Fraunhofer
IMM

FRAUNHOFER INSTITUTE FOR MICROENGINEERING AND MICROSYSTEMS IMM

2018/19

ANNUAL REPORT

2018/19

ANNUAL REPORT

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DEAR READERS,

„Research and development are a couple. They have fallen in love a long time ago. And they always come back to the place where they met. And no, this place is NOT Fraunhofer IMM. It is inside, in the mind of our people."

These are the charming but also powerful opening words of our new image film, launched in the beginning of the year. And these are also the words I have chosen to preface our annual report 2018/19. Why? Well, they contain a simple truth which, in our nearly 30 years of history, allowed us to overcome any time, as stormy and challenging as it may have been, as a team.

It is our team that really makes all the difference. It is them who bring research and development to life. And it is them who make all those things possible that have not been thought of yesterday. Laboratory technicians, physicists, biologists, engineers, chemists, precision mechanics and administrative staff are interdisciplinarily working in laser, bio and chemistry laboratories, mechanics workshops, clean room, technical center and office space on plants, smallest components, catalysts, analytical instruments, electronics assembly, microfluidic chips, heat exchangers as well as on contracts and offers, marketing concepts and controlling issues. When I started here in 2011 I was deeply impressed by this diversity and by the close but as well focused accompanying work atmosphere. And this is still valid up to the current day. No matter which new course we will set in the near or far future, together we will attain the goal. Whenever and wherever research is carried out with the necessary commitment there is a way to succeed. We will always keep our eyes open for the future topics, open for the people's needs, open for innovative and sustainable solutions.

„Research and development – in our minds the best of both worlds is getting together. For responsible handling of resources and novel technologies. For a healthy environment and a healthy life. For all of us."

With these concluding words I want to wish you an exciting reading of what our minds have been conceiving and my colleagues have been researching and realizing during the last year.

PROF. DR. MICHAEL MASKOS
DIRECTOR FRAUNHOFER IMM

PROFILE

FRAUNHOFER INSTITUTE FOR MICROENGINEERING AND MICROSYSTEMS IMM

As Fraunhofer Institute for Microengineering and Microsystems, we work in the two fields of **Energy and Chemical Technology** (processes, reactors, plants) as well as **Analysis Systems and Sensors** (methods, components, systems). We organize our competencies in these two pillars according to the priorities Energy, Chemistry and Raw Material, Safety, Health and Nutrition, Mobility and Transport and Industry 4.0. Our developments are used in the business fields Energy and Environment, Chemistry, Process Engineering and Aerospace, Biomedical Analysis and Diagnosis, Safety as well as Industrial Analysis. With our system and technology oriented innovations we contribute to the competitiveness of our customers and partners. In doing so, we stand for responsible handling of new technologies and for sustainable development to benefit private and public enterprise as well as society.

The division **Energy and Chemical Technology** comprises the product areas **Energy Technology, Chemical Technology** and **Nanoparticle Technology**.

In the product area **Energy Technology**, we deal with current and future issues concerning mobile and decentralized provision and storage of electrical energy, with thermal management in the automotive industry and with the production of synthetic (bio)fuels. The development work covers the entire technology chain in the fields of system design, process simulation, catalyst development, durability tests, reactor design, development of cost-effective manufacturing technologies, system control, system integration and testing. We improve the reliability and efficiency of compact material and energy conversion systems as well as of decentralized, mobile power supply units.

In the product area **Chemical Technology**, we focus on the intensification of chemical production using methods and devices of chemical micro process engineering. Based on a well-scalable, modularly designed reactor family or by means of specific, often highly integrated designs, we develop, design and manufacture milli- and microstructured flow reactors from laboratory to industrial scale, which are optimally adapted to the respective process or application, including downstream processing. We intensify chemical production processes and increase the availability of materials, data and information for product and production issues.

In the product area **Nanoparticle Technologies** we deal with the production and characterization of nanoparticles with different properties and their potential application in medicine, pharmacy and consumer goods industry as well as with the encapsulation of active ingredients and fragrances and their potential application in food and cosmetics industry. Our research is focused both, on metal (such as Cu, Pt, Pd), metal oxide (such as ZnO, SiO_2, Fe_xO_y, Al_2O_3) and semiconducting nanoparticles (quantum dots) as well as on polymeric nanoparticles. We improve the quality of nanoparticles, enhance the productivity of syntheses and increase both, the efficiency and the availability of agents at the target site.

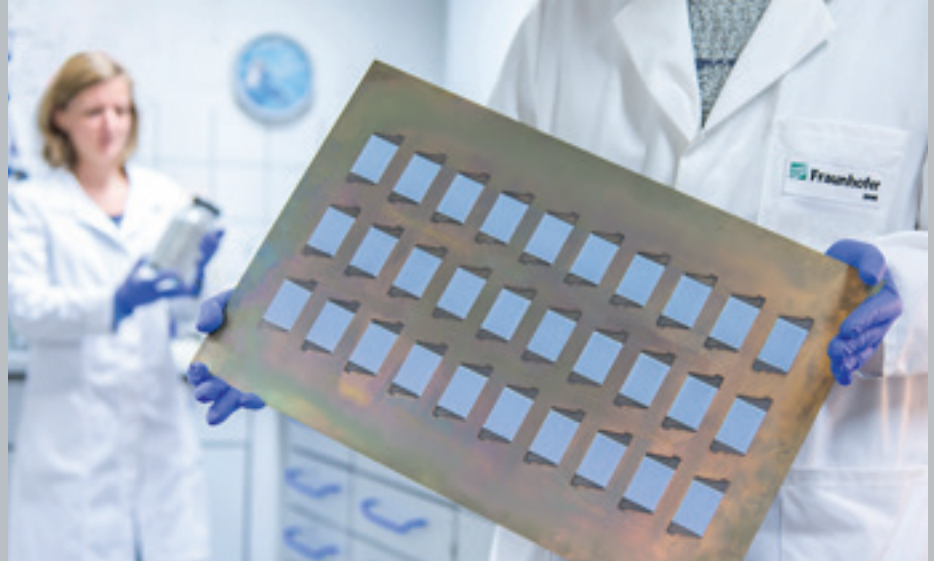
The division **Analysis Systems and Sensors** comprises the product areas **Microfluidic Analysis Systems, Sensor Technology** and **Equipment Engineering**.

As one of the pioneers of microfluidics, we have been developing fully integrated and automated **Microfluidic Analysis Systems** for over 20 years. Based on a "microfluidic construction kit" with comprehensive coverage of the required functional elements, we are able to develop an application idea to the proof of function and build fully functional demonstrators up to pilot production within short time. We accelerate and automate reliable analysis systems, increase the compactness of established processes and bring them to the place of action.

In the product area **Sensor Technology** we deal with the development of customer-specific optical, electrochemical and MEMS sensor technology. Comprehensive competencies in the design of microstructured components and their system integration associated with a wide spectrum of micro manufacturing processes such as mechanical precision machining, laser material processing, silicon and thin-film technology are our unique selling points. We increase the robustness of our customers' sensor technology and thereby minimize the effort in process monitoring.

In the framework of „Systems Engineering" our production portfolio ranges from numerous individual manufacturing processes up to **Equipment Engineering**. By this, we understand the integration of microfluidic cartridges or e.g. silicon-based sensors in mechanical constructions in functional connection with the necessary optics, actuators as well as with other electronic functional elements (heaters, motors, pumps, etc.). We combine and integrate fluidic elements and sensors in intelligent systems, thus creating new fields of application.

