to an industrial revenue share of 31.7%. This is still above the strategically important 30% mark, but is dangerously close to it. In terms of non-personnel resources, in 2021 we saved around € 1 million compared to the previous year, as was the case in 2020. Our total budget in 2021 was € 41.2 million, and we finished the year with a "black zero", i.e. a balanced budget.

Personnel statistics

Through careful economic management, we were able to retain our permanent staff and thus all our know-how. There has been very little change in our personnel statistics compared with the previous year: 170 scientists make up just under a third of our staff. They are strongly supported by 98 technical staff members and 100 assistants in the laboratories and workshops, as a prerequisite for applied research.

61 employees work in our administration. Compared to other Fraunhofer institutes, we thus have a comparatively low overhead.

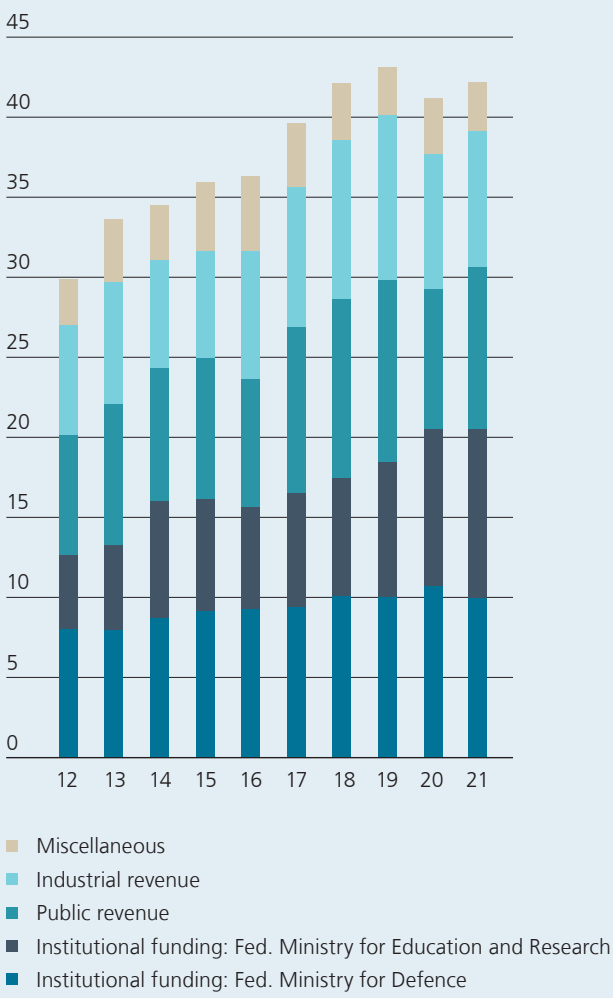
Even during the pandemic we continued to be a major training provider, with 20 apprentices training to become chemical laboratory technicians, industrial mechanics in plastics technology and material testers. We see this as both a social responsibility and an opportunity to gain a head start in times when there is a shortage of skilled workers.

Outlook

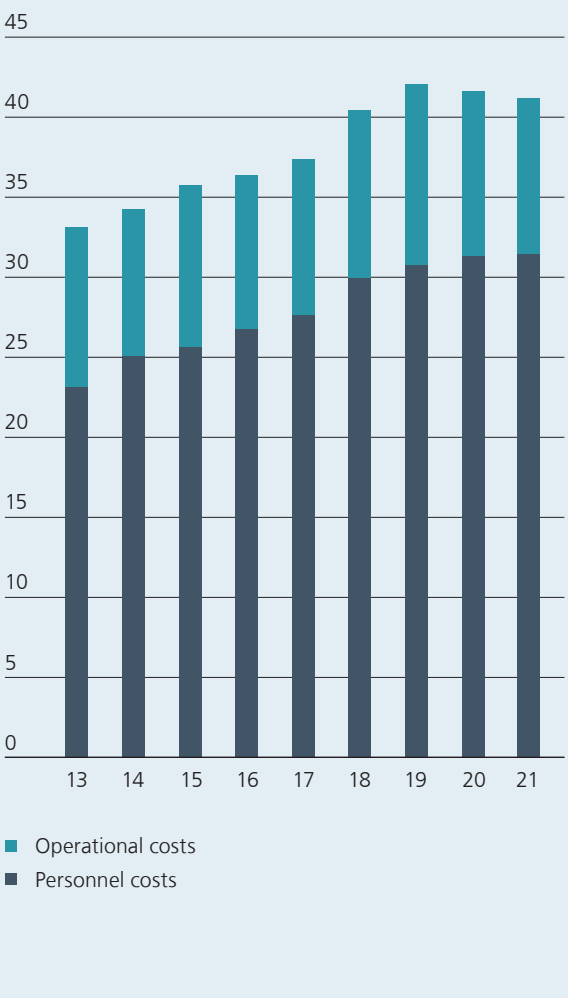
Since our basic funding is calculated according to our industrial revenue share, we started 2022 with less favorable conditions than in previous years. Due to the conversion of Fraunhofer's accounting system to SAP, and the fact that projects have not yet been fully migrated to the new system, our economic forecasts are currently very imprecise. We expect to cover our expenses in 2022 with the income from our projects, i.e. we will once again be in the black. However, we also expect a continued decline in our industrial revenues, due to the significant increase in energy prices and the current signs of recession (as of July 2022), which are leading to increased caution among our industrial customers.

