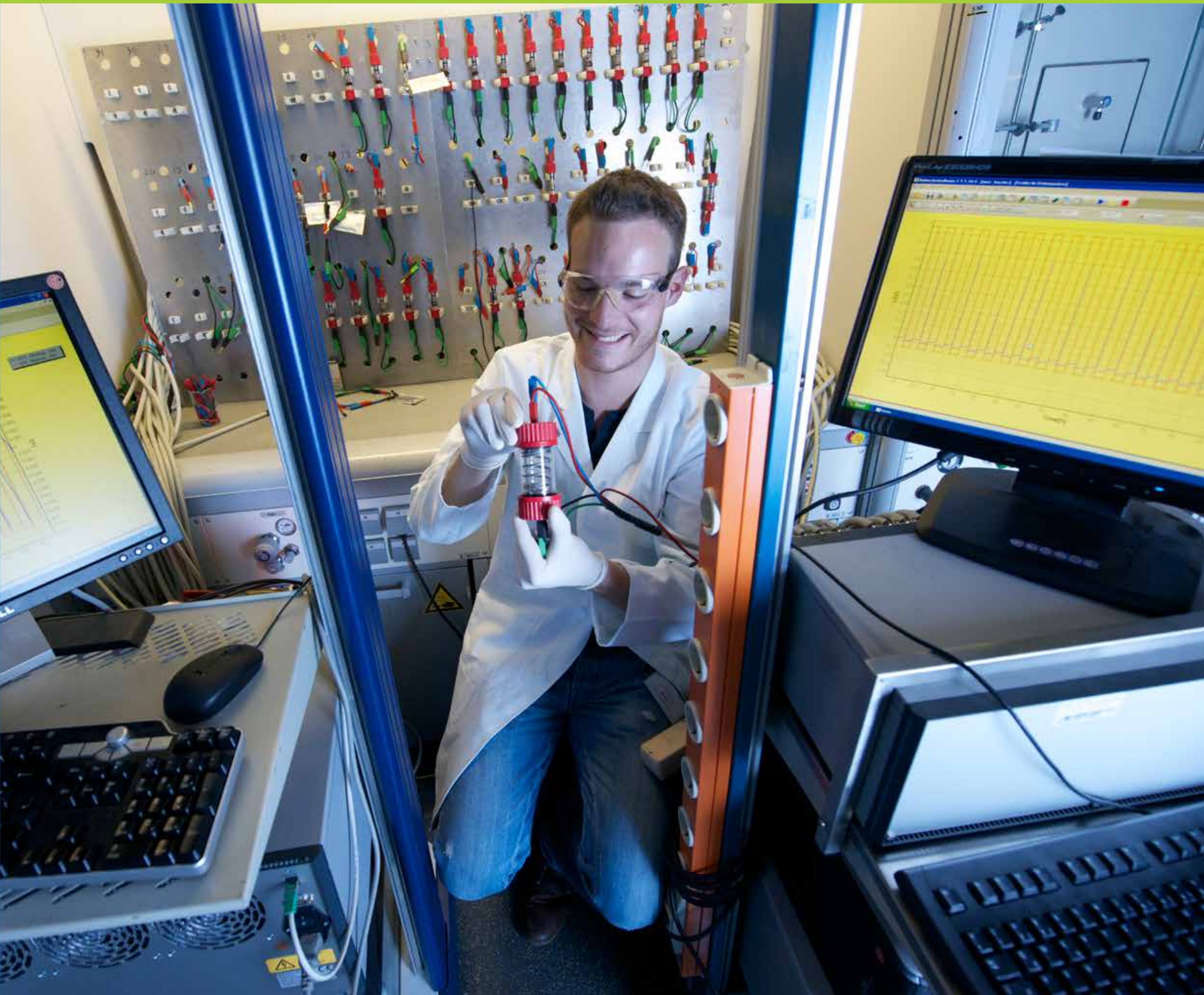
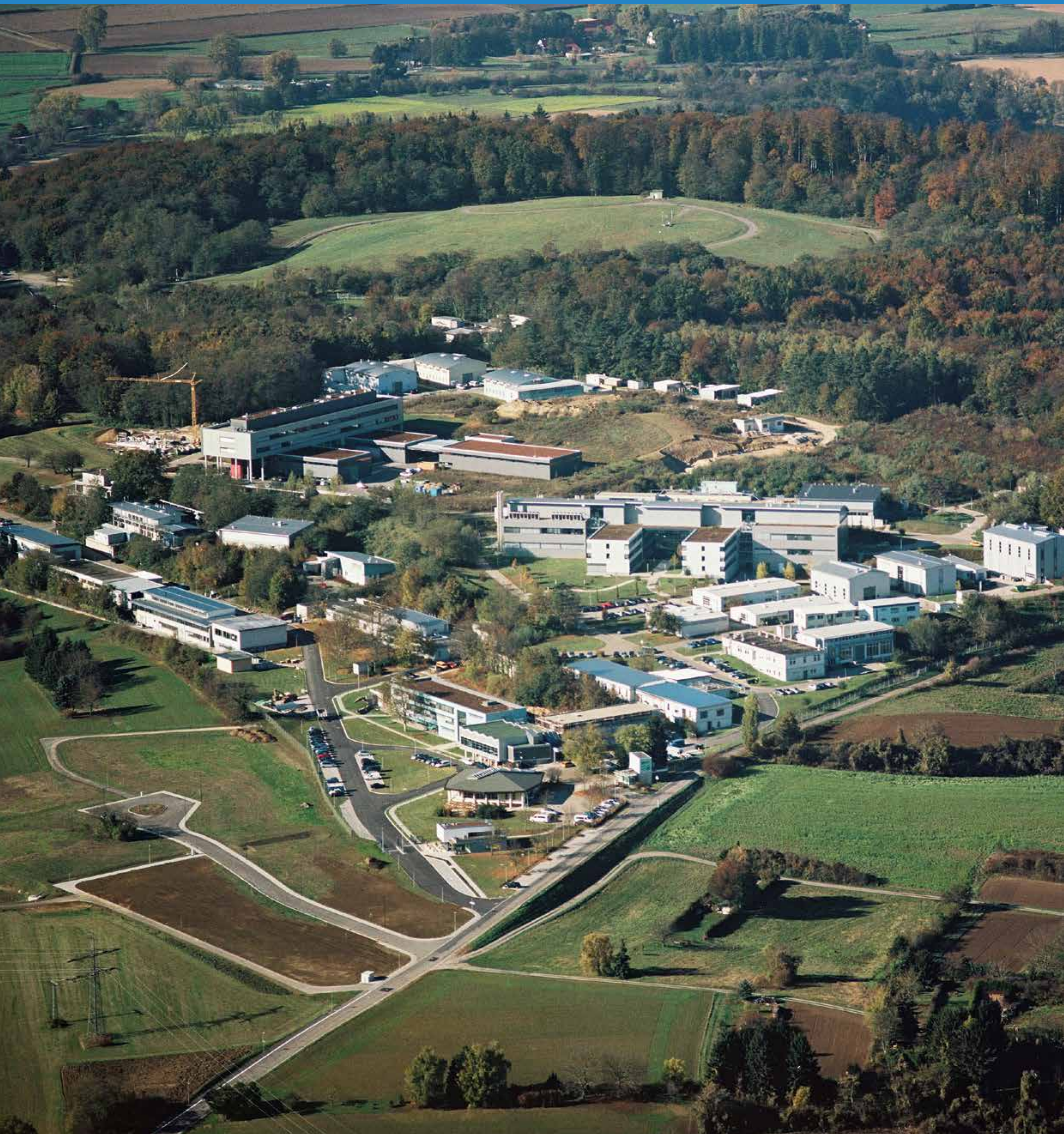
Fraunhofer
ICT

FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

FRAUNHOFER ICT – DESIGNING THE FUTURE





FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

The Fraunhofer Institute for Chemical Technology ICT carries out research and development work in the fields of energetic materials, energetic systems, applied electrochemistry, environmental engineering and polymer engineering. Our expertise ranges from the conception and design of processes, and material development, characterization and processing, through to the design, set-up and operation of pilot plants.