Our product areas are complemented technologically by our long-standing know-how in mechanical precision machining processes, electro discharge machining (EDM), laser material processing as well as by a series of clean room based chemical and physical structuring processes.



QUALITY POLICY

As a contract research organization a reproducibly high quality of our research and development services is the basis for a successful business activity and customer loyalty in the long term. Quality means for us to understand the partially complex customer requirements, whether expressed or unspoken, to transfer them into workable and customer-friendly solutions and to meet or exceed our customers' expectations. The quality of our work is crucial for customers to place an order and to successfully exploit the results.

We are not only developing solutions with and for industry, we as well strive for a project-oriented continued development of our capabilities. We are working together with industry, research organizations and universities in projects being co-financed by the federal government, the federal state or the European Commission in order to tackle important issues for the future. Fraunhofer IMM is a reliable partner and cultivates fair relationships to customers and suppliers. Without doing so the provision of our services would not be possible. To openly communicate with all stakeholders is the absolute precondition for any constructive collaboration.

Our employees are the backbone of our institute. Their skills, willingness and subjective well-being determine our target achievement. Our employees feel fully committed to our standards of quality and are being encouraged to further expand our high standards in project work and quality of service by continuous training. Essential prerequisites for professional operation such as adequate communication structures, training and qualification opportunities as well as a positive and productive working environment are created. Quality-determining process flows are clearly defined, documented and are continuously improved and adapted to changing requirements. Novel quality-determining processes are documented immediately. All related documents are clearly guided and controlled in order to guarantee a sustainable quality in all areas. Our quality awareness and understanding as well as the attitude of all employees towards quality are essential to achieving the project objectives and, by this, the satisfaction of our customers.

Our management stipulates the quality policy and ensures a consequent implementation of the quality management system. We are currently certified according to DIN EN ISO 9001:2015 and review the effectiveness of our quality management system by regular internal audits and quality meetings.

FRAUNHOFER IMM IN NUMBERS (2018)

28 %
INDUSTRIAL FINANCED R&D PROJECTS

72 %
PUBLICLY FINANCED R&D PROJECTS

REVENUES FROM EXTERNAL FUNDING SOURCES

< 20 %
PUBLIC

113
PROJECTS

> 80 %
INDUSTRIAL

5 %
CAPITAL SPENDING

12.4
MILLION EURO
CONTRACT RESEARCH

95 %
OPERATIONAL SPENDING

FRAUNHOFER IMM NETWORK

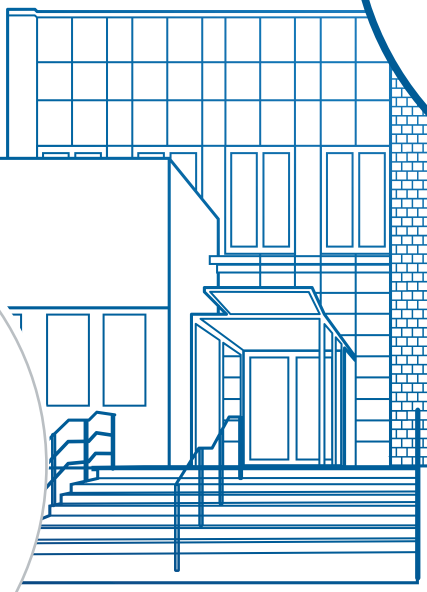
In order to secure our competitiveness and scientific excellence a close cooperation with research institutes and multipliers is of particular importance to us.
Our scientists and engineers therefore cooperate with universities, institutes and companies both nationally and internationally in development projects with a short-term and long-term focus.
Close connections to partners in the region are of special relevance in this process.

NETWORKS

CENTER OF SMART INTERFACES // DUAL CAREER NETWORK RHEINMAIN // MAINZ RESEARCH ALLIANCE E.V.// CLUSTER INDIVIDUALIZED IMMUNEINTERVENTION (CI3) E.V.

RESEARCH NETWORK

BMBF PROJECT PARTNERS // TU EINDHOVEN // EUROPEAN TECHNOLOGY PLATFORMS // EU PROJECT PARTNERS // BAM BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG // DECHEMA // PROCESS-NET



STUDENT RESEARCH PROJECTS AND DISSERTATIONS

UNIVERSITY OF MAINZ // UNIVERSITY OF APPLIED SCIENCES MAINZ // TU DARMSTADT // TU KAISERSLAUTERN // RHEINMAIN UNIVERSITY OF APPLIED SCIENCES // FRANKFURT UNIVERSITY OF APPLIED SCIENCES // KAISERSLAUTERN UNIVERSITY OF APPLIED SCIENCES // BINGEN UNIVERSITY OF APPLIED SCIENCES // UNIVERITY OF STUTTGART // UNIVERSITY OF DUISBURG-ESSEN

COOPERATIONS AND STAFF EXCHANGE

UNIVERSITY OF MAINZ // MAX PLANCK INSTITUTE FOR POLYMER RESEARCH MAINZ

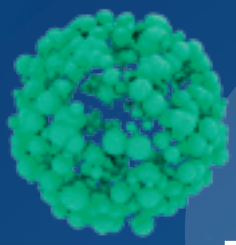
REGIONAL NETWORK

ASSOCIATIONS AND ALLIANCES

FRAUNHOFER
SPACE
ALLIANCE

FRAUNHOFER
ADDITIVE MANUFAC-TURING
ALLIANCE

FRAUNHOFER
ENERGY
ALLIANCE



FRAUNHOFER
NANO-TECHNOLOGY
ALLIANCE

FRAUNHOFER GROUP
MATERIALS

Joseph von Fraunhofer

FRAUNHOFER SOCIETY

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 26,600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