Financial development of Fraunhofer ICT, 2012 to 2021

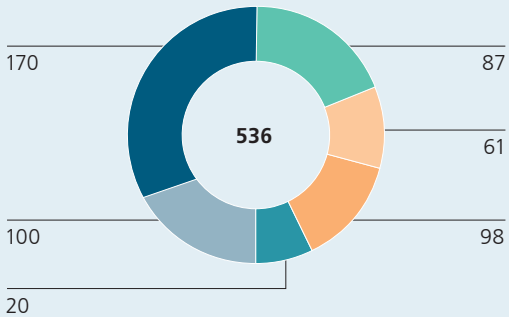
Revenue

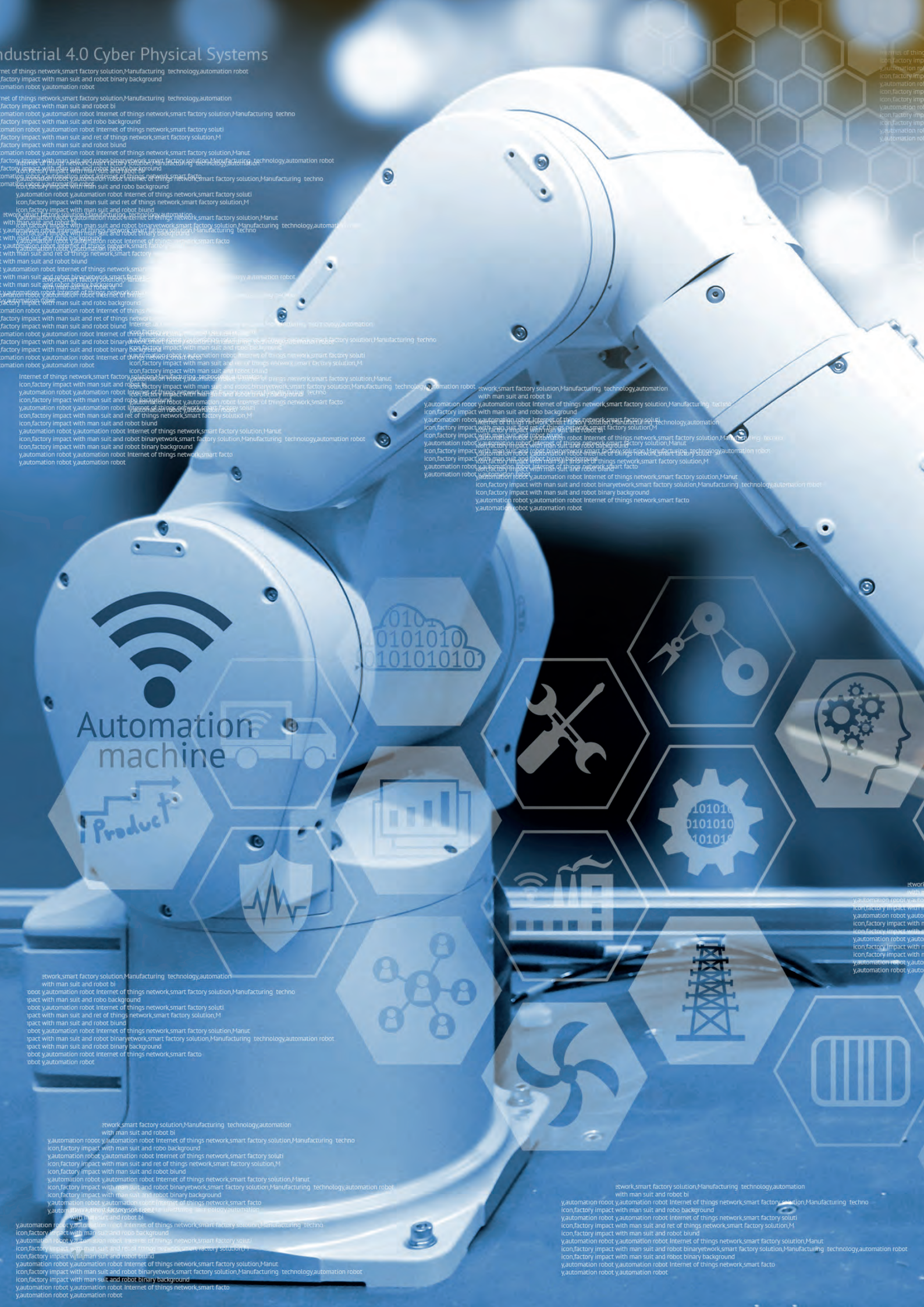


Expenses



Workforce structure of Fraunhofer ICT: Status on December 31st, 2021




Industrial 4.0 Cyber Physical Systems
Automation machine
Product

Core competences

Chemical processes

Our expertise in chemical processes comprises the ability to design and implement innovative, resource-saving chemical and technical processes from the laboratory through to the technical scale.

We cover the entire process chain from raw material processing, chemical reaction control, purification and separation technologies through to subsequent manufacturing processes.

Sustainable, defossilized and circular production processes are the focus of our research and development work.

Chemical processes for a sustainable future

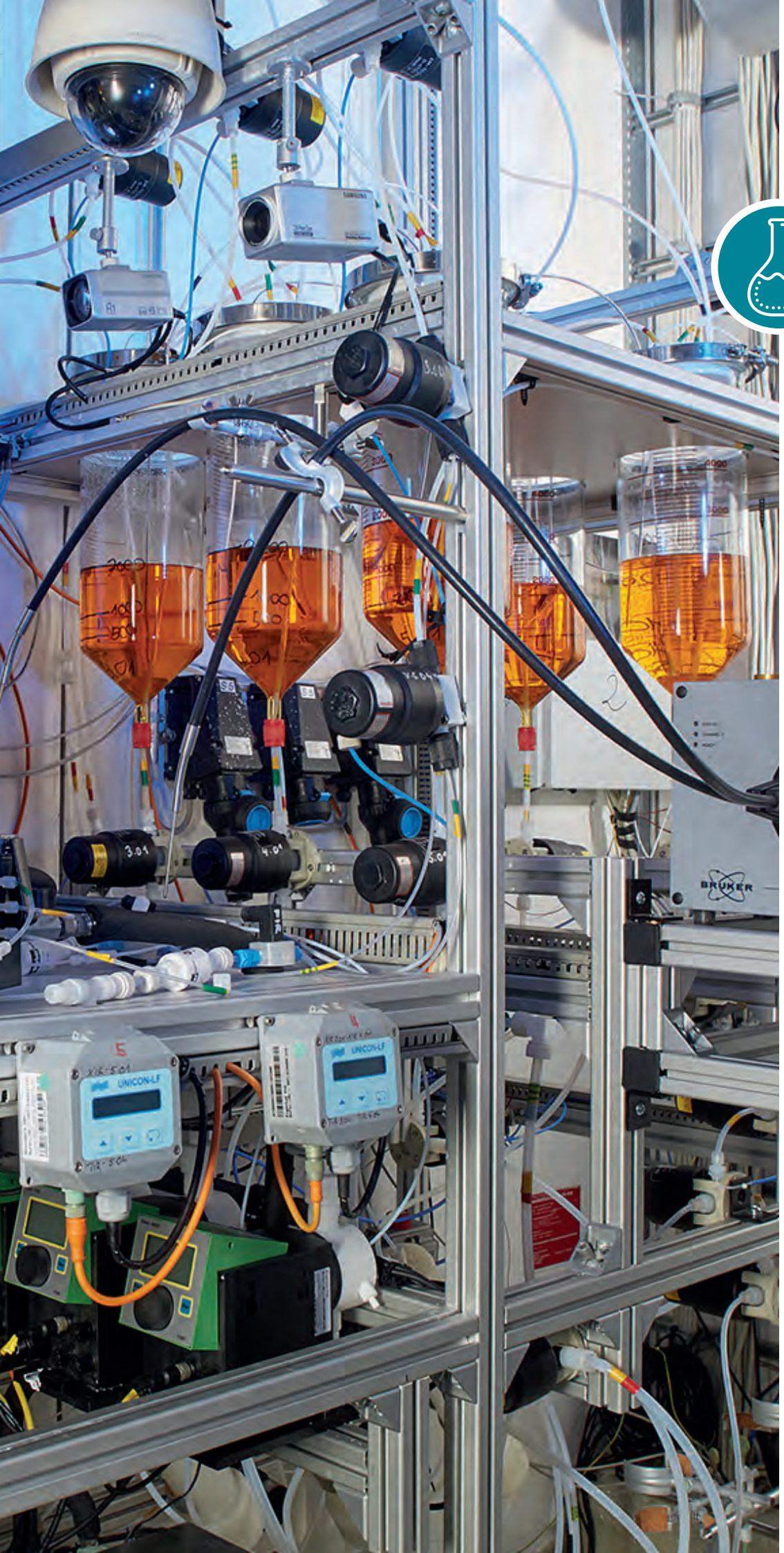
Chemical processes are essential for a wide range of industrial value chains, and ensure new product developments and innovations. However, in the light of global challenges in the field of climate protection, energy and resource efficiency, chemical processes must increasingly become independent of fossil raw materials and fuels, and be integrated into concepts for circular economies and greenhouse-gas-neutral material and energy conversion.

Besides increasing product quality, safety and cost-effectiveness, our central goals in the development, design and optimization of chemical processes therefore also include the sustainability of the products and their manufacturing processes. At Fraunhofer ICT, we meet these requirements by developing modern synthesis and process technologies that follow the principles of green chemistry, including energy-efficient and resource-saving process management, minimized waste streams, the recycling of material flows and the use of renewable raw material sources from the outset.

In our development work, we often bring about a paradigm shift from discontinuous to continuous processing techniques. For example, continuous processing involving micro-structured equipment plays a key role in process design and intensification. It allows safe process control in new processing windows, e.g. at higher temperatures, pressures and concentrations, as well as shorter reaction times. These process parameters are difficult or impossible to achieve in classical processes, and can consequently only be optimized technically and economically within continuous processes. We also systematically transfer continuous process control to other process steps and new fields of application. These include in particular the intensification of downstream processing for extractive purification under different pressure regimes, for 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.

We are making significant progress in the development and adaptation of fast spectroscopic and calorimetric process analyses, 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 significantly shortened, but also allows the increasing application of these data in the digitalization of chemical reaction processes.

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



Fiber-optic-based spatially resolved process spectroscopy in micro-reactor processes.

Areas of expertise in chemical processes

Non-fossil chemistry

For many years we have been using non-fossil raw materials, for example renewable raw materials and CO_2, in our internally-developed processes. In this way, we support industrial customers in adapting these new raw material sources in production. Our processes include the feed materials lignocellulose (wood), fats and oils, carbohydrates and other biomass materials which do not compete with food production.

There is an increasing demand for processes to recover originally fossil-based products, such as polymers and end-of-life plastics, in a high degree of purity that allows them to be returned to their original application. For these extractive processes, both the solvent selection and the process chain are the key to an economical and sustainable implementation.

Electrochemistry

In the field of electrochemistry we work on the selective synthesis of chemicals, the design of corresponding electrochemical cells and the related catalyst materials. In the context of downstream processing, we develop methods for isolating electrochemically generated platform chemicals. One example is the highly integrated electrochemical conversion of lignins to drop-in chemicals and intermediates for material applications. Continuous reactor concepts can be realized in separate electrode compartments producing both oxidized and reduced synthesis building blocks.

Chemistry with hazard potential

Our comprehensive know-how in the field of explosive technology means that we have advanced expertise in the safety-related design and operation of hazardous (explosive or toxic) processes. We are developing processes that enable the safe production and conversion of highly reactive synthetic building blocks, which can be used with high atom efficiency to produce downstream products. In the development of high-pressure processes we also benefit from our long-standing experience in the processing of supercritical fluids.