Commercial research

In the commercial research sector the institute works mainly on plastics-related projects such as material development and selection, product development, component design and processing technology, with particular emphasis on the further development of direct processes. Recycling management and sustainable development define company strategies for future generations. The Fraunhofer ICT is one of the most high-profile research institutes working in the environmental technology sector. The institute has played a key role in shaping the field of environmental simulation, which involves the investigation of environmental impacts on materials and technical products. For over 40 years the institute has been the headquarters of the well-known Gesellschaft für Umweltsimulation e.V. GUS (The Society for Environmental Engineering).

Defense research

The Fraunhofer ICT is the only explosives research institute in Germany to offer a full spectrum from laboratory testing and technical processing through to fully developed systems. It has many years of experience in the core competence of energetic materials, for example solid rocket propellants or high explosives, and has been a research partner of the German Defense Ministry for over 50 years. Important civil applications for energetic products include gas generators and airbag technology as well as solid-propellant rocket engines for space travel.

Synergy

The institute's current financial situation demonstrates that the broad range of competences and the unique combination of defense and civil research can ensure success independent of the economic climate. The Fraunhofer ICT has around 550 employees. Approx. 25,000 m² of well-equipped laboratories, pilot plants and offices are available for work on research projects.

ENERGETIC MATERIALS

ENERGETIC MATERIALS

Chemical and technical process development is the core competence of the Energetic Materials Department. We offer research and development services for the chemistry-based industries. Our long-standing experience in the development of propellants, explosives and pyrotechnic components forms a basis for the safe synthesis and processing of energetic substances, from the synthesis of the raw products through to small-series manufacture and demonstrators. In the context of security research we develop testing protocols for the detection of explosives, and fire protection for susceptible components.

Our interest in chemical and technical processes, from synthesis, chemical engineering and process development through to simulation and testing, forms a basis for the research and development services we offer our customers in the fields of chemistry, energy, environment, defense, security, aviation and aerospace.

In the field of chemistry and processing technology, our dedicated project team uses cutting-edge equipment and a comprehensive research infrastructure to support both small/medium-sized enterprises and large companies. In chemical process engineering, we work on the synthesis, processing and optimization of energetic materials and fine chemicals in laboratory and pilot-scale processes. This includes continuous microprocessing technologies, nitration techniques, supercritical fluid processes, comminution and coating technologies. In this research area we are particularly specialized in the safe design and optimization of hazardous processes.

In the field of microreaction technology we offer the chemical and pharmaceutical industries a versatile set of tools for process analysis, design and optimization. Reaction calorimetric data, which are recorded using tailored spectroscopic process analysis, enable us to analyze and evaluate chemical processes "under the microscope", and identify potential for improvement. We further develop and implement these processes from a laboratory scale up to pilot level, and integrate them into system concepts for our customers.

Safety and security research for civil applications is another important area in which our services are in high demand. In the field of explosives detection we use our extensive competence in explosive materials to test and validate existing or newly-developed systems, such as airport scanners, for the detection and identification of so-called improvised explosives. We are also an official test center for the validation of systems to detect liquid explosives. Through participation in various national and European expert committees, such as the EU-funded "Network on the Detection of Explosives NDE", international collaborative projects and national clusters (for example the innovation cluster "Future Urban Security"), we are working to further develop technologies for explosives detection.

Dissolver / bead mill combination for the wet milling of energetic materials.

In the field of defense research the majority of our work is carried out for the German Federal Ministry of Defence and the security industry. Our research agenda is internationally coordinated with the European Defence Agency (EDA) and the NATO. The Energetic Materials Department at the Fraunhofer ICT is also an experienced contact partner for other ministries, public authorities and commercial companies, and acts as a consultant on various national and international committees.

The field of smart materials is a cross-cutting research area that emphasizes the functionality of components and products and their targeted modification for various applications. For example, we develop new fire protection coatings with intumescent and/or ceramic structures which form a protective layer when exposed to fire. The property profiles of these coatings can be adjusted for application in construction and transport, and for protection against hazardous substances. Customer specifications, for example concerning the construction material class or decorative aspects (including transparency), can be implemented in the development.

Molecularly imprinted polymers (MIPs) are also developed as sensitive and selective low-cost sensor coatings. Highly cross-linked polymers are synthesized in the presence of template molecules. Once these molecules are removed, their "imprints" can only be occupied selectively and can consequently be used to detect the target molecules. Metal-organic framework structures (MOFs) are a new class of microporous material, and are characterized by high specific pore volumes and high specific surface areas. They are developed for applications in the fields of gas storage, sensor systems and catalysis. Other "smart materials" such as core-shell particles and co-crystals have emerged in the fields of particle technology, energetic polymers and energetic ionic liquids, and have been tested for example in the development of propellants.

Contact: Dr. Horst Krause | Phone +49 721 4640-143 | horst.krause@ict.fraunhofer.de

CURRENT RESEARCH TOPICS

CHEMICAL PROCESS ENGINEERING

- Process control with microreaction technology
- Process design and diagnostics
- Continuous catalytic processes
- High-pressure applications
  - Isostatic compression molding
  - Supercritical fluid processes
- Particle technology
- Energy harvesting

SAFETY AND SECURITY RESEARCH

- Test Center for Explosives Detection Systems, operated on behalf of the German Federal Police
- Detection of explosives
  - Stand-off detection using spectroscopic methods
  - European Network Detection of Explosives NDE, coordinated on behalf of DG HOME
- Home-made explosives
  - Manufacture, performance and safety evaluation
- Fire protection
  - High temperature insulation based on ceramizing elastomers
- Rapid pyrotechnical rescue systems

DEFENSE RESEARCH: EXPLOSIVES

- Synthesis of explosives
- Pyrotechnical compositions and gas generators
- Rocket propellants
  - Fast burning, low-smoke solid propellants
  - Gel propellants for rocket engines
  - Lighter engines for space missions
- Gun propellants
  - Foamed propellants
  - Temperature-independent propellants
- High-performance explosives and insensitive ammunition
- Analysis of explosives
- Aging, stability and compatibility