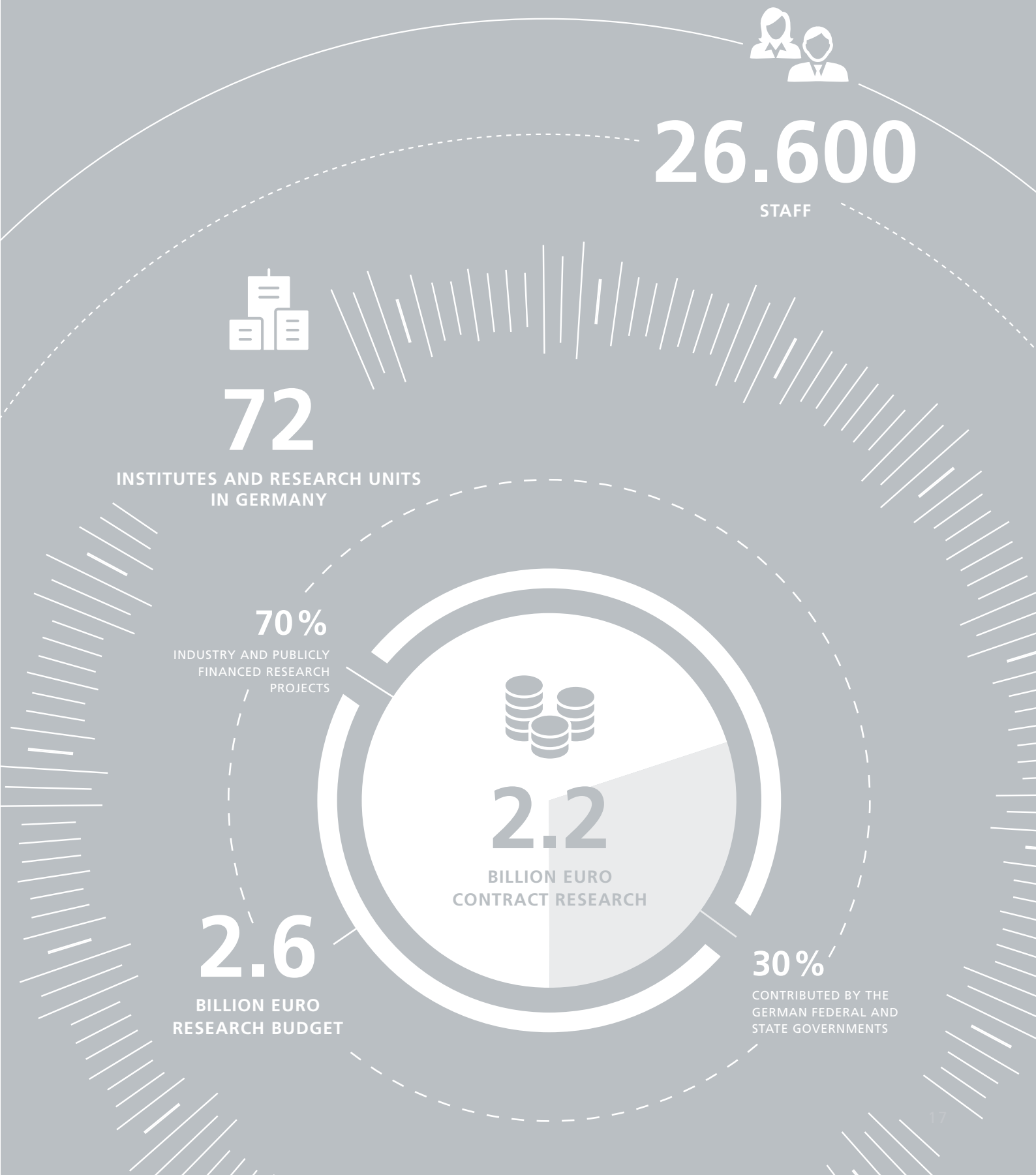
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

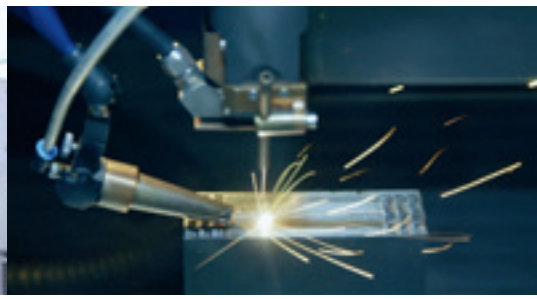
The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

FRAUNHOFER SOCIETY IN NUMBERS (JANUARY 2019)



After many years of cooperation with industrial enterprises we are familiar with our customers' requirements and markets in the field of Energy and Chemical technology and Analysis Systems and Sensors. We have the knowledge and experience to provide individually tailored and economically attractive solutions including:





ENERGY AND CHEMICAL TECHNOLOGY

PROCESSES, REACTORS, PLANTS

- Accelerated process development in fine chemistry
- Reproducible quality for customized cosmetics
- Increased efficiency and availability of active ingredients
- Increased process efficiency for complex photochemical applications
- Transforming biological waste into sustainable fuels
- Optimization of material and energy conversion systems
- Mobile energy supply
- Process analysis technology

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1 *Catalyst powder*
2 *Manual catalyst coating*
3 *Screen printing machine*

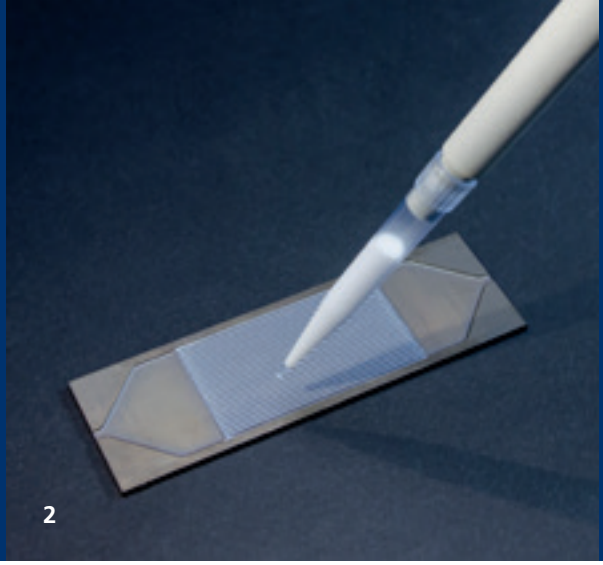
CATALYST DEVELOPMENT

The majority of chemical and petrochemical processes would not be possible without catalysis. This is also valid for the exhaust gas cleaning in the automotive segment. In close cooperation with the groups "Reactor and Component Design" and "Process Design and System Development" we at Fraunhofer IMM transfer catalyst formulations from fundamental research ready-to-use in real technical systems. The application of microstructured reactor technology allows for an easy upscaling of processes towards the megawatt scale. The currently available technical infrastructure enables the development and fabrication of novel catalysts, their coating on widely varying catalyst carriers as well as activity and stability testing. In this context the focus is as well on the project execution for industry as on the support of in-house research and development activities in fields of novel energy generation or storage systems and decentralized plants for renewable fuel synthesis. The resulting applied technologies and concepts will be path-breaking in many areas such as energy generation in aviation industry.

The development work of the Catalysis Group focusses on catalysts for hydrogen generation from fossil and renewable sources of energy, the generation of renewable fuels and on combustion reactions. In cooperation with partners from basic research, plant engineering and various industrial partners we synthesize, test and refine catalysts for use in the field of energy technology. The emphasis here is on long-term stability and robustness, for instance against catalyst poisons. All catalysts can be produced in an amount of several kilograms. The coating of microstructured reactors can be applied automatically by a self-developed, worldwide unique screen printing process. Due to their long-standing activities the Catalysis Group has established a far-reaching international network including partners from science and industry. Customers stem from chemical industry, automotive and aerospace but as well from medical technology.

> We develop catalysts and catalytic coatings being optimally adapted to the type of reactor and the scaling of the process.

The existing infrastructure at Fraunhofer IMM for the synthesis, characterization and evaluation of catalysts is, however, as well of interest for companies dealing with technologies for the utilization of electricity surplus from regenerative sources (power to x). In the framework of an internal cooperation with Fraunhofer IWES the methane synthesis from carbon dioxide is currently under investigation. A 50 kW scale plant is being constructed.