Continuous and microprocess engineering

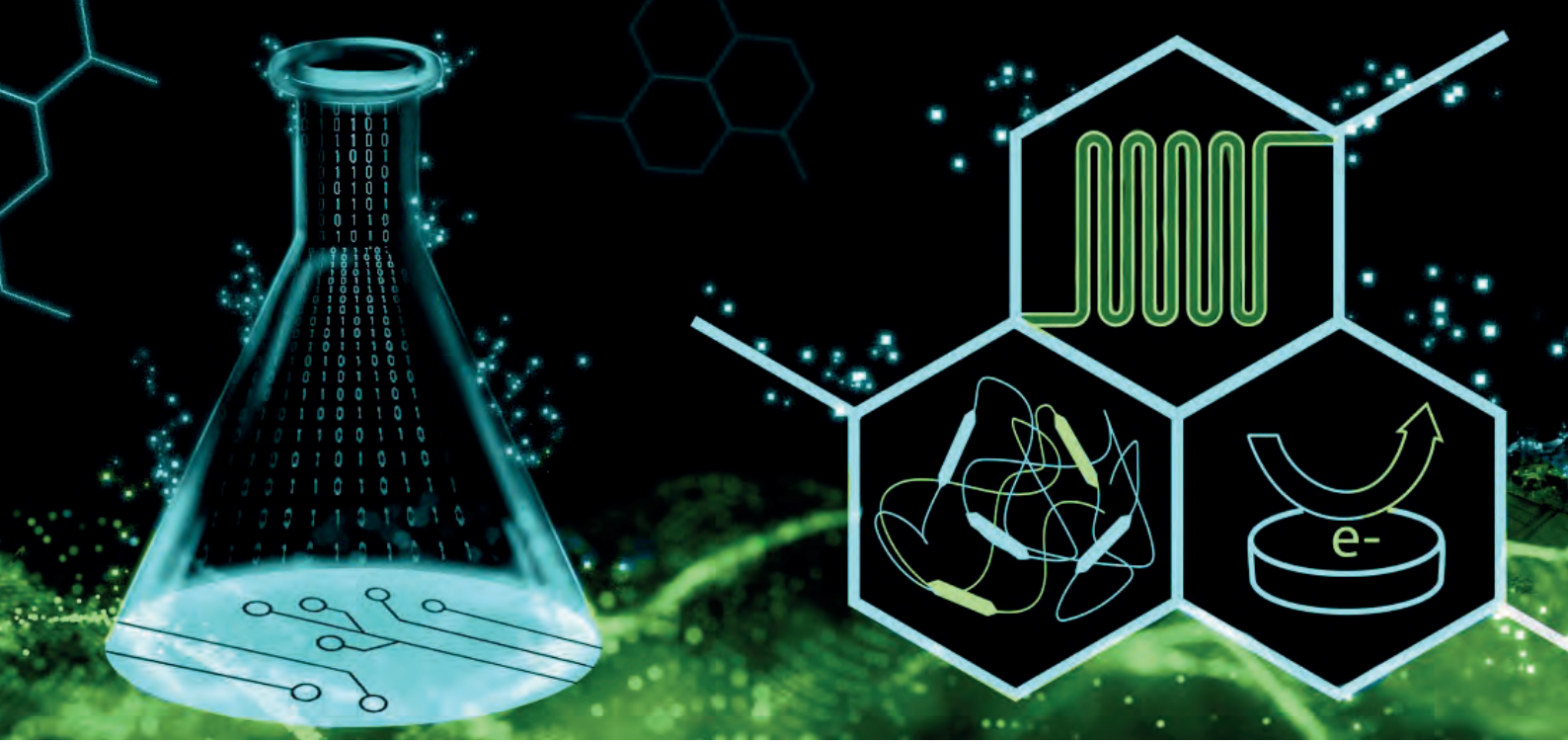
Another focus of our work is continuous process control in microreactors. We develop microprocessing equipment and processes in which residence time, mass and heat transport can be controlled very precisely, allowing target parameters such as selectivity and yield to be significantly improved.

On-line process analytics

Using cutting-edge spectroscopic and calorimetric process analysis techniques, some of which were developed in-house, kinetic, mechanistic and safety data are measured and applied in process design, including model-based design. Online analytics also plays an important role in process monitoring, as it provides timely information on whether changes in process control or maintenance work are required, for example due to a change in the composition of the product flow.

Process and operational safety of chemical plants

Many of the institute's own developments provide technical access to new processing windows. Our spatially and temporally resolved process diagnostics enable reliable process control. Through the use of extensive characterization methods combined with continuous process monitoring, high operational and process reliability can be achieved. Alongside experimental studies, we identify elemental product compositions, determine structures and carry out emission, aging and stability analyses on metastable compounds to enable their safe handling.



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 the parallel screening of synthetic approaches (including under high pressure)
- Numerous reaction calorimeters (batch and continuous)
- Cutting-edge process spectrometers for single or multi-dimensional inline, online or at-line process monitoring (UV/vis, NIR, IR, Raman)
- Continuous and discontinuous high-pressure plants for hydrothermolysis, oxidation, hydrogenation, and reactions in subcritical and supercritical water
- High-pressure extraction units for extraction in supercritical carbon dioxide
- Pilot 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 ultra-filtration
- 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
- Computer-aided design of processes (up to multi-ton scale)

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Rollers for measuring the haul-off speed.

Polymer engineering

In the field of polymer engineering, we conduct application-oriented research focusing on the development of materials, processes and components for plastic products. Material recycling, and sustainability concepts for complete value chains, are currently important drivers in this market.

To achieve these aims we research new processes in polymer and additive synthesis, develop application-oriented sustainable materials and formulations for specific products, and optimize processing technologies adapted to these materials. Areas of application include the automotive and construction industries.

Sustainable and intelligent solutions for plastics applications

Our research in polymer engineering focuses on the manufacturing and recycling of plastic components, from synthesis and processing through to component manufacture. Our research is accompanied by an evaluation of the raw material base and raw material efficiency, simulation of environmental impacts in the use phase, and product recycling including life cycle analysis (LCA).

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 application range. Our developments aim for sustainability, for example plastics based on bio-based raw materials or the full recycling of used plastics. The same applies to additive synthesis with halogen-free flame retardants, sustainable plasticizer systems or compatibilizers for new plastic compounds. Our polymer developments, for example, aim to combine thermoplastic and thermoset functionalities for application in highly resilient bonds.

The research group for **material development and compounding technologies** specializes in the development of 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.

Key tasks in the field of foam technologies are the development and use of particle foam technology and the manufacture of foamed semi-finished products in the direct foam process. 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.

The research group for **injection and compression molding** focuses on standard and specialized processes for (fiber composite) materials. The integration of local, load-path-compatible wound or tape-laid fiber composite structures into injection molded components significantly improves the mechanical properties.

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, and their handling, combination with polymer foams and metallic structures and subsequent resin infusion or shaping, are important steps within the processing chains.

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 the 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 research group 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, the material failure and the influences that led to it, using analytical and technological measurement methods.

In the field of online process monitoring we develop spectral and microwave-based measurement methods for plant-integrated process and material monitoring, and for process control. Our projects in the context of Industry 4.0 are based on the process integration of sensors. This also includes process-specific know-how in raw data evaluation. The application and integration of big data and AI algorithms enable learning or immature processes to be investigated.

In the area of **recycling and waste management** we develop processes and technologies for the material recycling of polymers, aiming for their complete reintroduction into high-quality applications. In the case of thermoset polymer systems this involves chemical, solvolytic cleavage into components that can be very specifically repolymerized to form this type of material. 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 (LCA) quantified the sustainability of these systems according to various impact categories. Further recycling applications can be found in the area of PET and PLA recycling at Fraunhofer ICT. Both classes of polyester can be depolymerized to their monomers via chemical and catalytic processes, purified and then recycled back to the original polymers. These processes were also evaluated in terms of their sustainability via a life-cycle analysis. Recent work relates to process development for the recycling of silicone materials.

In the synthesis of sustainable polymers, bio-based systems have always played an important role at Fraunhofer ICT, for example thermosetting, lignin-based epoxies for surface finishes or odor barrier layers to prevent evaporation.

Karlsruhe Research Factory for AI-Integrated Production

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.

At this site we conduct practice-oriented research on real manufacturing processes so that producers and machine and plant manufacturers can bring new products to the market in the shortest possible time. To achieve this we fully exploit the potential of comprehensive digitalization, and reliably implement artificial intelligence and machine learning methods into operational practice

Areas of expertise in polymer engineering

Polymer synthesis

Our work in polymer and additive synthesis includes the production of classic polymers such as polyurethanes, polyesters, their additives and auxiliary substances such as plasticizers, viscosity improvers, compatibilizers and halogen-free flame-retardant additives. Sustainability considerations play an important role. Thus, the use of sugar-based polyhydroxy compounds, but also polyphenolic tannins or lignins for the synthesis of polymeric precursors augments polymer syntheses in the field of biopolymers. Continuous polymerization and polymer modification by reactive extrusion, using the example of thermoplastic urethanes (TPUs), are very well established topics at our institute.