SMART MATERIALS

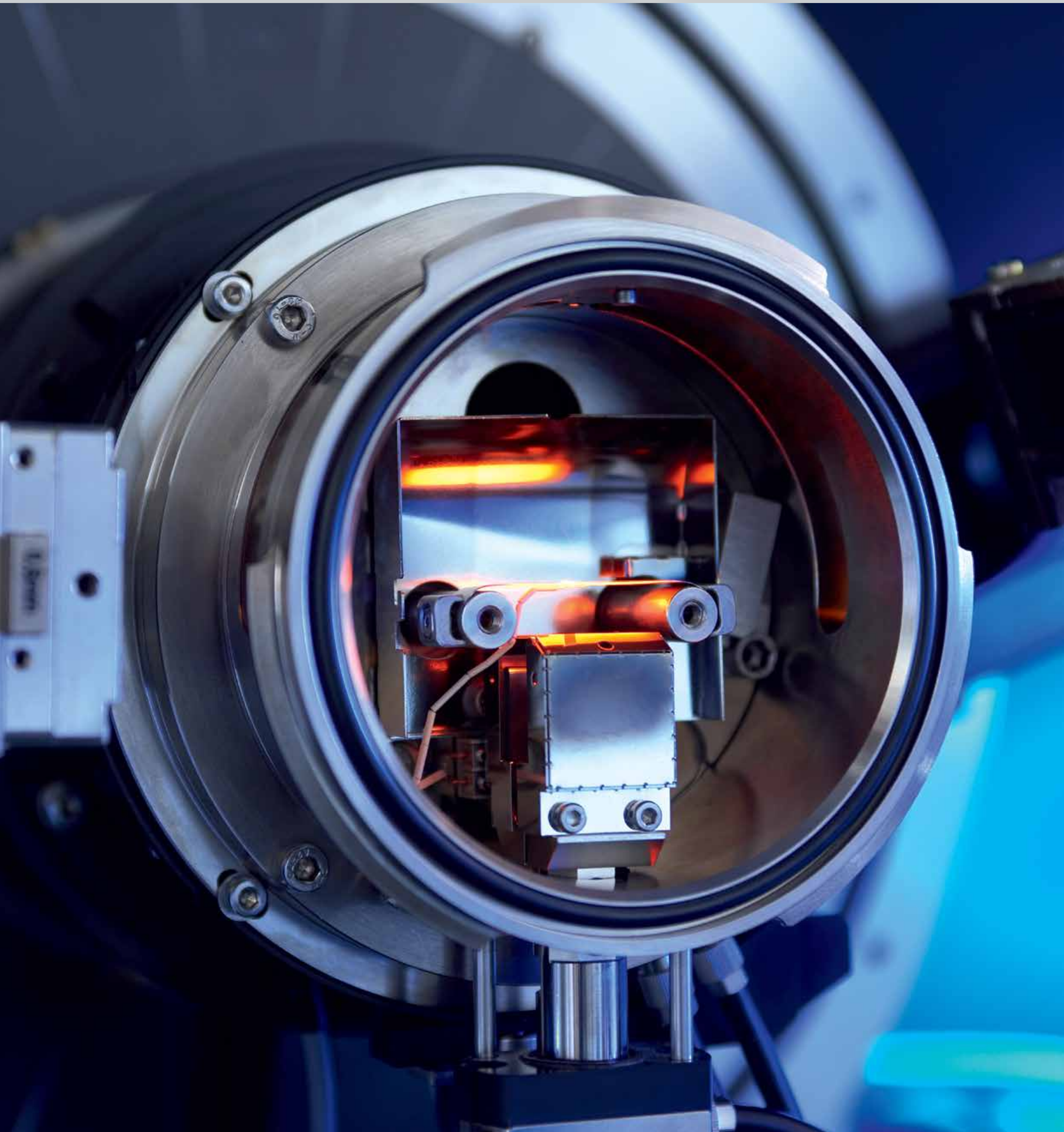
- Molecularly imprinted polymers (MIPs)
  - Selective sensor coatings
- Metal-organic frameworks
- Micro- and nanocomposites / co-crystals
- Gel propellants
- Energetic ionic liquids
- Energetic polymers
- Core-shell particles
- Phase-stabilized AN and ADN-prills

PHOTOS

Preparation of a measurement in an adiabatic calorimeter ARC (left) and test of an airport scanner for the identification of liquid explosives (right).

DEPARTMENTS OF THE FRAUNHOFER ICT

ENERGETIC SYSTEMS



ENERGETIC SYSTEMS

The main focus of research and development in the Energetic Systems Department is the production, conversion and storage of energy for civil and military applications. Further activities carried out on behalf of industrial and public clients relate to non-lethal weapons and analysis of the security and safety risks of reactive and explosive materials. Process monitoring, and the investigation and development of materials capable of withstanding high temperatures, complete the research portfolio. Cutting-edge laboratories and measurement technologies are available for project work with explosive substances. The unique infrastructure enables the real-scale investigation of reactive processes.

Competences

Fundamental knowledge and modeling/simulation of the physical properties of energetic systems form a basis for the department's activities. Applications for the energetic systems investigated at the institute range from explosive-based systems through to material and thermal energy storage devices. The experimental investigation of energetic materials and systems for civil and military applications enable the characterization and evaluation of their performance and sensitivity properties from manufacture through to transport, storage and application. This ability to characterize and model the reaction and combustion processes of explosives allows new systems to be developed and existing systems to be optimized.

High-temperature oven for material testing using X-ray diffraction.

Cutting-edge measurement technologies, partly developed in-house, provide detailed and time-resolved information on chemical reactions and the detonative or deflagrative reaction of explosive materials. Beside pressure and temperature measurement, the institute also uses contact-free optical and spectroscopic methods, such as high-speed cinematography, flow imaging, pyrometry and emission and absorption spectroscopy. Analysis of the various reaction processes is based on established theoretical models of reaction kinetics, flow simulation, and combustion and detonation physics. Both commercially-available computer programs and numerical calculations developed in-house can be used.

Core research and development topics

Research on the characterization, development and optimization of energetic systems is concerned not only with established military applications but also with civil applications for pyrotechnic systems in automobile safety (airbags) or the shaping of sheet metals. Activities in the field of energy storage devices and waste heat recovery focus on the thermochemical and latent storage of waste heat, ranging from the fundamental characterization of storage materials through to the design and construction of demonstrators or prototypes. The characterization and analysis of processes with reactive materials such as hydrogen enables a comprehensive risk assessment as well the development of safe operation strategies. Process monitoring enables the increasing demands placed on modern materials, products and their production processes to

be met quickly and reliably. Spectroscopic methods such as RAMAN spectroscopy enable the analysis of materials for precise product and process development in polymer processing. In the area of high-temperature materials, the oxidation and corrosion processes of (mainly) metallic materials are investigated and characterized. Emphasis is placed on the structural stability of coatings and materials for applications at temperatures of up to 1,700 °C under different environmental conditions.

The functionalization of materials through the use of nanoparticles, safety evaluation and the application of nanoparticles in fuels form a basis for our research in the field of nanotechnology. A specially-designed nano-workshop enables the secure handling of nanodusts and the investigation of their reactions.

Implementation

The combination of scientific multidisciplinarity and an exceptional research infrastructure, including cutting-edge laboratories and equipment, is ideally suited to research and development projects. In the topics outlined above the Energetic Systems Department is a competent partner for industry, local authorities and government. We have extensive experience in the coordination of large national and international research projects.

Contact: Gesa Langer | Phone +49 721 4640-317 | gesa.langer@ict.fraunhofer.de
Wilhelm Eckl | Phone +49 721 4640-355 | wilhelm.eckl@ict.fraunhofer.de

CURRENT RESEARCH PROJECTS

EVALUATION OF EXPLOSIVES

- Ignition, combustion, interior ballistics, detonation

PROTECTIVE SYSTEMS

- Non-lethal weapons, pyrotechnic incendiary compositions, flares

GAS GENERATORS

- Airbag systems, sheet metal forming, extinguishing technology

TECHNICAL SAFETY AND SECURITY

- Explosions, fires, hydrogen security

HIGH-TEMPERATURE MATERIALS

- Oxidation, corrosion, structural stability

MATERIAL AND PROCESS ANALYSIS

- Optical spectroscopy, material functionalization, chemometry, nanoparticles

ENERGY STORAGE DEVICES

- Thermal storage devices, material-based storage devices

PHOTO

Development of zeolite-based sorption storage units.

APPLIED ELECTROCHEMISTRY

APPLIED ELECTROCHEMISTRY

Batteries, fuel cells, electrochemical sensors and analysis systems are the main research topics of the Applied Electrochemistry Department. A wide range of civil and military research and development activities are carried out, from the evaluation and optimization of materials through to method development and the production of prototypes. Extensive testing and development methods for fuel cells, batteries and battery components have been elaborated and form part of our service. In addition to a fully-equipped laboratory we offer our customers wide-ranging electrochemical know-how.