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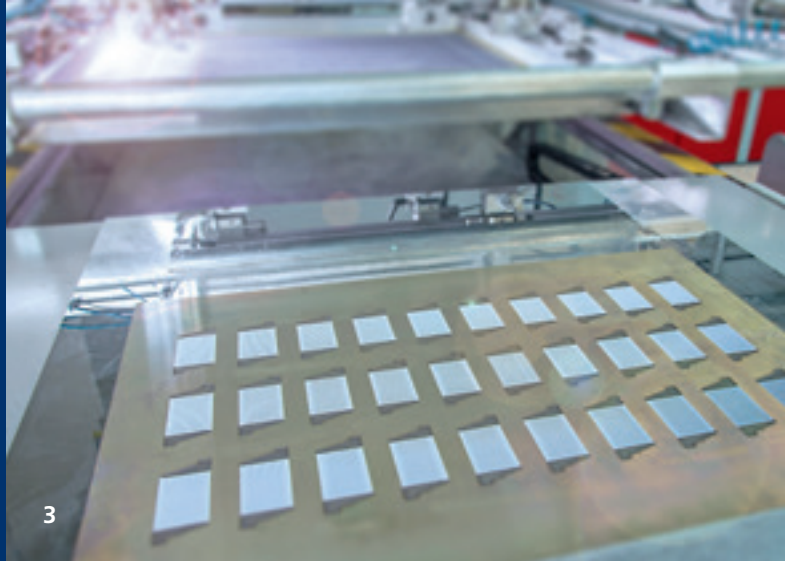

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Reaction Systems for Contract Research and Development

- **hydrogen production:** autothermal and steam reforming of (poly)alcohols and hydrocarbons, thermo catalytic decomposition and partial oxidation
- **catalytic combustion:** heat supply by combustion of hydrocarbons and (poly)alcohols, purification of synthesis gas / reformate / flue gas containing VOC, CO or hydrogen
- **reformate clean-up (CO removal) for fuel cells:** water-gas shift, methanation, preferential oxidation of CO
- **synthesis of oxygenated hydrocarbons:** e.g. methanol, dimethylether
- **methanation of CO2** (power to gas)

The Catalysis Group has a wealth of equipment at its disposal, including equipment for the synthesis of heterogeneous catalysts up to a semi-industrial scale via precipitation reaction, impregnation as well as further methods. Large ball mills and screening machines for the grinding and fractionation of the catalyst powder allow the production of sample quantities up to a kilogram scale. A screen printing machine is used for the application of catalyst coatings. The investigation of heterogeneously catalyzed gas phase reactions is done with 11 test benches equipped with a dosing of gaseous and vaporable feedstock, suited for activity investigation while varying various reaction parameters (temperature, pressure, gas composition, flow rate, etc. …). The product composition can be determined by means of on-line analysis systems such as 4 two-channel GC, 6 micro GC, 1 on-line MS, 3 GC-MS, 2 Fourier transformation infrared spectrometers. Long-term stability is investigated by using test rigs equipped with safety features as well as an automation for the investigation of catalysts under real process conditions.

From mid-2020, the new building with its laboratories and testing facilities will allow for even better working possibilities with respect to catalyst development as well as the examination and adaptation of pilot scale plants and large-scale chemical engineering reactors.

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1

1 *Grignard pilot reactor*
2 *Falling film microreactor for photo chemistry*
3 *Modular micro reactor*

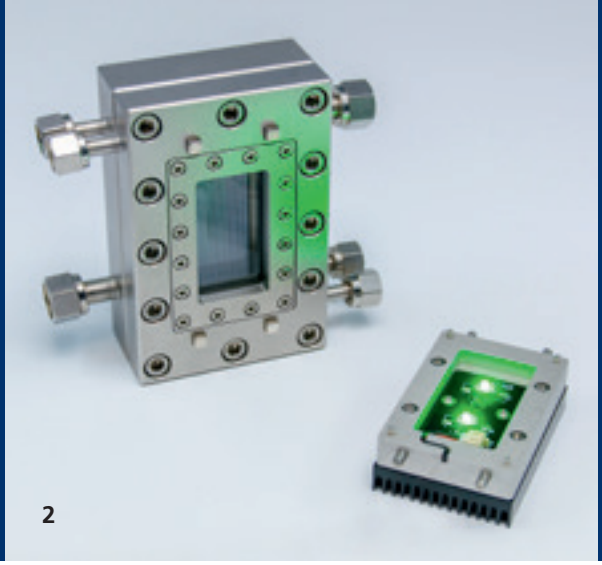
FLOW CHEMISTRY

The term flow chemistry in general is being used for chemical processes taking place in a continuously flowing stream with a defined reactor zone, which, in its most simple interpretation, can be a t-piece, a loop, a coil or a column. At Fraunhofer IMM microreactor technology is applied to convert chemical processes from batch to continuous allowing to improve their efficiency and to open up new process regimes. The structuring of the reactors leads to improved mass and heat transfer, allows regular streaming patterns and small reactor set-ups, and finally enables precise adjustment and control of optimum process conditions. Easy scalability is inherent for this approach.

> In a holistic approach we consider all influencing factors such as suitable catalysts as well as manufacturing technologies, components and plants appropriate for series production up to intensified process conditions.

The Flow Chemistry Group uses microstructured standard reactors available from an extensive hardware portfolio to perform single synthesis steps, usually being exothermic, mixing intensive or high pressure and/or temperature, to convert batch to continuous. The portfolio includes mixers and reactors for lab, pilot and close-to-production throughput. More challenging reaction classes are handled by designing and developing especially suited reactors being able to perform multi-step synthesis processes. Beyond the individual process engineering components, concepts are developed for the upscaling of processes and complete reaction systems up to pilot plants. The infrastructure for feasibility studies and process development work up to pilot scale is available. The group relies on a unique wealth of experience resulting from numerous projects with fine chemistry and pharma industry as well as from publicly funded projects dealing with chemistry and special plant engineering.

Ozonolysis, halogenation reactions, the synthesis of ionic liquids, nitration, hydrogenation, epoxidation and ethoxylation reactions as well as polymerizations are classic examples that benefit from being processed in flow reactors. The targeted use of harsh process conditions enabled by and controlled due to novel reactor concepts opens up significantly improved opportunities for processing. Increased productivity within the flow process itself can often be achieved in particular through faster reactions thanks to the increase of process temperature. We have for instance achieved successes in the anionic polymerization by realizing a high product quality, the epoxidation of soybean oil by reaching an increased space-time yield, the supercritical biodiesel production using lower value raw material.



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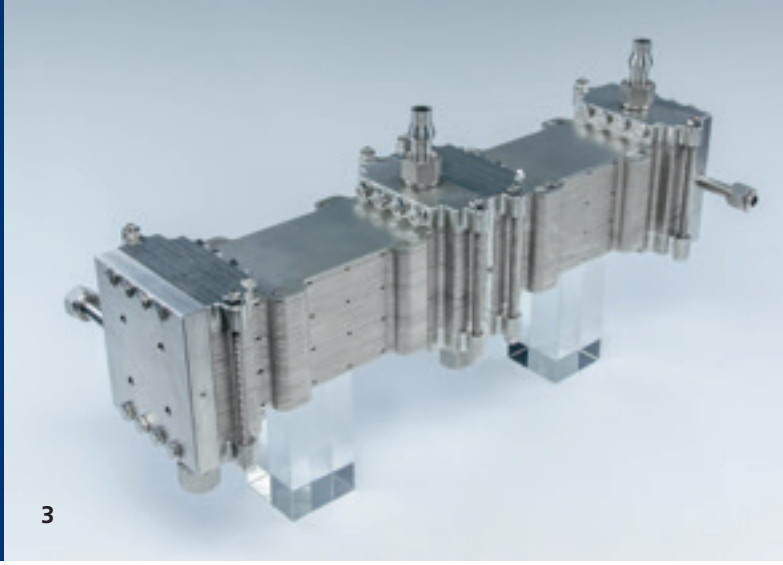

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We currently have a strong focus on exploiting the potential of photochemistry, electrochemistry and the synthesis of reactive intermediates.