Material and formulation development

Our focus in material and formulation development is on formulations based on classic thermoplastics and bio-based natural-fiber-reinforced polyesters for application in higher-strength components. We also emphasize emission-optimized and chemically purified recyclates and their monomers, as a very broad range of applications can be covered by reformulation. Our newly developed functional compounds have found an interesting field of application in 3D printing. We also develop formulations for thermoset systems suitable for injection molding or the SMC process.

Processing technologies

We draw intensively on our many years of experience in process development on twin-screw extruders in the design of new processes for reactive extrusion, and in the removal of impurities by extractive extrusion. We have continuous process chains both in particle foam technology and in the manufacturing of foamed semi-finished products in the direct foam process. Our research emphasizes the new development and optimization of conventional, bio-based, recycled and foamed engineering thermoplastics and their processing methods. Examples include the development of particle foams using autoclave processes, and the processing of particle foams using radio frequency technology.

We have built up extensive process know-how in the injection molding of thermoplastic and thermoset molding compounds, e.g. for inline technologies to incorporate fillers and fibers into flowable thermoplastic and thermoset molding compounds, and for the development of processes for thermoplastic monomaterial sandwich systems. Our microwave and plasma technology is used to develop energy-efficient and flexible process technologies.

Component development and service life analyses

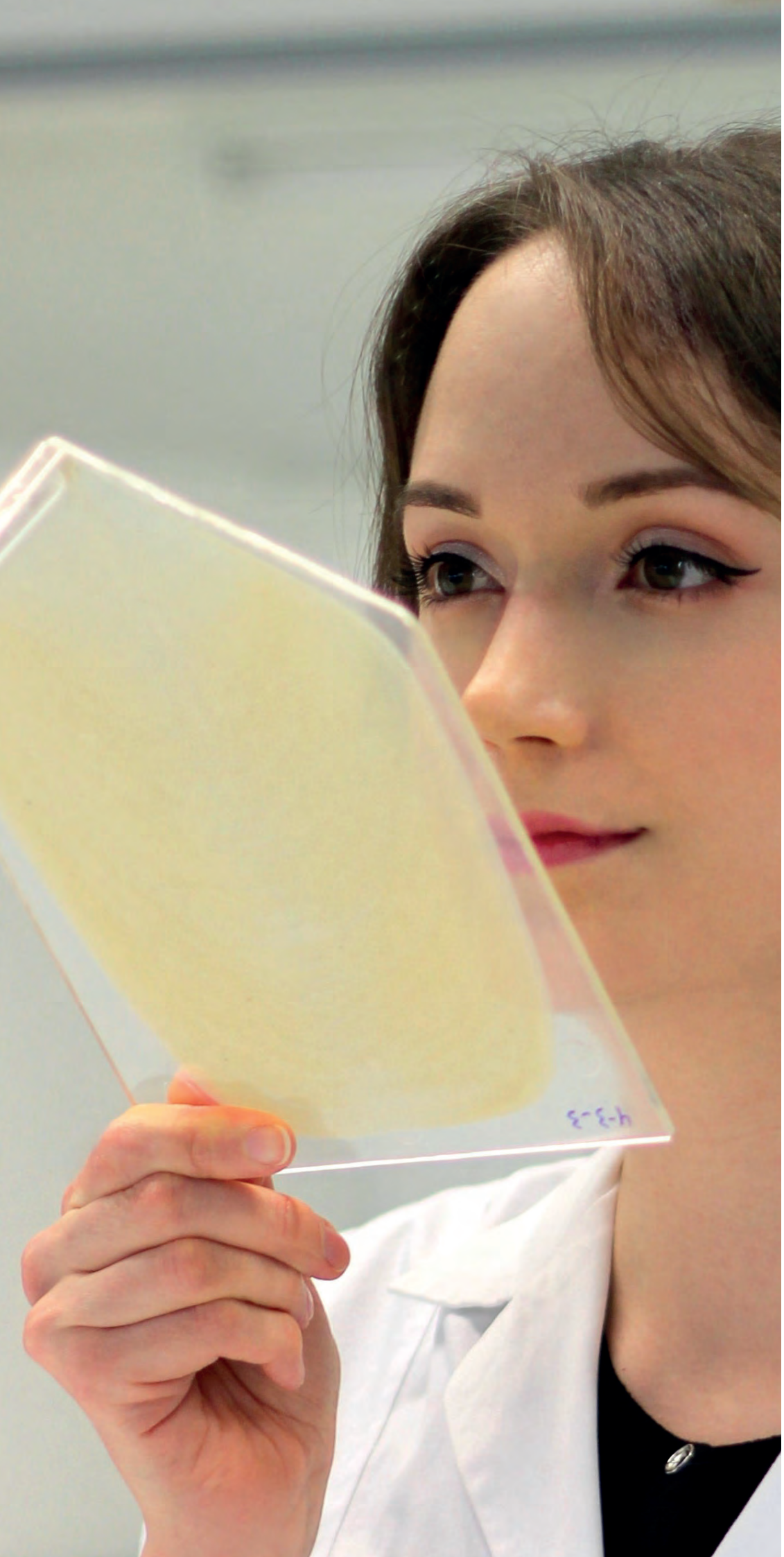
We are continually expanding our expertise in component design and component and process simulation, and increasingly applying this knowledge in our projects. We also have significant expertise in the simulation and evaluation of environmental influences on materials, components and assemblies on the market or under development. Complex products, shorter innovation cycles and extended product liability issues require adapted and expanded testing procedures. The focus of our work in this area is on component testing during development, under climatic conditions and also on exposure to dust and vibration, in order to investigate mechanisms of aging, corrosion, material fatigue and reliability during the component's service life.

Lightweight construction and composites

Our expertise in the field of lightweight construction and composites lies in material development and material modification, as well as in the further development and industrialization of processes such as RTM, extrusion, pultrusion, tape and winding technologies. We use these processes to manufacture structurally highly stressed components, or components with multiple integrated functions.

Recycling and sustainability concepts

In the area of recycling and sustainability concepts we develop processes and technologies for material recycling. One key topic is concepts for mechanical and chemical recycling. To achieve this it is important to consider the recyclability of materials during component development to allow recycling after the service life of the component.



Sandwich test specimen with recycled core (brown) and a skin material without odor-reducing additives during sensory evaluation.

PREDATOR

The high-pressure resin transfer molding (RTM) process is used to produce high-quality applications, for example in the automotive industry. Due to their good material properties and low weight, the components have strong lightweight potential and are suitable for structural parts in automotive engineering, e.g. roof, doors and trunk lids.

The HP-RTM process has cycle times suitable for the series production of composite components, but still poses a challenge in terms of robustness and reliability.

This leads to relatively high reject rates, and makes the process unprofitable for many applications.

A major reason for this is the manual process data acquisition. A transmission of process data along the individual process steps, and the use of this data for a quality assessment (QA), is not possible with conventional technology. The PREDATOR research project is now providing a solution. The project will develop a reliable HP-RTM process for large-scale industrial production using intelligent data processing systems.

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
- Injection molding units with clamping forces between 350 and 7,000 kN
- Special injection molding processes in injection compression molding, multi-component injection molding, thermoplastic foam molding, expansion foaming, thermoset injection molding
- Automated thermoplastic tape-laying process for non-wovens with a diameter of 2 m
- Plant for radiation-induced vacuum consolidation for thermoplastic non-wovens
- Automated winding technology to produce complex loop structures
- 3D printing technologies for processing functionalized polymers
- 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
- Polymer synthesis autoclaves on a 5-kilogram scale
- RIM/RTM technologies for processing 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
- Extensive, cutting-edge equipment in the field of materials testing and analysis

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Energy and drive systems

A sustainable, safe 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 Fraunhofer-Gesellschaft, our institute is defined by holistic, systemic approaches to combine energy and drive systems. Our main areas of expertise are energy converters such as combustion engines and fuel cells, chemical and thermal energy storage systems such as batteries and heat storage systems, and electric powertrain components and their application in various powertrain topologies in the energy sector. This expertise enables us to research and develop solutions for sustainable energy storage and conversion for various application areas - including portable, mobile and stationary systems and complete drive systems - from the concept through to validation on material, component and system level.