Batteries

Our key research topics in the area of battery technology are lithium-based energy storage devices (in particular the relevant safety concerns) and the development of new systems with high energy densities (e.g. lithium-sulfur and lithium-air batteries). In well-equipped safety laboratories destructive and non-destructive tests are conducted on lithium-ion cells and modules, in combination with extensive gas analysis. The temperature control of lithium-ion battery systems is particularly important for safety reasons. A variety of in-situ and ex-situ thermal measurements are therefore conducted on cells and their components. On this basis thermal simulations are generated, and optimized functional models constructed. The most significant challenge in the development of "next-generation" batteries, such as lithium-sulfur, is the lithium-metal anode, which is prone to dendrite formation as well as electrolyte decomposition and reactions with polysulfide on its surface. In this field, current projects focus on new electrode concepts and separators.

Redox-flow batteries

Work at the Fraunhofer ICT is principally aimed at the investigation of new electrolytes, electrodes and membranes, as well as process parameters. Emphasis is placed on the scaling of the technology into the MW and MWh range for stationary applications, and on the production and implementation of the storage systems.

In the context of a public project funded by the State of Baden-Württemberg and the Federal Ministry for Education and Research (BMBF), a 2 MW / 20 MWh redox-flow battery, in combination with a 2 MW wind turbine, will be constructed on the grounds of the Fraunhofer ICT. Aside from challenges in process engineering, a further limitation of redox-flow technology is that the materials and the stack construction applied – mostly derived from fuel cell development – are too complex and therefore economically uncompetitive. Current projects are therefore aimed at reducing the costs to less than 1,000 €/kW, and at the integration of functional materials (electrode materials, membranes) into the manufacturing concept in order to simplify stack construction.

Safety/abuse tests involving the overcharging of a lithium-ion cell (pouch cell).

Fuel cells

As electrochemical converters, fuel cells generally have a higher electrical efficiency than thermal engines, especially in the low and medium power range. Compared to batteries, fuel cells also have higher energy storage densities. Beside increasing the storage density, the use of liquid propellants also simplifies the handling, and therefore increases the market potential. However, obstacles to commercialization include the high costs and the lack of infrastructure for the commonly-used fuel hydrogen.

In order to overcome these obstacles the Fraunhofer ICT is carrying out applied research in the field of fuel cell materials. In order to reduce costs, catalysts and binder materials for alkaline fuel cells are investigated with an anion-exchange membrane. The aim is to eliminate the need for platinum metals and electrocatalysts for the direct conversion of alcohols in alkaline medium-temperature polymer electrolyte membrane fuel cells, so that (cheaper) liquid fuels can be applied. Through these activities the Fraunhofer ICT has gained significant expertise in the in-situ investigation of electrochemical processes in fuel cells. This expertise is available to our customers, for example in the investigation of degradation processes. As regards complete systems, the Fraunhofer ICT works intensively on the development of fuel cell systems such as APUs or range extenders for electric vehicles, as well as the development of demonstration systems for the German Federal Ministry of Defense and the related authorities.

Sensors and analytical systems

Fields of application for electrochemical sensors include environmental measurement, security monitoring, process control and medicine. Electrochemical sensors are superior to conventional sensors due to their high sensitivity, ease of use and low manufacturing costs. They can be used for the investigation of liquids, gases and soil samples. In addition, due to the large number of variable parameters, they can easily be adjusted to the specific requirements of our customers. We are currently developing highly sensitive sensors for the detection of hazardous substances in air and sea water. We are also working on sensors for application under extreme environmental conditions (e.g. at high temperatures).

A further research focus is the use of pattern recognition methods for the flexible application of electrochemical sensors in complex matrices. Unwanted corrosion effects in batteries and components of any kind can also be investigated using electrochemical measuring methods. Using X-ray spectroscopy, for instance, damage analyses are carried out on corrosion products to determine their elemental composition. Leakage measurements and real-time hydrogen monitoring, from the lower ppb up to the high percentage range, also form part of our portfolio.

Our research group for analytical systems has spent many years working on analytical tasks in a broad range of thematic fields. Emphasis is placed on electrochemical issues, which are solved using comprehensive electrochemical and analytical facilities and equipment. Activities include abuse tests on lithium-ion secondary batteries, during which gaseous and sometimes toxic components (HF, sulfur compounds) can be released that are difficult and time-consuming to identify.

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

CURRENT RESEARCH TOPICS

BATTERIES

- Cell / module
  - Lithium-sulfur batteries
  - Sodium-based batteries
  - Performance, abuse and post-mortem investigations
  - Simulation of thermal behavior
  - Super-caps
- Battery systems
  - Design / development
  - Joining techniques
  - Hybrid energy storage systems
  - Thermal management

REDOX-FLOW BATTERIES

- Materials and stack
  - Metal and polymer-filled bipolar plates
  - Aqueous and organic electrolytes, ionic liquids, vanadium and bromide systems
  - Sealing and stack concepts
  - Modeling of flow batteries from individual cells up to the entire system
- System
  - Design of regenerative energy systems (generator + storage), microgrid simulation
  - Vanadium-air / metal ion - air systems
  - Uninterruptible power supply

FUEL CELLS

- Materials and stack
  - Electrocatalysts and membrane-electrode units for alkaline direct-alcohol fuel cells
  - Sulfur-tolerant electrocatalysts and membrane-electrode units
  - Oxygen reduction electrodes
- System
  - Direct ethanol fuel cells
  - Fuel cells as range extenders and APUs
  - Use of fuel cells in a military environment by the German armed forces