- **Photochemistry:** Light as energy carrier in combination with microstructured reactors allows for novel, more efficient and controllable reaction conditions due to an excellent contacting and mass transfer between liquid and gas phases. Falling film microreactors for immobilized photo catalysts and capillary photo reactors for longer irradiation times are available. Established processes are the in-situ generation of singlet oxygen for photo oxygenations and the photochemical C-H arylation by photochemically activating diazonium salts as reactive intermediate.
- **Electrochemistry:** Chemicals can be produced under mild and exactly controllable reaction conditions with the electron as sole reaction partner. Improved conversion, yield, selectivity and energy efficiency by a homogeneous current density distribution and electrolyte flow. A variety of electrodes and electrode materials is available for use. Throughputs up to 1 l/min at a current density higher than 8.1 kA/m^2 are possible. Established processes are Kolbe electrolysis, anisic aldehyde synthesis and cation flow method as well as peroxydicarbonate electro synthesis.
- **Reactive intermediates:** Core competence is the continuous preparation of reactive intermediates such as Grignard reagents with an integrated activation and continuous supply of the required solid component. Using a large excess of the solid component suppresses unwanted side reactions. Feasibility has already been demonstrated at lab scale level for 1M and 2M PhMgBr, 1M EtMgBr, 1M AllylMgBr, all in THF. Pilot plant level is supposed to be achieved by the end of 2019.

We design chemical processes in a safe, flexible and versatile manner.

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1 *Assembling of a pilot plant*
2 *Laser welding of a reactor*
3 *CAD model of a fuel processor system*

REACTOR AND COMPONENT DESIGN

The demand for increasingly customized products taking into account individual requirements leads to ever-shorter product cycles across industries. Accordingly, companies need to respond rapidly and flexibly to changing market situations in order to maintain the acceptance of their products and their competitiveness.

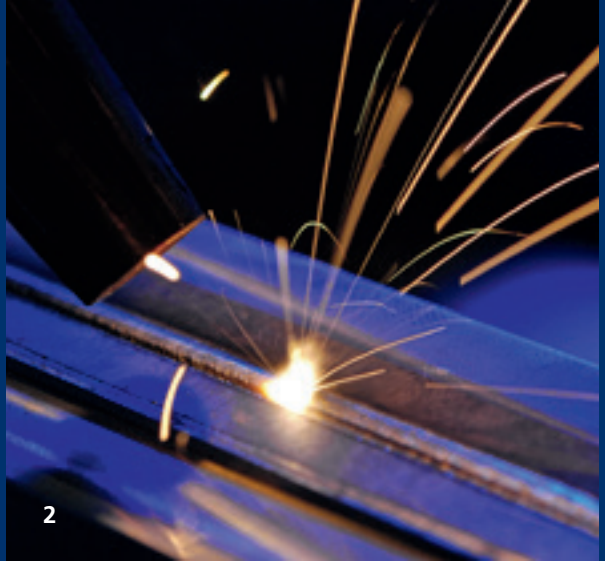
As many of these products contain special and fine chemicals, which were specially formulated, the production of these chemicals needs to take place in an increasingly environmentally friendly, resource saving, safer and more cost-efficient manner. This consistently implies a decentralized production in small plants close to the consumer as well. A further approach relies on the intensification of the processes involved. We use our extensive hardware portfolio as well as our long-time experience to develop individually adapted reactors in a modular and scalable design, meeting the requirements of the process to be optimized. Thanks to their properties, micro- and millistructured reactors or devices are ideally suited to solve the issues described. Even larger quantities are technically well feasible.

The development work of the Reactor and Component Design Group focusses on applications in the fields of energy and chemistry, designing the reactors and components for a continuous operation mode. A range of mixers and reactors is available for lab, pilot and small production scale as well as decentralized concepts for energy technology. Fast and intense mixing, dispersion and heat exchange are enabled by the structure dimensions. Reactors are designed by CREO Elements (3D CAD) and self-developed design tools. The implementation of catalyst coatings allows performing catalyzed gas and liquid phase processes as well as gas/liquid processes in special designs. A wide portfolio of solutions for single-phase or multi-phase processes as well as for non-catalytic, heterogeneously and homogeneously catalyzed reactions is at hand.

> Micro- and millistructured reactors allow for production at the point-of-use.

This includes reactors for heterogeneous gas phase reactions for temperatures up to 800 °C (e.g. reforming of hydrocarbons).

The development and use of various cost-efficient fabrication technologies for the plate stack reactors often used is part of the work, such as wet chemical etching, rolling and embossing for the structuring of reactor plates as well as laser welding and vacuum brazing for joining the plates of a stack, including additive manufacturing processes such as laser melting. The reactors for applications in the field of energy technology are future mass products similar to automotive exhaust cleaning reactors. We continuously work on the cost reduction for the production of reactors for these applications. A wealth of experience is available in reactor design, plant layout and plant automation. Thus, the customer is guided from the initial idea via simulation up to the realization of a functional model, but as well up to fabrication of pilot series or a technology transfer.



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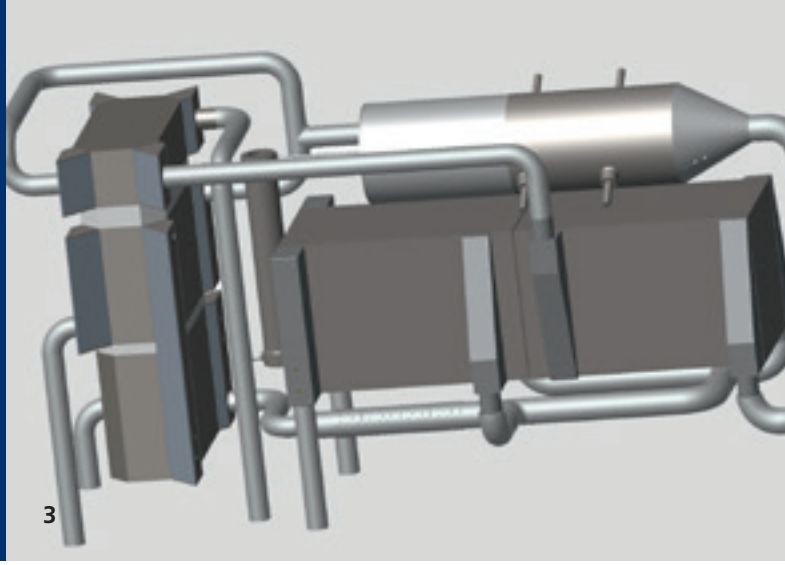

3

The main advantages of the reactor technology are:

- **increased compactness and system dynamics:** integrated cooling function and integrated coupling of reactions, approach is in most cases based on the microstructured plate heat exchanger technology with proven mechanical and thermal stability
- **higher energy and resource efficiency:** exact adjustment and control of process conditions allow for higher selectivity and yield as well as a concerted adjustment of product properties, improved mass and heat transfer, regular flow patterns
- **increased process safety:** smaller reactor hold-ups
- **process intensification:** development of new process regimes for chemical processes (novel process windows), enabling higher productivity
- **faster time to market with less risk:** easy scalability of reactor concepts
- **decentralized approach for the production of chemicals and energy:** possible due to intensified processes and increased compactness of reactors
- **flexibly adaptable production of chemicals:** modular concepts for the reactors themselves and the plant engineering

Applications include highly exothermic processes, integrated reactors to obtain and work up gases containing reformers and complete fuel processors for hydrogen production from different conventional and renewable fuels as well as reactors for the decentralized production of critical chemicals. A wide temperature range between -250 °C and 1200 °C has already been realized. Extensive experience exists with the welding of high temperature steels. Lightweight aluminum is used whenever the weight of the components is crucial such as in aerospace.

One of our cooled reactors for the combustion of highly toxic waste gases is running with an endurance of 35,000 hours for more than 8 years now at the premises of one of our industrial customers.