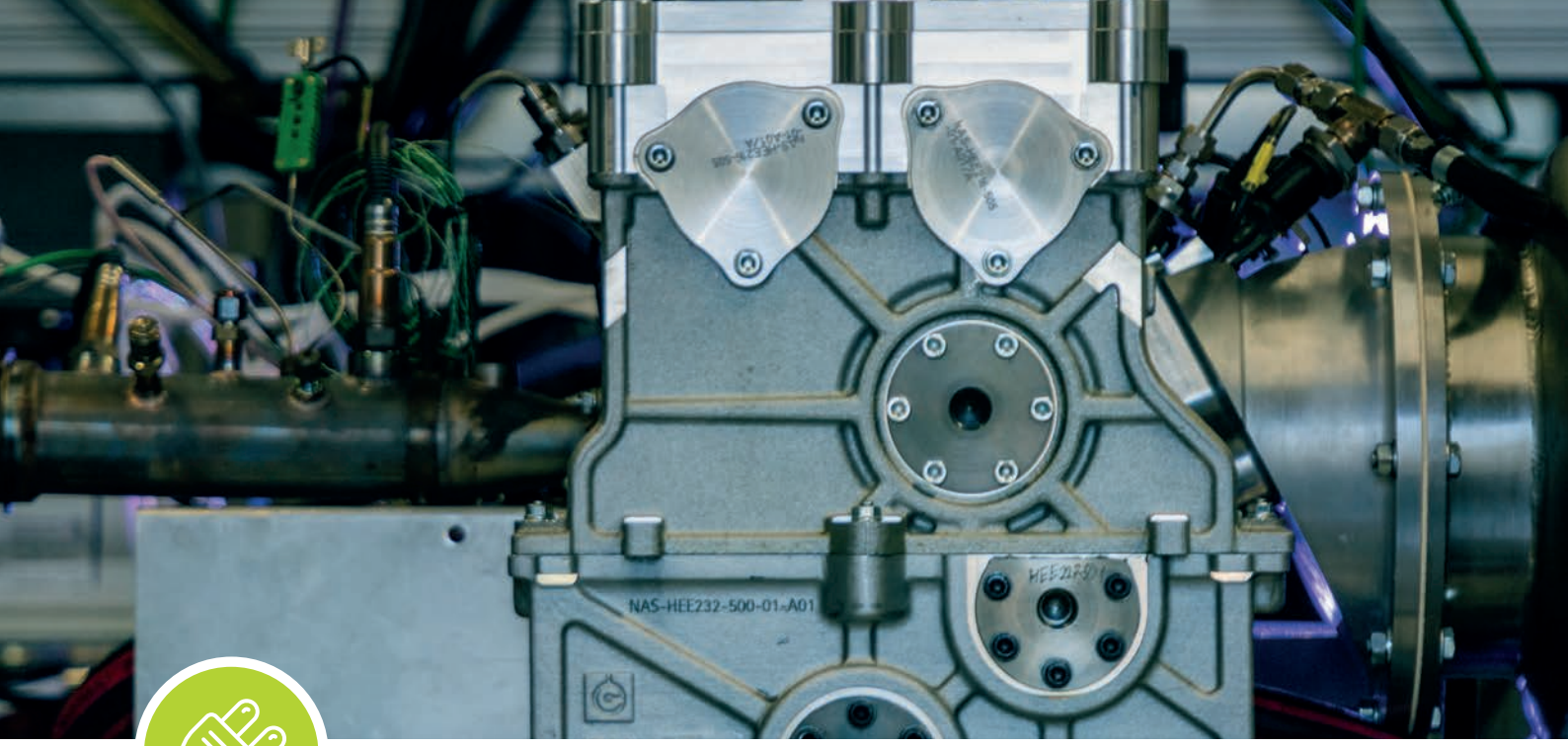
Application-oriented research on energy storage and conversion, and on drive systems

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. We also carry out safety and abuse tests 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 the field of redox-flow batteries we investigate 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 research 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, materials for oxygen evolution/(OER) catalysts for PEM electrolysis and 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, we develop methods to investigate degradation processes, in particular carbon and ionomer corrosion, using online mass spectrometry. 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 control systems.

We continue to research hydrogen as a fuel to power fuel cells in mobile and stationary applications. The main topic here is hydrogen safety in the respective system. We investigate various operating states up to the worst-case scenario. For this purpose we calculate possible leakages and errors, and conduct trials on our test site - which is designed for up to three kilograms of TNT equivalent - to validate the conversion of hydrogen. In addition, we examine issues relating to the safety distance in the refueling area and the pressure protection of fuel tanks. For energy supply in residential quarters with regeneratively produced hydrogen, we design the overall layout of the system including fuel cells for reconversion, the use of waste heat from the fuel cells, and demand-oriented distribution via local heating networks.

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.



Universal single-cyclinder crankcase that forms the basis of various development engines and can be adapted to specific projects.

In the field of electric drive train concepts, we research and develop electric engines and transmission 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 centers 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. In the area of combustion engine concepts, we aim to develop technical solutions in the entire drive train for mobile applications. We research and develop combustion engines both as the sole drive unit and in combination with an electric engine, as a hybrid drive system.

We provide design and simulation support for all developments relating to drive systems, and validate them through experimental trials on our test stands.

In this competence area, 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."

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Areas of expertise in energy and drive systems

Drive systems for mobility

In the area of electric engines we develop high-voltage drive systems for hybrid as well as purely electric mobility. We focus on technologies with a high gravimetric specific power density and high efficiency. Our research and development activities in the area of internal combustion engine drive systems address technical solutions for increasing efficiency in the entire drive train of mobile and stationary applications, and thus also the reduction of pollutant and greenhouse gas emissions across sectors. We research and develop combustion engines both as the sole drive unit and in combination with an electric engine, within a hybrid drive system.

Batteries

To store electrical energy, we are researching new storage options and also investigating and further developing commercially available batteries. Our focus is on lithium-ion batteries, redox-flow batteries and on so-called "next-generation" systems, such as solid-state batteries, sodium batteries, and metal/air and metal/sulfur systems. We emphasize material development and the material characterization of electrodes, electrolytes, separators and their thermal and electrical characterization in battery cells and battery modules up to complete battery systems. Furthermore, cells and battery modules are simulated and modeled thermally and electrically, and cells and modules are optimized in terms of their electrical, thermal and mechanical properties for different applications and requirement profiles.

Fuel cells and electrolysis systems

In the area of electrical energy storage, hydrogen production by electrolysis is an important topic. We work on material development to reduce the use of critical raw materials. The most important approach here is to improve electrode structures by developing suitable support materials for catalytically active components, for example for oxygen evolution. Our material development in the field of fuel cells addresses not only the reduction of critical raw materials but also the possibility of converting liquid fuels into electricity. Our technological focus is on high-temperature polymer electrolyte membrane fuel cells (HT-PEMFCs) and anion exchange membrane fuel cells (AEMFCs). Our aim in the area of HT-PEMFCs is to enhance the electrode structure through improved catalyst support materials and the incorporation of ionomeric binders, which reduce the phosphoric acid content and thus the resulting performance losses and aging processes. In the field of AEMFC and the corresponding anion exchange membrane electrolysis, we develop cells based on platinum-free or low-platinum catalysts.

Thermal storage devices

In addition to energy storage and conversion, development work to improve energy efficiency plays an important role. We emphasize the development and production of thermal storage systems based on phase change materials (PCMs) and zeolites. Our expertise covers physico-chemical sorption storage systems based on zeolites, and their basic physico-chemical characterization including their model description. We also characterize adsorption and desorption phenomena using thermoanalytical methods, and design, construct and test sorption storage systems. Further topics include heat storage systems based on phase-change materials as well as the design, construction and testing of latent heat storage systems.

Battery and hydrogen safety

Our main research focus in the area of battery safety is safety, abuse and aging investigations with in-operando gas analysis, post-mortem investigations on cells and battery modules, and the development and validation of safety concepts for battery operation, transport and storage.

We also investigate hydrogen as an energy source. Using high-pressure hydrolysis, we study the production of hydrogen for the material storage of excess electrical energy, characterize the conversion efficiency of membranes, and investigate the stability and aging mechanisms of membranes under specific electrolysis conditions. In the field of hydrogen safety, activities relate mainly to the handling and especially the safe storage and transport of hydrogen, the development and performance of specific tests and the evaluation, concept and design of hydrogen storage systems.

Data logger for autonomous recording of a wide variety of measurement data in cars, trucks or production plants.

Facilities and equipment

The equipment of the institute in the competence area of energy and drive systems includes:

- A swivel test stand for testing electric drive systems for urban air mobility (UAM) applications
- Thermodynamics test benches (VBM, ATL) for combustion engine measurement, analysis and evaluation technology and a 1-cylinder research unit for combustion process and component development
- A hot-gas test bench for complex thermodynamic and mechanical turbocharger development as well as systems for residual heat utilization and exhaust gas aftertreatment
- Application center for redox-flow batteries and stationary energy storage with a 1 MW/10 MWh RFB battery storage system in conjunction with a 2 MW wind turbine
- Electrochemical test stands for testing fuel cell stacks at elevated operating pressure up to 5 bar
- Safety test equipment for batteries
- Special measuring cells for material development for batteries, electrolysers and fuel cells
- Extensive laboratory and workshop infrastructure

With our excellent facilities, we can offer a wide range of application-oriented research services for technology transfer."