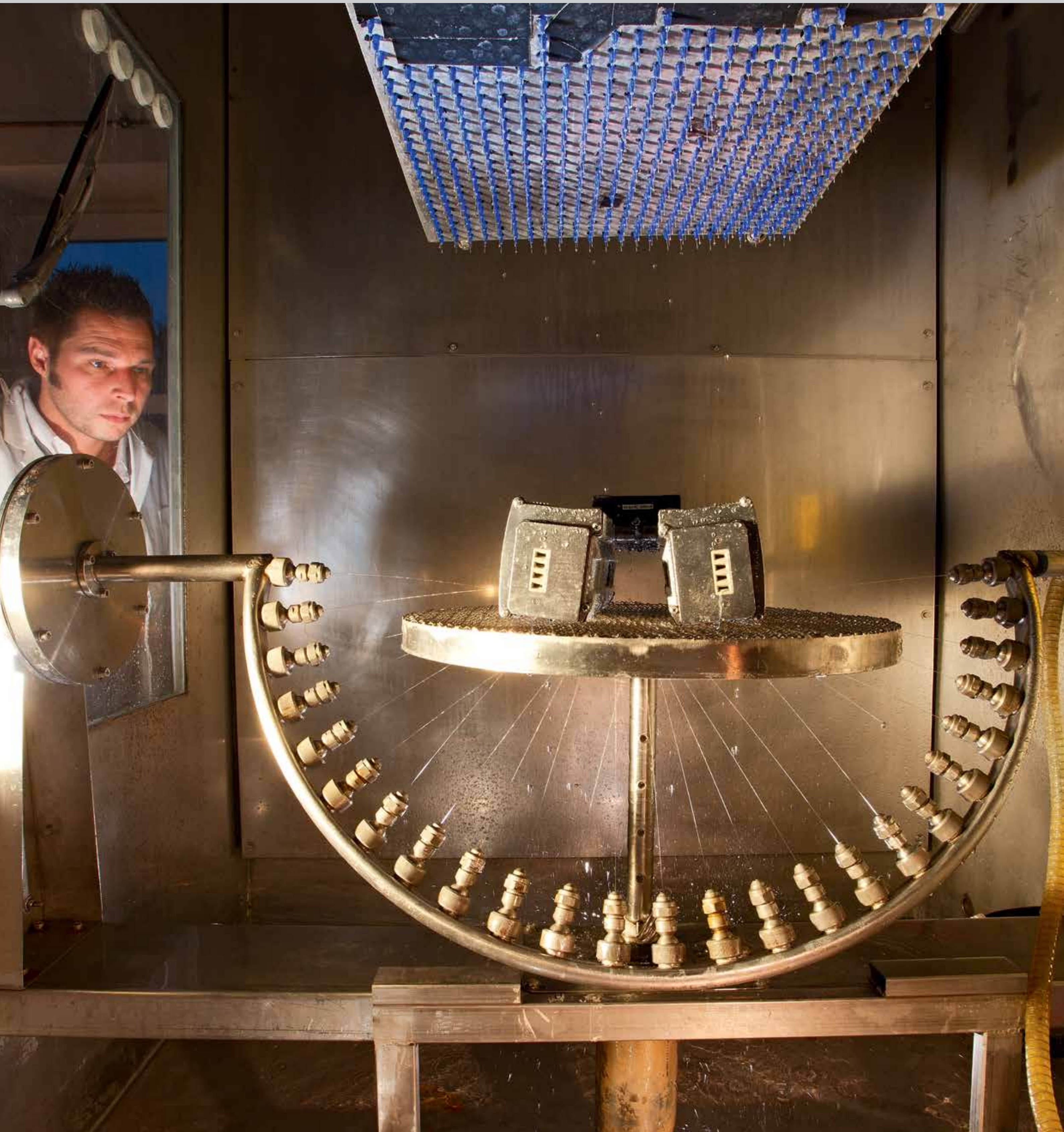
SENSORS AND ANALYTICAL SYSTEMS

- Detection of explosives
  - Preparation of defined concentrations of explosives in the gas phase
  - Electrochemical detection down to the ppt range
- Electrochemical sensor technology
  - Smelling and tasting: trace detection and pattern recognition
  - Construction of sensor systems
- Investigation of corrosion damage, leakage measurement and component failure
- Analysis of battery and combustion gases
- Ionic liquids in electrochemical systems

PHOTOS

Investigation of an unrolled separator and the electrodes of a lithium-ion cell (left) and redox-flow laboratory cell for the testing of new materials (right).

ENVIRONMENTAL ENGINEERING



ENVIRONMENTAL ENGINEERING

The Environmental Engineering Department has many years of experience in the research fields of resource-efficient production technology and innovative waste management. Beside advanced chemical process engineering, the department offers its customers support in classic mechanical process engineering, and a product portfolio extending from chemicals and materials based on sustainable resources through to new materials (biopolymers, nanomaterials, functional and smart materials) and special recycled materials. Another important field of work is the environmental qualification of technical products according to standardized or customer-specific testing methods.

Recycling and resource efficiency management

The research group for recycling and resource efficiency management develops raw material- and energy-optimized products and processes. Using a hydrothermal method, an efficient recycling process for construction materials has been developed, generating high-value raw materials for the construction sector. Material recycling enables textiles and polymer fibers recovered from vehicle seats to be reused in new products. At the Fraunhofer ICT fiber composite components are first fractionated by material recycling and subsequently reused in high-value applications. Particular emphasis is placed on the recycling of carbon fibers and glass-fiber composites. Cutting-edge technologies from the field of energetic disassembly are applied. Ecological and economic tools for a holistic evaluation of these processes in terms of their life cycle assessment (LCA) complete the portfolio of this group.

Reaction and separation techniques

The research group for reaction and separation techniques carries out process development for the synthesis of platform chemicals based on sustainable raw materials. The chemical processes comprise the entire process chain from the selection and fractionation of biogenic raw materials, and downstream processing, through to the quantitative characterization of the products. The goal is the industrial use of vegetable raw materials such as sugar, starch, cellulose, hemicellulose, lignin, terpenes, chitin or oil and fat for the production of organic intermediate products, fine chemicals and polymers. For example, phenolic building blocks (guaiacols, catechol and syringol) can be generated using the base-catalyzed decomposition (BCD) of lignin. These building blocks have already been used successfully in the production of phenol formaldehyde resins. In this respect hydrothermal catalytic processes, which use near-critical water as a solvent and reaction partner, are also of particular interest. Examples include the extraction of olefins or polyalcohols from cellulose, hemicellulose and sugars for the production of polymer foams, and also the extraction of furan derivatives (5-HMF, 2,5-furan carboxylic acid) from hemicelluloses for the production of thermoplastic elastomers. As water is used as a solvent and reaction medium, these processes can easily be combined with biotechnological processes.

Test of protection class and leak tightness.

During so-called downstreaming (i.e. separation of the components) thermal process engineering (distillation) and mechanical separation techniques (cross-flow membrane processes) as well as supercritical fluids (SCFs) are used for extraction. Supercritical fluids combine a high dissolving power with gas-like transportation properties.

Polymers and additives

The main focus of the research group for polymers and additives is the development of synthesis processes for the production, processing and modification of polymers based on sustainable raw materials. Furan dicarboxylic acid-based polyesters and polyamides, which are produced from sugars, are of particular interest. However, oil-based and fatty acid derivatives, which are produced from natural resources via metathesis reactions and a subsequent derivatization, are also useful for the synthesis of new polymers. In the field of polymers there is a growing demand for improved flame protection systems. For this reason a group of scientists is developing reactive flame protection systems which are chemically integrated into the product during the polymer synthesis.

Analytics

The Environmental Engineering Department has a comprehensive analytics unit which enables quantitative results (including trace analysis) to be obtained for organic and inorganic materials, for both internal research groups and external customers and partners. In the past few years, the group has extended its competence in the characterization of natural materials and biomaterials (NREL analysis, fat analytics, LC-MS), polymer products (pyrolysis-GC-MS) and mineral components in recyclable substances such as asphalts, railway sleepers and luminous coatings.

Emission test chamber methods detect possible material emissions, for example for interior applications. Beside VOC measurements, other air pollutants and particles such as fine dust are detectable.

Environmental simulation and product qualification

Throughout their service life, technical products are exposed to a wide variety of environmental influences that affect their function, service life, quality and reliability.

The research group for environmental simulation and product qualification simulates and evaluates environmental influences and their effects on technical products, commissioned by numerous customers from different sectors. Using long-term simulation combined with defined aging, service life predictions can be generated. Application areas include the quantification of vehicle components and the development of durable components for the food industry. Corrosion processes can be simulated through tests with gaseous or liquid media, for example to demonstrate the efficacy of corrosion protection measures. The problem of exposure to dust has been brought to public attention due to the hazards associated with particulate matter. Dust loads are therefore recreated in the testing process in order to achieve accelerated aging.