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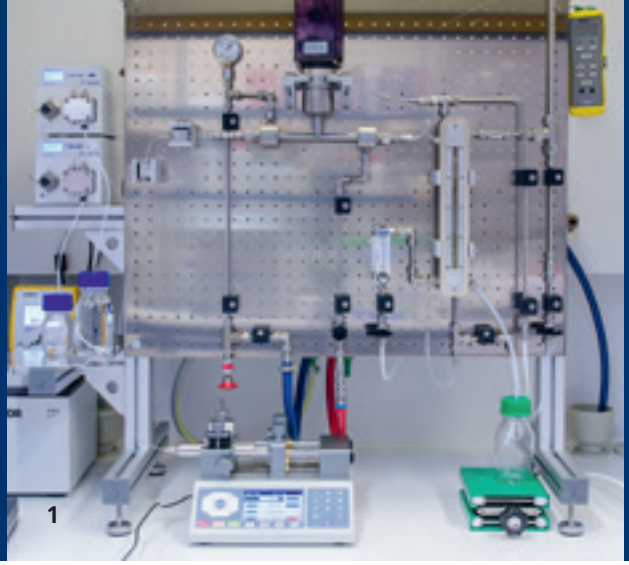


1 *Lab scale plant for the encapsulation of nanoparticles*
2 *Flow diagramm of a pilot plant*
3 *Pilot plant for drug synthesis*

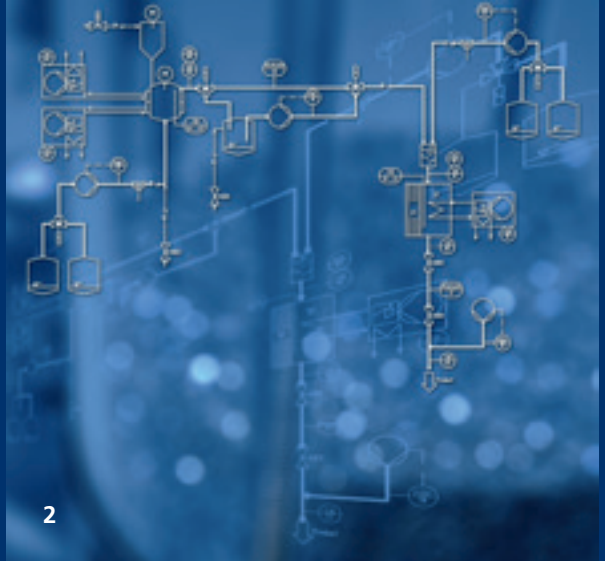
PROCESS DESIGN AND SYSTEM DEVELOPMENT

Microreactors and -devices permit an improved control over exothermic reactions or process conditions. Interconnecting microreactors and -devices in process systems allows very compact plants, which are predestinated for decentralized applications in chemical and energy technology. Taking into account the use of renewable energies and resources for the storage of energy and for the production of fuels as application field, the development work contributes to a sustainable use and utilization of resources in urban systems organized in a decentralized way. The service comprises in general the whole or partial chain from simulation, CAD design via method and process development, basic engineering and detailed engineering up to the provision of components, assembly and initial operation. Risk assessment and safety-related considerations are integral parts of all development work.

The portfolio of the Process Design and System Development Group comprises process development, system design and heat integration (PROSIM, COMSOL), basic engineering (PTC Creo, AutoCad), system control and regulating technology development (LabView, Step7, C++) providing balance of plant concepts, development of auxiliary processes and tests of reactors and complete complex systems. For that purpose a variety of test rigs is available allowing gas flows up to the m³/h range, pressures up to 400 bar and temperatures from -270 °C up to 1100 °C. Plant development is performed from miniplant technology up to pilot scale and includes plants for gaseous, liquid as well as supercritical fluids and mixtures. An energy turnover up to the megawatt range can be realized.

Thanks to a profound wealth of experience from more than 15 years of development services, the group has realized complex projects in cooperation with many partners. The interdisciplinary team consists of coworkers for plant engineering comprising engineers, scientists and technicians in the disciplines chemical process engineering, chemical engineering, control technology, construction and manufacturing. Beyond that, a well-positioned network of business partners and service providers can be involved in the development work on demand. Of course, there is an inevitable and intense interaction with the Catalysis, Flow Chemistry and Reactor and Component Design Groups.

> The optional integration of the plants can be done into an existing plant periphery or as all-in-one-system in 20 to 40 inch containers.



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The developments are preferably used by automotive industry, aerospace, chemical, petrochemical and pharmaceutical industry, energy supply and plant engineering.

Typical application scenarios the group is dealing with include:

- **hydrogen generation for fuel cell systems:** development of complete fuel processors based on microstructured plate heat exchanger technology, reformer technology
- **systems for exhaust gas treatment:** in the field of fuel processing technology particular expertise in eliminating carbon monoxide out of the reformate flow via water-gas shift, preferential (selective) oxidation of carbon monoxide, selective methanation
- **air-conditioning technology** for mobile and decentralized stationary applications
- **decentralized fuel synthesis based on renewable feedstock:** producing bio fuels flexibly and on-site, and without long transport routes
- **safety-related systems** based on catalytic combustion
- **synthesis of fine and special chemicals as well as pharmaceutical ingredients:** for more detailed information refer to the Flow Chemistry Group
- **photochemistry:** for more detailed information refer to the Flow Chemistry Group
- **heterogeneously catalyzed organic reactions**
- **synthesis of reactive intermediates:** for more detailed information refer to the #whatsnext? chapter
- **nanoparticle synthesis:** for more detailed information refer to the Nanoparticle Technology Group

Our developments are preferably used in the sectors exhaust gas treatment, air-conditioning, automotive industry, aerospace, chemical, petrochemical and pharmaceutical industry, energy supply and plant engineering.

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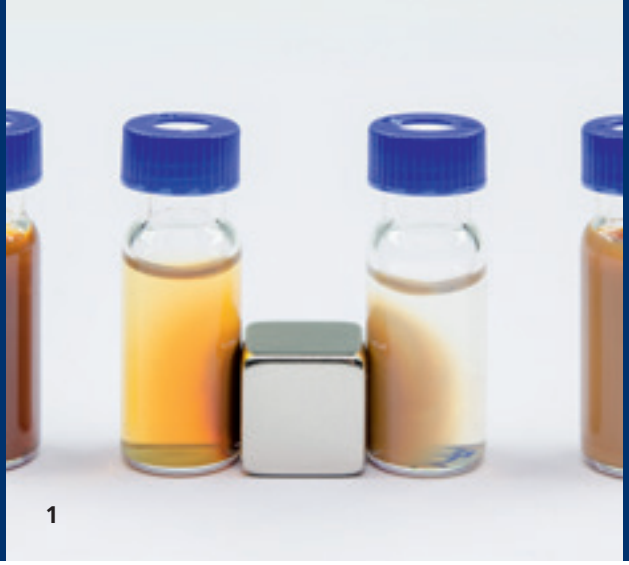

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1 *Magnetic nanoparticles*
2 *Fluorescent quantum dots*
3 *Pilot plant for nanoparticle synthesis*