Explosives technology, safety and security

We are the only German research institute to cover the entire development chain for propellants and explosives. The continuity and the ongoing relevance of this expertise has shaped our research for the Federal Ministry of Defence since our foundation in 1959. The institute also supports industrial customers and the public sector in investigating national and international security questions.

From molecules to prototypes

We research and develop new energetic materials and systems for the German army, and our expertise serves to maintain 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 ignition and initiation systems. Within the framework of national and European security research we develop 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.

In our development of propellant and explosive systems, we adjust the performance characteristics for individual application profiles and requirements. For this purpose, new energetic materials are synthesized, modified and optimized in our laboratories, suitable process technologies are developed and the energetic products are formulated and manufactured in our pilot plants.

Besides achieving application-specific performance characteristics, our research and development of propellant and explosive systems also emphasizes their insensitivity and stability.

Plant combining spray drying and spray solidification processes.

There is also an increasing demand for technologies and products that conserve resources, that are environmentally friendly and that do not pose a health risk.

Our current research topics include performance-enhanced, environmentally compatible and low-signature solid rocket propellants for defense and civilian (e.g. aerospace) 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 the additive manufacturing of energetic materials to achieve material gradients and complex geometries also form part of our work.

Our many decades of experience cover the entire development chain from the raw product to the system prototype in the development of propellants and high explosives.

Networks and alliances

In the field of explosives technology and security research, we are part of the Fraunhofer Segment for Defense and Security VVS, in which eleven institutes have pooled their expertise to coordinate and implement research activities in the field of defense and security. We are also a member of the Fraunhofer Lead-Market-Oriented Alliance for Aviation and Space

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Areas of expertise in explosives technology, safety and security

Development of propellants and explosives
We deal with all aspects of the development, production and application of propellants and explosives, and can consequently manage the complexity of explosives technology along the entire competence chain. This includes molecular design, chemical synthesis, processing, shaping, and analytical characterization of high-energy materials and derived formulations for rocket propellants, gun propellants and explosives, which we develop and evaluate in the form of prototypes, small batches and demonstrators.

In line with our founding motivation as the "Institute for Propellants and Explosives" in 1959, this expertise is primarily defense-oriented, and serves to maintain the analysis and evaluation capability of the German army. This advisory expertise is secured by basic funding from the Federal Ministry of Defense (BMVg).

Synthesis, processing and manufacturing methods
Modern propellant and explosive formulations are highly filled plastics. Their burning behavior, detonation behavior, sensitivity and mechanical properties are strongly dependent on the particle and crystal properties of the fillers. The optimum design of the fillers (explosives and additives) is therefore the key to achieving subsequent product properties.

For this purpose, we develop and test comminution, crystallization, prilling and coating processes.

New substances must be available on a kg scale in order to test their performance properties in formulations. Our reaction technology therefore forms the bridge from laboratory synthesis to robust, upscalable production techniques, in order to provide sufficient sample material for further steps, including industrial developments. For the various product groups of gun propellants, rocket propellants, gas generators, explosives and pyrotechnics, special processing techniques tailored to the respective explosives are applied and developed. These include processes for mixing and homogenizing, pressing, extruding, injection molding or foaming.

Performance measurement and characterization
The chemical synthesis of new explosives, whose properties are not yet known or are poorly understood, is challenging and requires special methods to measure and characterize performance. Our basic methods include the measurement of friction and impact sensitivity, thermal behavior, stability, compatibility, purity, crystal structure, mechanical behavior and the determination of other chemical and physical parameters. A particular area of expertise is thermodynamic power calculations with our own Fraunhofer ICT code. We have the secure

infrastructure and extensive measurement technology needed to characterize the burning, deflagration and detonation behavior of propellants and explosives. This includes technology developed within the institute.

Modeling and simulation

We accompany experimental investigations with modeling and simulation calculations. These include quantum mechanical and molecular dynamic simulations, the modeling of burnup behavior using kinetic models, and calculation of the expected stability, aging and performance.

Stability and aging behavior

We have extensive experience and experimental methods to determine the kinetic parameters of energetic materials. This allows us to measure thermal and mechanical stability, aging behavior including long-term predictions, and compatibility in formulations. We are proficient in handling all types of energetic materials, including highly sensitive materials such as nitroglycerin or TATP.

Explosives detection

Our knowledge of the production and properties of explosives makes us particularly well qualified to engage intensively in national and European security research. One focus of our work is the remote and trace detection of explosives, including so-called home-made explosives (HMEs) and improvised explosive devices (IEDs). We determine the properties of HMEs and IEDs, and research methods to detect them. Because we can safely assess terrorist explosives and fabricate them for testing purposes, we operate a test center for aviation security detection equipment on behalf of the German Federal Police, and support them with security issues relating to HMEs. In our test center for detection systems, we offer the manufacturers of airport scanners and detection devices the opportunity to carry out tests with real explosives and reference substances, in order to evaluate and optimize their systems. In cooperation with the German Federal Police, the institute also tests and certifies such systems for use in European airports.

Furthermore, we draw on our explosives expertise to solve current challenges in technical safety, for example hydrogen safety, explosion protection, fire protection and the control of thermal runaway reactions in chemical synthesis processes and energy storage systems.

X-ray scanner for the detection of liquid explosives.

Facilities and equipment

Handling explosives requires structural and technical precautions as well as organizational measures for working under maximum safety. All the necessary facilities and technical equipment are available at Fraunhofer ICT, some of which are very complex.

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 100g 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

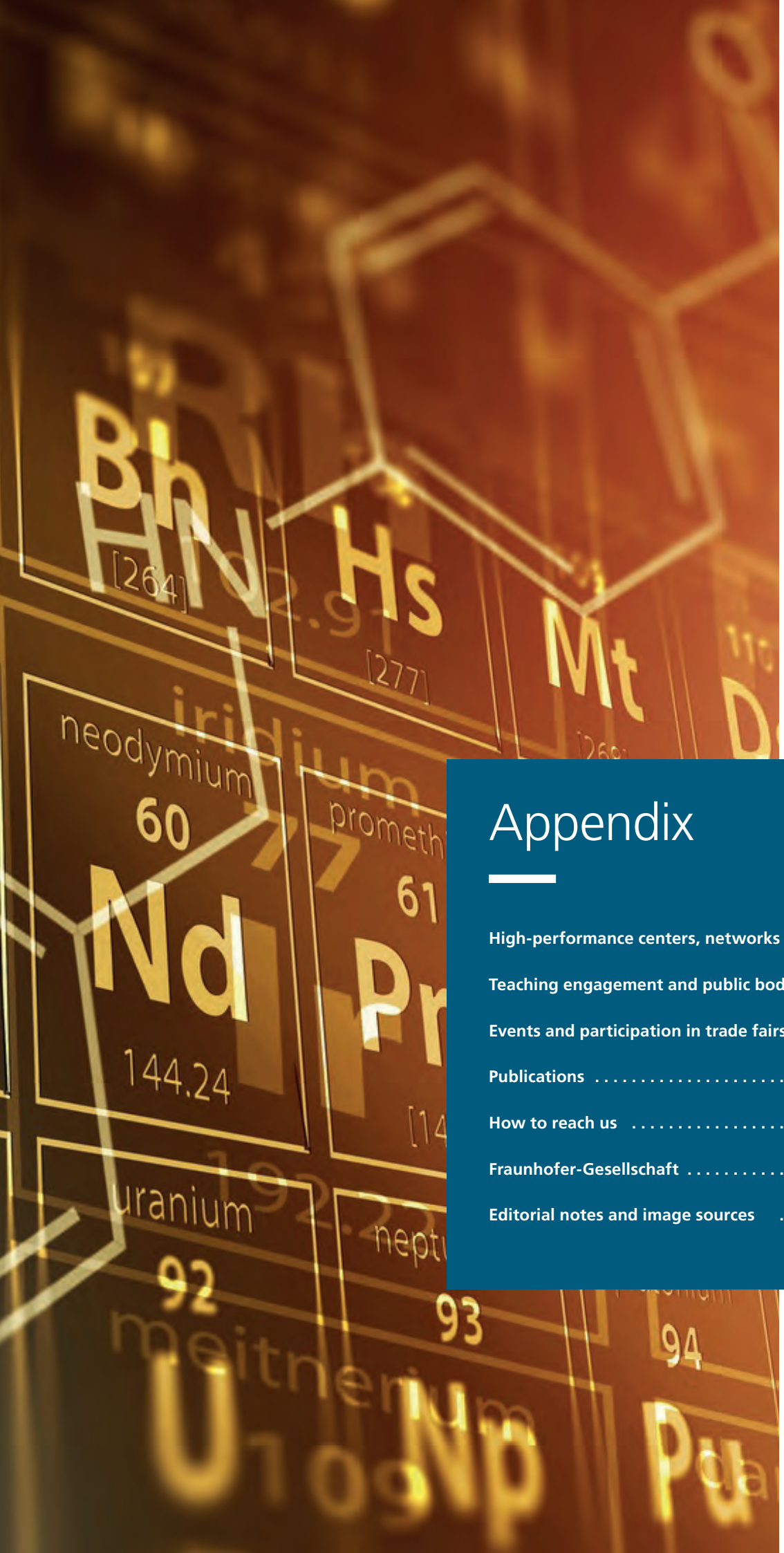
- Thermochemical codes for the thermodynamic evaluation of propellants, RFTS, SS and pyrotechnics. Examples: ICT Thermodynamic Code, EKVI code, Cheetah 2.0., EXPLO5
- ICT thermodynamics database with over 14,000 substances
- Computational fluid dynamic (CFD) codes, such as SPEED, Ansys Fluent, Ansys Autodyn, Ansys Mechanical,...
- ICT-BAM for spectroscopic temperature measurement
- Interior ballistic codes such as SimIB-0D, FNGun-1D, ballistic analysis and evaluation tool BAA, software tool for powder burn-off, software tool for 3D form function
- 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 nano-computed tomograph
- 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