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

CURRENT RESEARCH TOPICS

REACTION AND SEPARATION TECHNIQUES

- Implementation of biorefinery concepts on a mini-plant scale at the Project Group Fraunhofer CBP in Leuna
- Use of sustainable raw materials in the production of chemical raw materials
- Use of supercritical fluids in synthesis and the separation of materials
- Pressure fractionation unit for the continuous extraction of lignocelluloses into their main components

ENVIRONMENTAL SIMULATION AND PRODUCT QUALIFICATION

- Methods for the simulation of corrosion processes
- Methods for the simulation of cleaning processes in the food industry
- Chemical resistance of surfaces
- Development of processes to accelerate the effects of environmental influence
- Investigations into the accelerated aging of components
- New test standards for product qualification in climate chambers

PROCESS AND EMISSION ANALYSIS

- Development of new measurement methods for material characterization

RECYCLING AND RESOURCE EFFICIENCY MANAGEMENT

- Recycling concepts and strategies for secondary raw materials in cooperation with the joint research group of the Simon-Ohm University in Nuremberg
- Concepts for the recycling of materials from fiber-reinforced composites (carbon fibers) and construction materials, as well as the production of high-quality products
- Recovery and reuse of textile fibers
- Recycling of PET in food grade quality
- Closed-loop processing of plastics from discarded electronic devices and vehicles
- Recycling of electronic waste
- Sustainability in the development and manufacture of aircraft

POLYMERS AND ADDITIVES

- Synthesis of new biopolymers (polyesters, polyamides and polyurethanes) based on renewable raw materials
- Recovery and reuse of raw materials from polyurethane slabstock foams (glycolysis and acidolysis)

PHOTO
Product qualification in climate chambers.

POLYMER ENGINEERING

POLYMER ENGINEERING

For almost two decades the Polymer Engineering Department has offered innovative polymer solutions from the initial idea, and the product, material and method development through to the manufacture of prototypes. The development of cost- and resource-efficient material formulations and production processes plays a major role in application-oriented plastics research. In the department's research projects, thematically-focused groups work closely together with international partners, Fraunhofer alliances and the Karlsruhe Institute of Technology (KIT). Our association and scientific cooperation with the KIT furthermore enables us to strengthen our fundamental research through professorships in lightweight construction and polymer technology.

Competences at the Pfinztal site

The Polymer Engineering Department mainly concentrates on future-oriented research in the area of polymer technology, such as the development of temperature-resistant thermoplastic, natural-fiber-reinforced polymers for technical applications. Materials research increasingly focuses on tailored foamed material systems and foam compounds, which, as a result of their optimized properties, can be used for example as sustainable alternatives for building insulation. In order to achieve the optimal result in material development, the interaction between material and foam processing technology is crucial. The principle of optimized material and technology use also applies to current developments in the field of nanoparticles. The use of injection molding to produce electrically-conductive paths with sensor properties demonstrates the significant potential of polymer nanocomposites. Integrated reactive processes are among the most significant new research topics in the field of process development. Examples include reactive extrusion, which enables chemical syntheses or material modifications in a continuously-operating reaction extruder. Current research projects such as the reactive material recycling of PET also demonstrate the important synergies that can be achieved through collaboration with the Fraunhofer ICT's Environmental Engineering Department in the area of polymer chemistry.

Semi-finished product consisting of a hollow fiber composite structure reinforced with a braided insert.

With advances in injection molding technology, it is possible to increase the scope of research and development projects, including in the area of foam injection molding. For example, this technology now enables the development of components with a sandwich structure and high weight-specific stiffness – a topic that has already attracted industrial interest. The foam sheet extrusion line in the PE pilot plant is still unique within the German research infrastructure. This unique selling point explains the significant increase in project revenues in the area of foaming technologies. Beside the development of new foam materials, there is also continued interest in the development of formulations for conventional materials. Nucleation and alternative flame protection systems are important examples.

Our work on fiber composite technology is also concerned with integration methods, production processes for long-fiber-reinforced thermoplastics and thermosets (LFT, SMC), casting processes for thermoplastic resins (T-RTM/RIM), resin transfer molding (HP-RTM) for large series production and PUR-LFI fiber spraying technology. In order to further develop these topics, one current focus is the visualization of entire production

processes, and especially the industrialization of fiber composite technologies originally deployed in small-series production. In spring 2014 a fully automated preform unit for textile semi-finished products will be assembled to complement the production chain for high-performance fiber composites using the RTM process. Another important research focus is the development of optimized processes for the placement of thermoplastic high-performance tapes and their handling in further processes.

In the field of microwave and plasma technology one of the department's research groups is carrying out process and technological development in the field of microwave-assisted processing. The department's equipment for the accelerated curing of resins and adhesives was expanded with the purchase of a compact induction unit. Plasmas are used to coat polymer or metallic components with a (usually transparent) coating. Aside from their application in scratch-resistant coating, in the past few years they have increasingly been used in corrosion protection, including the coating of hybrid components. Compounds of high-performance aluminum alloys and carbon-fiber composites are especially prone to corrosion on the contact surface. Insulating coatings which are deposited on the aluminum component during the plasma process present an economically-viable and technologically high-quality alternative.

The department's plastic testing facilities were further expanded in 2012/2013: reliable methods to measure the conductivity of polymer compounds, and expanded testing methods especially for high-performance composites, complete the testing portfolio.

Project Group for Functional Lightweight Design FIL

In May 2013 the project group FIL moved into its new research complex on the Augsburg site. Almost 60 employees are carrying out application-oriented research in the field of lightweight construction and automated manufacturing processes for the cost/ energy-efficient production of high-performance composite structures for automotive and mechanical engineering. The research work spans the entire process chain.

Fraunhofer Project Center FPC for Composite Research

Through the unique cooperation between the Fraunhofer Project Center for Composite Research FPC at Western University in London, Ontario, Canada and Western University itself, the competences of the Fraunhofer ICT in the field of fiber composite materials are combined with the know-how of the Canadian university in the fields of material and surface research. The FPC has a cutting-edge press with a molding pressure of 2500 t. Commissioned research projects, in particular for the automotive industry, can therefore be carried out on an industrial scale.

Karlsruhe Innovation Cluster for Hybrid Lightweight Design

The Fraunhofer Innovation Cluster KITe hyLITE "Technologies for hybrid lightweight construction", under the leadership of Professor Dr. Frank Henning, links the Fraunhofer institutes ICT, IWM and LBF with institutes of the Karlsruhe Institute of Technology KIT, as well as industrial enterprises, for the joint development of hybrid lightweight construction technologies based on fiber composite materials. The core research topics are materials, production and methods.

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

CURRENT RESEARCH PROJECTS

COMPOUNDING AND EXTRUSION

- Natural fiber / biopolymer compounds
- Particle foam components made from biopolymers
- Development of foamed or propellant-containing granulates
- Reactive extrusion of biopolymers
- (Nano)cellulose-fiber-reinforced plastic compounds
- Long-glass-fiber-reinforced granulates based on recycled materials

THERMOSET PROCESSING

- Fiber-reinforced polyurethanes based on PUR fiber spraying technology
- Development of lightweight SMC formulations

HIGH-PERFORMANCE COMPOSITES

- Process and component development in high-pressure resin transfer molding (HP-RTM)
- Chemical fixing of technical textiles – "chemical stitching"
- Automated preforming of textile semi-finished products for mass production

MICROWAVE AND PLASMA TECHNOLOGY

- Accelerated curing of (carbon-fiber-reinforced) composites using microwaves
- Transparent coatings for protection against scratching / corrosion, using a PECVD plasma process
- Purification, desizing and sterilization using coronas and microwaves

NANOTECHNOLOGY

- Components with injection-molded conductive structures
- Nanostructured adhesive layers for hybrid components
- Microcellular and nanoparticle-reinforced foams
- Antimicrobial surfaces
- Nanocomposites to replace wires, and for sensor applications
- Filler adhesion and interface characterization

FOAM TECHNOLOGIES

- Hybrid foams
- Particle foams based on recycled materials
- Extruded (bio-based) foam sheets (XPS)
- Enhanced EPS and EPP materials and hybrid foams

THERMOPLASTIC PROCESSING

- Thermoplastic foam injection molding
- Thermoplastic tape-laying for local reinforcement of components
- Shaping of continuous-fiber-reinforced thermoplastics / composite laminates
- Injection molding of foamed (fiber-reinforced) structures
- Hybrid components made of EPP and fiber composite structures
- Energy-absorbing hybrid structures
- Load-oriented fiber-reinforced composite components (battery box, underbody panel, triangular girder)

PHOTOS

Automated process chain (left) for the production of a truck storage compartment flap (right) using a thermoplastic matrix.