NANOPARTICLE TECHNOLOGY

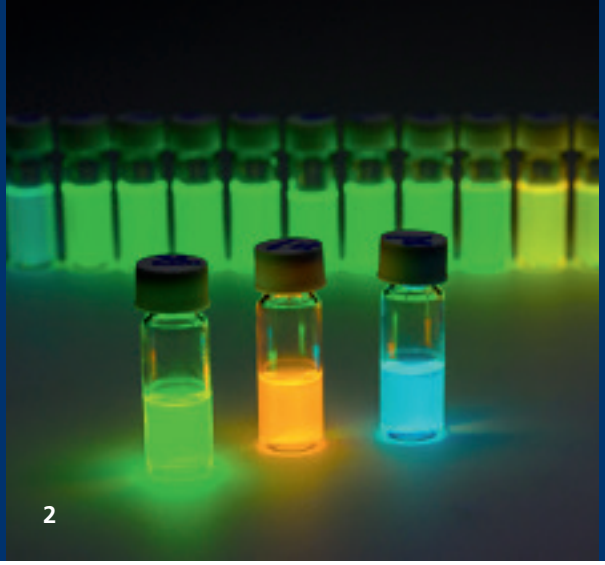
Nanoparticles made from inorganic and organic/polymer materials have unique properties, which have already been demonstrated in various applications in material sciences and life sciences. This comprises coatings, adhesives, polymers, catalysts, paper, assembly and packaging technology, textiles, food, cosmetic and pharmaceutical products. Higher chemical reactivity and biological activity as well as an enhanced catalytic performance are properties usually attributed to nanoparticles. This is primarily due to the higher surface area to volume ratio. The more complex application scenarios are, the more urgent the demand for tailor-made and, above all, consistent product quality is getting. The product quality often directly depends from particle size and size distribution.

> Small particles allow to open up complex application scenarios.

The development work of the Nanoparticle Technology Group comprises on the one hand the adaptation and development of processes to achieve high quality uniform nano formulations. This part of the work is mainly based on a continuously operated micromixer based platform technology, which allows adjusting flow rate and temperature precisely. Size-controlled formulations of hydrophobic and hydrophilic substances in a range between 50 and 300 nm are possible. Particle diameters can be precisely tuned to achieve values between 5 and 230 nm. Concentrations range from 5 to 1500 mg/l with maximum flow rates of up to 200 ml/min. In order to improve specificity and effectivity particles can be functionalized, active ingredients can be encapsulated for in-situ release. On the other hand, the characterization of nanoparticles in liquid and solid media is integral part of the work. The method diversity in the characterization of nanoparticles includes, for instance, electron microscopes, dynamic light scattering, static light scattering, analytic centrifugation, optical spectroscopy (transmission, absorption, fluorescence, thermo FTIR), streaming potential and zeta potential.

Further projects deal with the development of close-to-reality systems for the examination of the interaction between nanoparticles and biological material.

Specific particle systems we are working on comprise fluorescent quantum dots, single core iron oxide nanoparticles as well as polymer particles and capsules made of, e.g., polyacrylates, polyurethanes as well as crosslinked polysaccharides.



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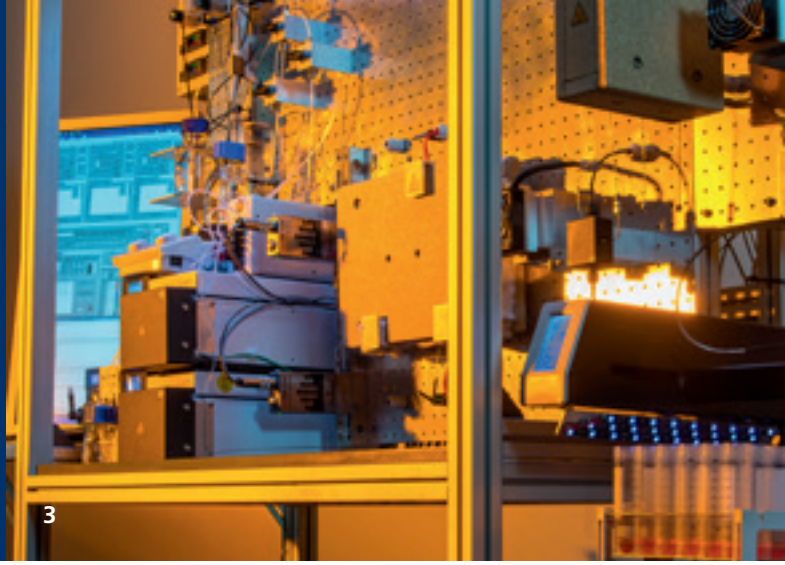

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The main advantages of the technology are:

- **scalable, continuous synthesis processes** while exactly controlling process parameters like flow rate and temperature, scalable from lab over pilot to production scale
- transfer of product specific batch processes into fast and easily controllable **continuous processes**
- **size- and shape-controlled continuous production** of nano formulations without post treatment, in just a few minutes on a decaliter scale
- **fast and controlled production and loading** of various nano formulations and carrier systems such as liposomes, polymersomes, niosomes, tensid-stabilized lipid and polymer particles
- **implementation of desired properties** such as fluorescence, magnetism, catalytic activity, fouling inhibition, durability (for instance against temperature, humidity, heat, light), antimicrobial surfaces, protein repelling, biocompatibility or ion and gas selectivity
- **integrated purification and on-line analysis** resulting in a feedback process control for rapid development
- **access to novel formulations** that can hardly be achieved following the conventional way due to challenging solubility properties
- **determination of nanoparticle diameter in flow via dynamic light scattering:** compact device using cost efficient standard components, compensation of flow speed via image processing is included, at-line and off-line measurements possible, fully functional device is available

Further developments towards higher particle concentrations and the simultaneous size determination of various particle sizes are targeted.

Due to our long-time experience in the field of chemical micro process engineering as well as in the design and realization of continuous chemical processes in flow chemistry we are capable to confer the desired properties to our customers' particles in a reproducible quality.

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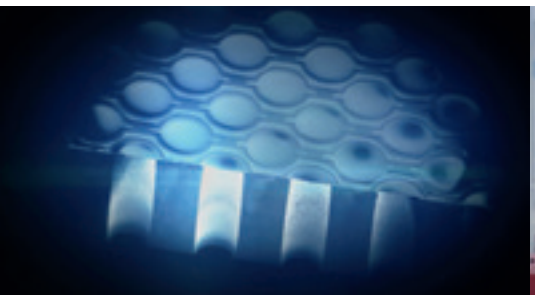
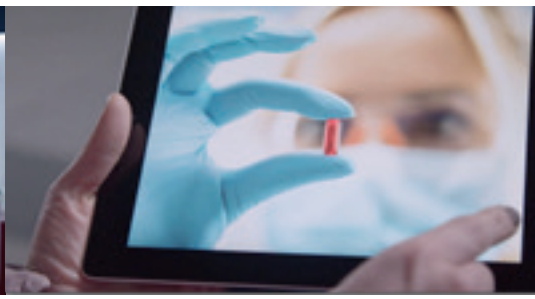
After many years of cooperation with industrial enterprises we are familiar with our customers' requirements and markets in the field of Energy and Chemical technology and Analysis Systems and Sensors. We have the knowledge and experience to provide individually tailored and economically attractive solutions including:





ANALYSIS SYSTEMS AND SENSORS

METHODS, COMPONENTS, SYSTEMS

- Isolation of circulating tumor cells (CTCs) from blood
- Micro flow cytometry
- Mobile platform for versatile Point-of-Care testing
- Simultaneous and continuous µ-titration on a chip
- Lab-on-chip for rapid liver monitoring
- Microelectrodes for neural recording and stimulation
- Radiation measurement in fusion experiments
- High-precision double slit for earth observation
- On-line oil monitoring in machines/motors
- Nanoparticle characterization in-line

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1

1 *Device for continuous µ-titration*
2 *Multi-parameter oil sensor*
3 *Fluid dynamics simulation*