Remote synthesis of energetic materials


[261]
Db
[262]
Sg
[266]
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 their expertise within flexible structures according to demand. This secures their leading position in the development of system solutions and the implementation of comprehensive innovations.

Performance centers are characterized by excellent infrastructure, training concepts and know-how that can be used by multiple organizations."

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.

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Groups

Institutes working in related subject areas cooperate in Fraunhofer groups and foster a joint presence on the R&D market. They help to define the Fraunhofer-Gesellschaft's business policy and implement its functional and funding principle

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

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Materials and components - MATERIALS
- Health
- Energy and environment
- Mobility
- Construction and living
- Machinery and plant engineering
- Microsystems technology
- Safety

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Alliances

Fraunhofer institutes, or departments of institutes, with different areas of expertise 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 expertise, research offers spanning multiple institutes, and competent, flexible project consortia. Fraunhofer ICT is involved in the lead market "energy sector" through the Energy and Battery Alliances.

Fraunhofer Battery Alliance
The Fraunhofer Battery Alliance currently consists of 20 member institutes working together in the field of battery technology. The expertise of Fraunhofer's Battery Alliance covers 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 accompany the material, process and manufacturing development topics. Fraunhofer ICT is a member of the Battery Alliance and is also its Central Office, as Prof. Jens Tübke is the spokesperson for the Alliance.

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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

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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.

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

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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 by a single provider, taking account of both 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

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Teaching activities and public body membership

Teaching activities and public body membership are important tasks of a research institution. In 2021 Fraunhofer ICT staff 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)

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, Mosbach

Mechatronics
Eyerer, Peter
- Polymer engineering (2 units per week, January to April 2022)

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/engineering science (4 units per week, WT)
- Materials for lightweight design (3 units per week, ST)

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

Faculty of Mechanical Engineering, Material Science
Eyerer, Peter
- Polymer engineering (48 teaching units, June to August 2022)

Henning, Frank
- Lightweight design and composite manufacturing (2 units per week, WT)

University of West Bohemia in Pilsen, Czech Republic

Mechanical Engineering Department
Kolarik, Vladislav
- X-ray diffractometry as an in-situ method (guest lecture, one 2-hour unit, WT)

Public body membership

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

Becker, Wolfgang
- Member of the "Nano-Initiative Bavaria" in the "Nanosilver" cluster
- Member of the ICNIRS (International Council for Near Infrared Spectroscopy)

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)
- Member of the German Society for Thermal Analysis (GEFTA)
- Member of the International Steering Committee of the International Pyrotechnics Seminar USA (IPS-USA Seminars)
- Member of the Organizing Committee of KISHEM, Korea (South)
- Member of the Scientific Committee of 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
- Member of the standardization body DKE 131 "Environmental Simulation"
- Member of the standardization body DKE 212 "IP Protection Categories"
- Member of the Society for Environmental Simulation
- Deputy Chair of the Working Group "Effects on Products" of the Clean Air Commission
- German Engineers' Union (VDI), Leader of the Working Group "Personnel in Environmental Simulation" of the Air Quality Control Commission (AQCC)
- Member of the Society for Environmental Simulation (GUS e.V.)
- Leader of the Working Group "Guidelines" of the Society for Environmental Simulation (GUS e.V.)
- Deputy leader of the Working Group on "Particles – Properties and Effects" within the Society for Environmental Simulation (GUS e.V.)
- Member of various working groups of the GUS
- DAkkS Technical Assessor in the field of environmental simulation

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

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
- Evaluator in the VIP+ Funding Program of the Federal Ministry of Education and Research, Berlin; Project Executive Agency VDI/VDE-IT
- Evaluator in the NETC Funding Program of the Federal Ministry of Education and Research, Berlin; Project Executive Agency VDI/VDE-IT
- President of the "Offene Jugendwerkstatt" (youth workshop), Karlsruhe

Fischer, Thomas
- Member of the Working Group "Interior Ballistics" of the Bundseswehr 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 Force "Interior Ballistics Simulation"

– Member of the Working Group "3D Printing of Propellant Powders" of the Bundeswehr Technical Center for Weapons and Ammunition

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– Member of the Water Chemistry Society (professional group of the GDCh)

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)

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– 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 on Cellular Materials

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

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

Kolarik, Vladislav
– Member of the German Society for Corrosion Protection (GfKORR)
– Member of the 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

Lietz, Martin
– Member of the Working Group "Interior Ballistics" of the Bundeswehr Technical Center for Weapons and Ammunition
– Member of the Task Force "Interior Ballistics Simulation"
– Member of the Working Group "3D Printing of Propellant Powders" of the Bundeswehr Technical Center for Weapons and Ammunition

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)

Müller, Torsten
– AVK Working Group on Environmental and Occupational Safety

- AVK Working Group on Composite Recycling
- Cluster ESW/ BZ BW - Working Group on Circular Economy

Noack, Jens
- Member of 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 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)
- Member of Flow Battery Europe
- 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

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- Member of the National Hydrogen Council of the German Federal Government
- Member of the Advisory Board of the Hydrogen Roadmap Baden-Württemberg
- 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)
- 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)

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 "Particles – Properties and Effects" within the Society for Environmental Simulation (GUS)
- Consulting expert of the Federal Ministry for Education and Research and DFG (German Research Foundation)
- Member of the Editorial Board of the journal "Chemical Engineering Technology"
- Guest editor of the journal "Chemical Engineering & Technology", thematic area of particle technology

- Chair of the Working Group "Effects on Products" of the Clean Air Commission (KRdL)
- Liaison lecturer of the DFG at the Technical University Nuremberg
- Appointed Member of the ProcessNet Technical Group "Raw Materials"
- Appointed Member of the Council of Science and Humanities

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- Spokesman of the Fraunhofer Battery Alliance
- R&D Advisory Board of the Bundesverband Energiespeicher (BVES) (German Energy Storage Association)
- Member of the Executive Board of fokus.energie e.V.
- Scientific Advisory Board of MEET – 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)

Ulrich, Christian
- Member of the Trace Explosive Study Group (ECAC)

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

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- 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 "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
- Member of the Task Force "Interior Ballistics Simulation"
- Member of the International Ballistics Society (IBS) and Member of the Education Committee of the IBS Associate Editor of the Propellants, Explosives, Pyrotechnics Journal

Events, trade fairs and exhibitions

In the first quarter of 2022, many trade shows in Germany had to be canceled due to COVID restrictions. Fraunhofer ICT's main trade shows were also postponed to later in the year. This led to a concentration of trade fairs in the summer and fall. Until late summer, neither exhibitor nor visitor numbers at German trade shows reached pre-COVID levels.

A return to in-person events

Fortunately, traditional event formats such as Fraunhofer ICT's Annual Conference could once again take place in-person after a two-year break. Interest was high, although the number of participants was slightly lower than in pre-COVID years.

In terms of content, Fraunhofer ICT's international Annual Conference covers scientific and technological developments in the field of energetic materials and related disciplines.

Fraunhofer ICT's Annual Conference has achieved global prominence over half a century, with hundreds of attendees each year."