FRAUNHOFER ICT-IMM INSTITUTE FOR MICROTECHNOLOGY, MAINZ

In September 2013 the Fraunhofer ICT gained a new branch: the IMM (Institute for Microtechnology Mainz GmbH). Until 17th September 2013 the IMM was owned by the state of Rheinland-Pfalz, which was its sole shareholder. After a comprehensive evaluation, the decision was taken to integrate it into the Fraunhofer-Gesellschaft. From 2013 to 2017 the Fraunhofer ICT has the task of introducing the team at the IMM to the working methods and philosophy of the Fraunhofer institutes. The aim is to prepare the ICT-IMM to become an independent Fraunhofer institute by 2018.

Scientists at the ICT-IMM carry out research and development in the following product areas:

The division for decentralized and mobile energy technology covers the entire technology chain, with expertise in catalyst development, stability testing, process simulation, system design and control, the development of cheaper production techniques, reactor construction and complete system integration and testing. Beside the development of individual components and complete fuel processing systems for conventional and regenerative fuels, researchers at the ICT-IMM are working on liquid hydrogen technology, exhaust-gas treatment and biofuel syntheses. With around 20 employees it is one of the largest groups for fuel processing in Europe.

The development of customer-specific MEMS sensors and electrodes for signal detection is the key task of the division for medical probes and technical sensors. Comprehensive competences in the design of micro-structured components and their system integration, combined with a wide spectrum of micro-fabrication technologies such as mechanical precision engineering, laser material processing, and silicon and thin film technology, are a unique feature of this division. Application areas range from industrial gas analytics, and the analysis of liquids and liquid films, through to medical diagnostics.

The division for nanoparticle technologies is concerned with the production and characterization of nanoparticles with diverse properties, for potential application in catalysis, medicine, pharmaceutics and the consumer goods industry. A further group is working on bio-nano interfaces.

The division for continuous chemical engineering is concerned with the optimization or even redefinition of chemical production processes using methods and devices of chemical micro-process engineering. Core competences range from the development and simulation-assisted design of microreactors to the realization of plants on a laboratory, pilot and production scale. An additional focus is process development based on microreactors and flow chemistry.

The division for process design develops technologies which are mainly applied in the fields of fine and specialty chemistry. However, the pharmaceutical and consumer goods industries, as well as the bulk and petrochemical sectors, also benefit from developments at the Fraunhofer ICT-IMM. Chemical processes can be tailored to ideally match the very high mass and heat transfer capacities of the reactors while maintaining a short residence time (maximizing the throughput).

The focus of the division for microfluidic analysis systems is the consumer-specific development of integrated, automated microsystems and components for medical diagnostics, environmental analysis, biological security/safety applications, food quality control, industrial analytics and process control. With the help of micro-structuring processes and model-based design the division develops efficient biomedical diagnostic systems ("lab-on-a-chip" or micro total analysis systems (µ-TAS)) for a variety of applications. The systems developed enable rapid analysis of the sample with regard to biological organisms or their building blocks or metabolites, on site at the point of care or point of use.

The division for future technologies at the ICT-IMM is characterized by two topics: business development and simulation. The development of targeted activities to advance the institute is thus linked with the possibility of testing their feasibility before implementation. The team has both the scientific expertise and the close networking within the research landscape that will enable it to play an active role in shaping the ICT-IMM's future as a Fraunhofer institute.

1 *The ICT-IMM in Mainz.*

Contact: Prof. Dr. Michael Maskos | Phone +49 6131 990-100 | michael.maskos@imm.fraunhofer.de

FRAUNHOFER PROJECT GROUP FOR NEW DRIVE SYSTEMS NAS

Over the past year the Fraunhofer Project Group for New Drive Systems NAS has undergone further development. Beside tests carried out on the group's own engine test stand, a fully-functional workshop was built for the necessary pre- and post-processing of experiments. In addition to the existing engine test stand, plans have been made to purchase a hot gas test stand in the coming year. Preparations have also started for the first interim evaluation of the project group.

Project participation and cluster activities

In addition to its work on publicly-funded projects (State of Baden-Wurttemberg and Federal Government), the project group NAS has contributed to cluster initiatives on a state level, such as the excellence cluster »Electromobility South-West« and the flagship project »Living-Lab«. Within the cluster initiatives the NAS has taken part in different assignments in the research field of range extender technologies as well the acquisition of data on the use of electric vehicles under real-life conditions. Together with the project group's strong commitment to the Fraunhofer Innovation Cluster “REM 2030”, these other cluster activities are important for the development and validation of innovative technologies and especially for the further expansion of networks and contacts in the electromobility field.

Beside networking and collaboration with external partners in joint research and bilateral projects, cooperation with the parent institutes intensified over the past year. This enabled joint research to be carried out and published in the fields of waste heat recovery and lightweight power train design. In the area of block heat and power plants, a zeolite long-term thermal storage device was developed for an innovative mini block heat and power system.

The establishment of networks between the project group NAS and other Fraunhofer institutes was also a goal over the past year. This led to a successful application for funding from Fraunhofer's industry-oriented internal research program "WISA", in collaboration with the Fraunhofer ISE in Freiburg. In this context simulative as well as experimental work on innovative fuel evaporators for an HCCI combustion process will be carried out.

1 *NAS hot gas test stand on the KIT´s east campus (manufacturer: Kratzer Automation AG).*

Expansion of test stands and infrastructure

In 2013 the project group NAS experienced a significant development in its infrastructure. In addition to the existing engine test stand, plans have been finalized for the purchase of a complete hot gas test stand. An application for ERDF funding was made and granted for this investment. The test stand will be used for research in the field of waste heat recovery. A possible research topic is the development and testing of mobile waste heat recovery systems such as turbo generators, which use a high speed generator to convert thermal energy from the exhaust gases of combustion engines into electrical energy. This technology will be applied for example in hybrid power trains. The test stand will be built and operated as an independent container test stand on the KIT's east campus.

Construction of container workshops

The project group NAS has constructed its own container workshop for the pre- and post-processing of test stand experiments. The two-story container building includes a workshop area on the ground floor, where work can be carried out on various power train components, and where vehicles can be prepared for testing. The upper floor of the container consists of further work stations for laboratory tests, especially for projects in the field of e-competence. Here, among other tasks, employees are working on centralized control systems for conventional and electrified power trains and power electronics for battery-electric vehicles.

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

FRAUNHOFER PROJECT GROUP FOR FUNCTIONAL LIGHTWEIGHT DESIGN FIL

Increasing environmental awareness and dwindling resources mean that lightweight construction is one of the most important future technologies in the aviation, automotive and mechanical engineering sectors. High-performance fiber composites will play a particularly important role, as they offer not only the highest lightweight potential but also a wide range of functional advantages. The most important materials in this class are carbon-fiber-reinforced plastics with continuous fiber reinforcement adjusted to the load. These materials are up to 30% lighter than aluminum and up to 60% lighter than steel. However, hybrid construction using metal-fiber composites, which combines the advantages of the two materials, also has significant potential in numerous applications.

This significant lightweight potential can only be exploited where new concepts are developed that combine a design suited to the fibers and textiles involved, innovative construction methods, new structural and material concepts and resource-efficient large-scale manufacturing technologies with a high level of automation.

Under the direction of Professor Klaus Drechsler (Professorship for Carbon Composites at the Technical University of Munich) and Professor Frank Henning (Professorship for Lightweight Construction at the KIT Karlsruhe), the Fraunhofer Project Group for Functional Lightweight Design is working towards this aim in collaboration with research institutions and industrial partners from the Augsburg region and beyond. The aim is application-oriented research in the field of resource-efficient construction and manufacturing technologies for high-performance fiber composite structures in machinery and vehicle construction. This includes generating fundamental know-how and improving the competitiveness of industrial partners by creating products that are optimized and sustainable in terms of their entire life cycle, and opening up new fields of application. The objectives are reflected in the core activities of the project group, which span the entire value chain. Activities range from simulation and the calculation of key data for CFRP components, online solutions for process monitoring, material development and characterization, through to automatable production processes and a recycling process following the application phase of the corresponding products. A further aspect relevant to all the development areas and subprocesses is sustainability analysis and the identification of optimization approaches in a holistic life-cycle assessment.

1 *Fraunhofer Project Group FIL in Augsburg.*

The project group, which was established in February 2009, now employs 45 research staff, who are assisted in their project work by about 20 technicians. In February 2013, the research team moved into the new institute building in the Augsburg Innovation Park. This five-floor building has roughly 1,900 m² of well-equipped offices and laboratories as well as its own pilot plant with an area of about 1,200 m². The expansion of the pilot plant and the installation of the high-duty units was carried out in the first quarter of 2013. Firstly, the FiberForge and the pultrusion unit were moved from Pfinztal to Augsburg, and the cooling section of the pultrusion unit was extended. Subsequently, the AFP unit (Coriolis) was relocated from the university into the pilot plant building. In order to process thermoplastic matrix systems, a laser unit was coupled to the AFP unit. A hazardous material storage facility, which is located in the pilot plant building, also came into operation. The region of Bavaria has provided 22 million € for the new Fraunhofer facilities and the project group. In addition, the city of Augsburg has contributed 3.5 million €, the Federal Ministry for Education and Research 3.5 million € and the European Union 3.9 million € (in the context of the program "Investing In Your Future" - European Regional Development Fund).

The founding of the project group in Augsburg, with the aim of developing it into an independent Fraunhofer institute, results from the concerted action of numerous institutions in the region and beyond: in particular the Bavarian Ministry of Economic Affairs, the companies involved in the Carbon Composite e.V. network, the Swabian Chamber of Industry and Commerce (IHK), the Institute for Physics at the University of Augsburg and the city of Augsburg.

In June the project group was evaluated by a team of scientific and industrial experts. The result was very positive: the evaluators noted that the FIL is very well connected with industry and has a strong scientific profile which is reflected in its structure and the competence of its employees.

Contact: Prof. Dr.-Ing. Klaus Drechsler | Phone +49 821 90678-200 | klaus.drechsler@ict.fraunhofer.de
Prof. Dr.-Ing. Frank Henning | Phone +49 721 4640-420 | frank.henning@ict.fraunhofer.de

ORGANIZATION CHART AND CONTACTS

DIRECTOR

Director
Prof. Dr.-Ing. Peter Elsner

Deputy Directors
Dr. Horst Krause, Prof. Dr. Frank Henning

DEPARTMENTS

Administration
Dr. Bernd Hefer

Deputy Head of Department
Claudia Steuerwald

General Management
Dr. Stefan Tröster

Energetic Materials
Dr. Horst Krause

Deputy Heads of Department
Dr. Thomas Keicher, Dr. Stefan Löbbecke

Energetic Systems
Dipl.-Phys. Wilhelm Eckl,
Dipl.-Phys. Gesa Langer
Deputy Head of Department
Dr. Jochen Neutz

Applied Electrochemistry
Dr. Jens Tübke

Deputy Head of Department
Dr. Karsten Pinkwart

Environmental Engineering
Dipl.-Chem. Rainer Schweppe

Deputy Head of Department
Dipl.-Ing. Steffen Rühle

Polymer Engineering
Prof. Dr.-Ing. Frank Henning

Deputy Heads of Department
Dr. Jan Diemert, Dr. Jan Kuppinger

PROJECT GROUPS

Mainz branch: Fraunhofer ICT-IMM
Prof. Dr. Michael Maskos

Project Group for Electrochemical Storage Devices, Garching
Dr. Jens Tübke, Dr. Kai-Christian Möller

Project Group for Functional Lightweight Design FIL, Augsburg
Prof. Dr. Klaus Drechsler (TUM), Prof. Dr. Frank Henning

Project Center for Composites Research, London/Ontario, Canada
Prof. Dr. Frank Henning, Dipl.-Ing. Tobias Potyra

Project Group for New Drive Systems NAS, Karlsruhe
Dr. Hans-Peter Kollmeier
Prof. Dr. Peter Elsner, Prof. Dr. Peter Gumbsch (KIT)

Project Group for Sustainable Mobility, FH Braunschweig-Wolfenbüttel, Wolfsburg
Dr. Jens Tübke

DIRECTOR

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

Deputy Directors
Prof. Dr. Frank Henning
Phone +49 721 464-420 | frank.henning@ict.fraunhofer.de
Dr. Horst Krause
Phone +49 721 4640-143 | horst.krause@ict.fraunhofer.de

DEPARTMENTS

Energetic Materials
Dr. Horst Krause
Phone +49 721 4640-143 | horst.krause@ict.fraunhofer.de

Energetic Systems
Dipl.-Phys. Gesa Langer
Phone +49 721 4640-317 | gesa.langer@ict.fraunhofer.de
Dipl.-Phys. Wilhelm Eckl
Phone +49 721 4640-355 | wilhelm.eckl@ict.fraunhofer.de

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

Environmental Engineering
Dipl.-Chem. Rainer Schweppe
Phone +49 721 4640-173 | rainer.schweppe@ict.fraunhofer.de

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

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

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

PROJECT GROUPS

Mainz branch: Fraunhofer ICT-IMM
Prof. Dr. Michael Maskos
Phone +49 6131 990-100 | michael.maskos@imm.fraunhofer.de

Fraunhofer Project Group for Functional Lightweight Design FIL
Prof. Dr. Klaus Drechsler
Phone +49 821 598-3503 | klaus.drechsler@ict.fraunhofer.de

Fraunhofer Project Group for New Drive Systems NAS
Dr. Hans-Peter Kollmeier
Phone +49 721 9150-3811 | hans-peter.kollmeier@ict.fraunhofer.de

Fraunhofer Project Center for Composites Research
Prof. Dr. Frank Henning
Phone +49 721 4640-420 | frank.henning@ict.fraunhofer.de

Fraunhofer Project Group for Sustainable Mobility and Fraunhofer Project Group for Electrochemical Storage Devices
Dr. Jens Tübke
Phone +49 721 4640-343 | jens.tuebke@ict.fraunhofer.de

SERVICES AND TECHNOLOGY TRANSFER

Consulting Office for Particle Technology
Dr. Michael Herrmann
Phone +49 721 4640-681 | michael.herrmann@ict.fraunhofer.de

Consulting Office for Plastic Compounds
Andrei Holzer
Phone +49 721 4640-357 | andrei.holzer@ict.fraunhofer.de

Gesellschaft für Umweltsimulation e. V. (GUS) (German Society for Environmental Engineering)
Dr. Thomas Reichert
Phone +49 721 4640-462 | thomas.reichert@ict.fraunhofer.de

TheoPrax Center
Dörthe Krause
Phone +49 721 4640-305 | doerthe.krause@ict.fraunhofer.de

Fraunhofer Institute for Chemical Technology ICT

Joseph-von-Fraunhofer-Strasse 7
76327 Pfinztal (Berghausen)
Germany

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

www.ict.fraunhofer.de