51st International Annual Conference of Fraunhofer ICT

Events

March 11, 2021
Next Generation – Flow Battery Conference and Networking Event
Online conference

March 24-25, 2021
49th Annual Conference of the Society for Environmental Simulation GUS "Capture, Simulate, Evaluate Environmental Impacts"
Online conference

June 28 – July 1, 2022
51st International Annual Conference, Fraunhofer ICT
Karlsruhe

Trade fairs and exhibitions

January 13 – 15, 2021
Construction 2021, digital

April 16 - 18, 2021
Energy Storage, digital

April 27 – 29, 2021
Battery Conference 2021, digital

June 1 - 2, 2021
JEC Composites Connect, digital

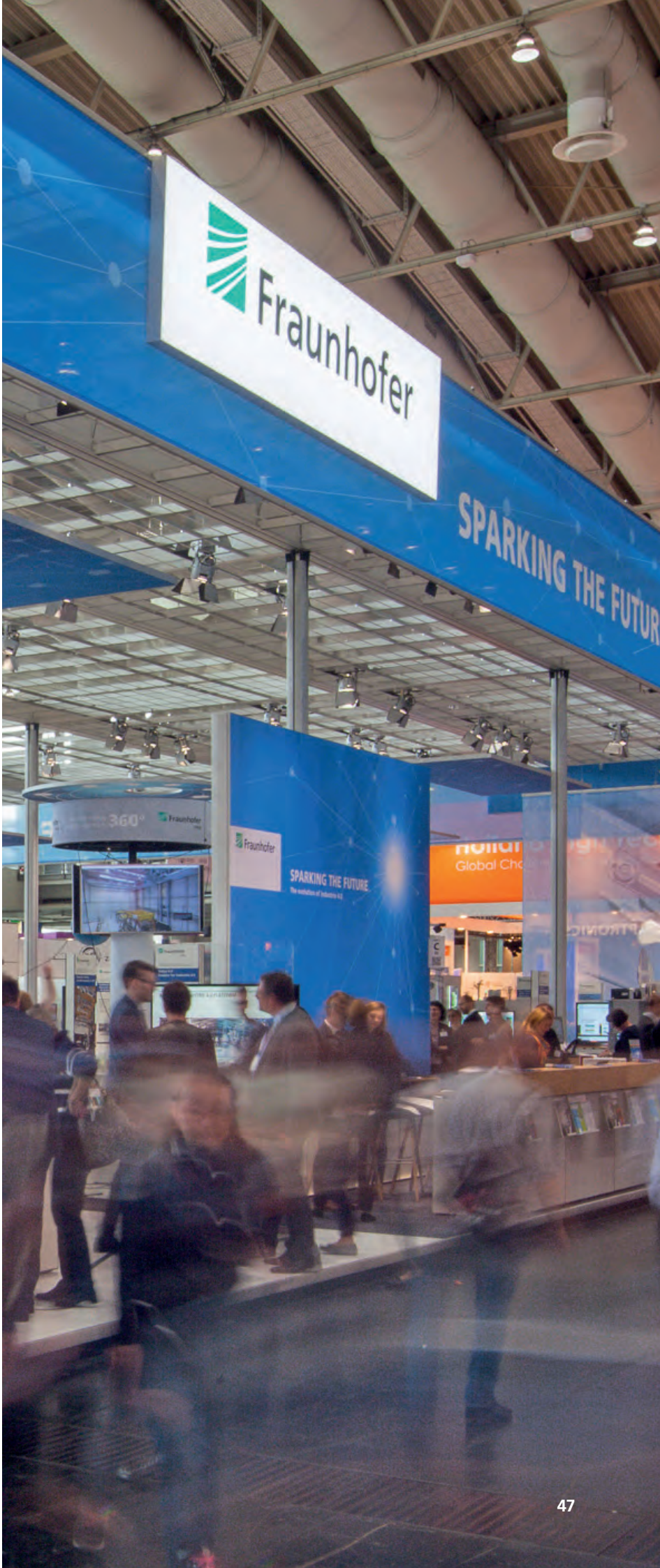
June 15 – 16, 2021
Achema Pulse, digital

October 12 -16, 2021
FAKUMA 2021, Friedrichshafen

November 9 – 11, 2021
Foam Expo Europe, Stuttgart

February 8 -10, 2022
E-World, Essen

March 8 -10, 2022
JEC World, Paris



> **The Fraunhofer-Publica has been successfully documenting the research results of the Fraunhofer-Gesellschaft for over 30 years.”**
>
> **Dr. Stefan Tröster,**
> PR Spokesman, Fraunhofer ICT

Fraunhofer-Publica

In the database “Fraunhofer-Publica” all publications made by Fraunhofer are available for your literature inquiries. Fraunhofer-Publica is a multidisciplinary database for publications of the Fraunhofer-Gesellschaft, its institutes and its employees.

The following documents are included in the Fraunhofer-Publica database

- Books and journal articles
- Articles from books or conferences
- Conference proceedings
- Dissertations
- Research reports
- Patents

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Publications of Fraunhofer ICT

The most frequent publications by Fraunhofer ICT scientists in 2021 were individual articles in journals, followed by contributions to conferences, dissertations, and reports and posters for conferences.

Fraunhofer ICT's publications from 2021

Here you can find the first 100 publications made by Fraunhofer ICT in 2021.

Here you can find all publications made by Fraunhofer ICT in 2021.

Contact

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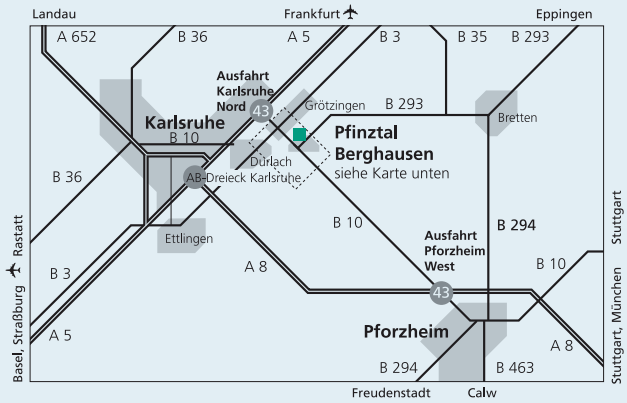
Fraunhofer Institute for
Chemical Technology ICT
Joseph-von-Fraunhofer-Str. 7
76327 Pfinztal

How to reach Fraunhofer ICT

By car

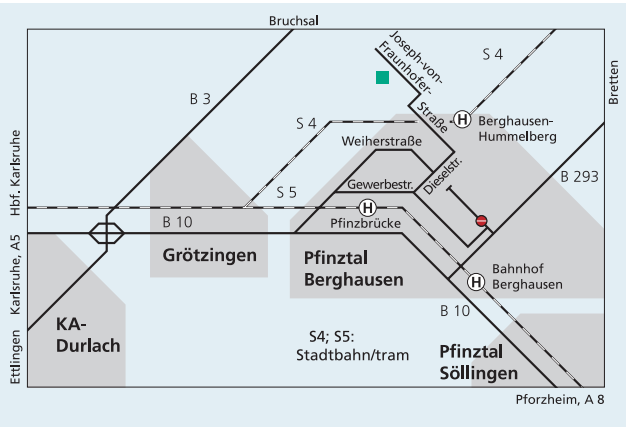
From the direction of Frankfurt/Main or Basel (CH):
Freeway A5, exit Karlsruhe-Nord [43], B10 direction Pforzheim, approx. 300 m after the tunnel turn left and follow the signs to Fraunhofer ICT; follow the road Joseph-von-Fraunhofer-Straße approx. 1.5 km uphill.

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 based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. It is a trailblazer and trendsetter in innovative developments and research excellence. The Fraunhofer-Gesellschaft supports research and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

The Fraunhofer-Gesellschaft's interdisciplinary research teams turn original ideas into innovations together with contracting industry and public sector partners, coordinate and complete essential key research policy projects and strengthen the German and European economy with ethical value creation. International collaborative partnerships with outstanding research partners and businesses all over the world enable for direct dialogue with the most prominent scientific communities and most dominant economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research. Industry contracts and publicly funded research projects account for around two thirds of that. The federal and state governments contribute around another third as base funding, enabling institutes to develop solutions now to problems that will become crucial to industry and society in the near future.

The impact of applied research goes far beyond its direct benefits to clients: Fraunhofer institutes enhance businesses' perfor-mance, improve social acceptance of advanced technology and educate and train the urgently needed next generation of research scientists and engineers.

Highly motivated employees up on cutting-edge research constitute the most important success factor for us as a research organization. Fraunhofer consequently provides opportunities for independent, creative and goal-driven work and thus for professional and personal development, qualifying individuals for challenging positions at our institutes, at higher education institutions, in industry and in society. Practical training and early contacts with clients open outstanding opportunities for students to find jobs and experience growth in business and industry.

The prestigious nonprofit Fraunhofer-Gesellschaft's namesake is Munich scholar Joseph von Fraunhofer (1787–1826). He enjoyed equal success as a researcher, inventor and entrepreneur.

Figures as of: January 2022

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