METHOD DEVELOPMENT ANALYTICS AND SIMULATION

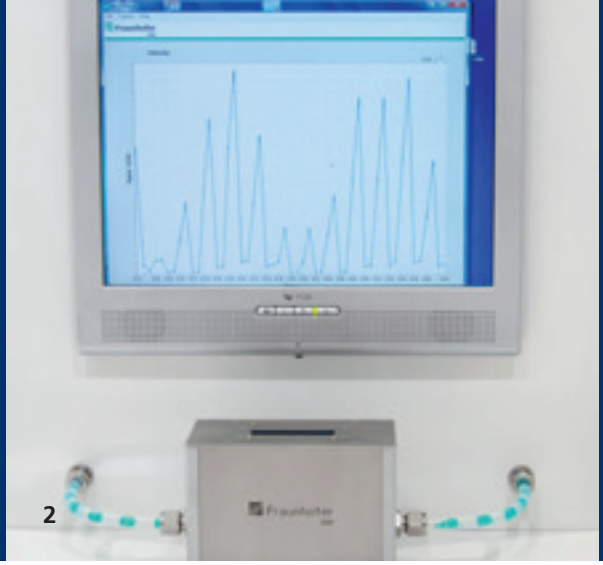
The use of microfluidics and the related system technology for the handling of liquid quantities from the micro- to picoliter range, the so called lab-on-a-chip technology, contributes significantly to the development of efficient analysis methods and, thus, is about to revolutionize lab technology. The combination of high sensitivity and resolution combined with shorter analysis times and high throughput makes lab-on-a-chip technology interesting for a variety of applications.

The Method Development Analytics and Simulation Group at Fraunhofer IMM has particular expertise in the downsizing of macro applications to fit to µ-fluidic requirements. As pioneer in this field for more than 20 years the group serves business fields such as medical diagnostics and life science, protection against biological hazards, food and beverage, power plants, semiconductors, environmental monitoring, automated laboratory measurement instrumentation as well as process and quality control for industrial production processes, water and waste water treatment as well as aerospace. For life science applications the group's spectrum of methods comprises sample preparation, assay development or modification, development of chemical analysis methods, lyophilization of reagents, surface treatment, liquid biopsy, amplification, immuno-magnetic cell separation, DNA isolation and extraction. For chemical analysis purpose extensive experience exists with the measurement of density, flow rate, pH value, conductivity and potentiometry. Ion-selective detection, voltammetry, refraction, viscosity, photometry, light scattering and capillary electrophoresis complement the portfolio. Diffusion, vibration, deflection, radiation absorbance, gravity, light scattering, molecule or ion sensitivity form a sound basis for sensing and detection tasks.

> We use innovative physicochemical methods and implement automated and optimized workflows in order to develop tailor-made solutions.

Advantages resulting from the use of microfluidic methods include:

- increased reproducibility by eliminating application errors
- increase of throughput due to faster measurements reducing reagent consumption
- opening-up of measurements (on-site or in-line) which were not feasible before
- integrated data analysis and transfer



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As speed and quality of product development can significantly benefit from applying numerical simulation and mathematical modelling, these are integral part of the research and development projects. With more than 20 years of experience in the modelling of microsystems, especially in microfluidics, Fraunhofer IMM accompanies its customers through the whole process of problem analysis, the selection of the appropriate simulation environment, the optimization of components, systems and processes ending with data interpretation – always placing a strong emphasis on the interplay between simulation and experimental development work. At the same time we work on further developing and improving simulation tools being optimized for the use with microsystems. There is a range of CFD software at our disposal, which is based on either the finite volume method or the finite element method.

Moreover, this gives us the possibility to perform so called "multiphysics" simulations, i.e. to interlink several physical phenomena in order to address the systems in their entirety in the best possible way. Typical questions refer to fluid dynamics, heat transfer, mixing and chemical reactions as well as interaction with electric and magnetic fields and multi-phase systems (solid-liquid, gaseous-liquid or gaseous-solid).

Resulting benefits are:

- faster development times
- cost reduction in the development process due to better planning and data interpretation
- improved performance and robustness of the system
- better product understanding

The close interaction with the experimental validation and the technical prototyping makes modelling at Fraunhofer IMM outstanding.

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1 *Injection moulding*
2 *Lab-on-a-chip system*
3 *PCR cartridge made by injection moulding*

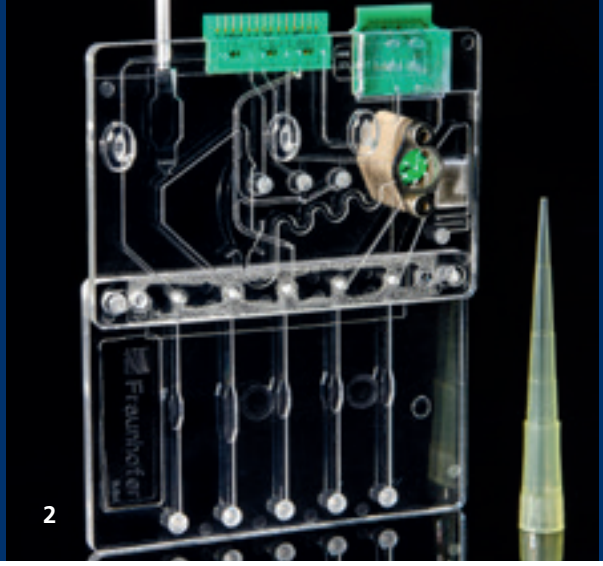
MICROFLUIDICS, COMPONENTS AND ASSEMBLY DEVELOPMENT

Today, it is well known that the transfer of (bio-)chemical standard assays into disposable microfluidic polymer cartridges facilitates a considerable reduction of precious chemicals and resulting wastes as well. Furthermore, the option to employ highly efficient microfluidic mixing strategies for reagents and samples together with accelerated heat transfer in small volumes opens up the advantage of significantly reduced processing times.

The Microfluidics, Components and Assembly Development Group at Fraunhofer IMM deals with the realization of various types of microfluidic chips and the components required for the sophisticated functionalities implemented on the chips. It as well provides any kind of peripheral component or technology needed to yield a fully functional system. The group possesses a long-time knowledge in liquid sample handling in custom developed microfluidic cartridges of various polymer materials. Functions achieved so far include metering, splitting, mixing, aliquotation, spotting of a wide variety of chemical agents, bio-reagents and cell dispersions, PCR on-chip, cell culturing on-chip, electrochemical sensing, optical sensing, dry and wet reagent storage on-chip, positive and negative enrichment, cell lysis and purification. The related polymer devices may integrate different types of valves as well as pumping functions. A variety of processes is available to render polymer surface properties either by means of chemical or mechanical surface modification or by coatings to realize hydrophilicity, hydrophobicity or the ability to bind certain marker species specifically. For sensing purposes, the direct on-chip integration of passive micro-optical features like gratings, mirrors and wave-guides is possible as well as the integration of electrochemical sensors. In cooperation with the Method Development Analytics and Simulation Group expertise in design and numerical simulation of polymer-based microfluidic cartridge systems is provided.

> We transfer results into a “microfluidic circuit diagram” for the microfluidic cartridge including, where appropriate, the interface for sample collection, integrated sample preparation and the required sensors.

Knowing all the applicable regulations (e.g. IVD, CE and machinery directive), the availability of essential manufacturing methods on-site as well as application labs being equipped to high excellence ensure that all aspects of feasibility later on are appropriately considered at any time.



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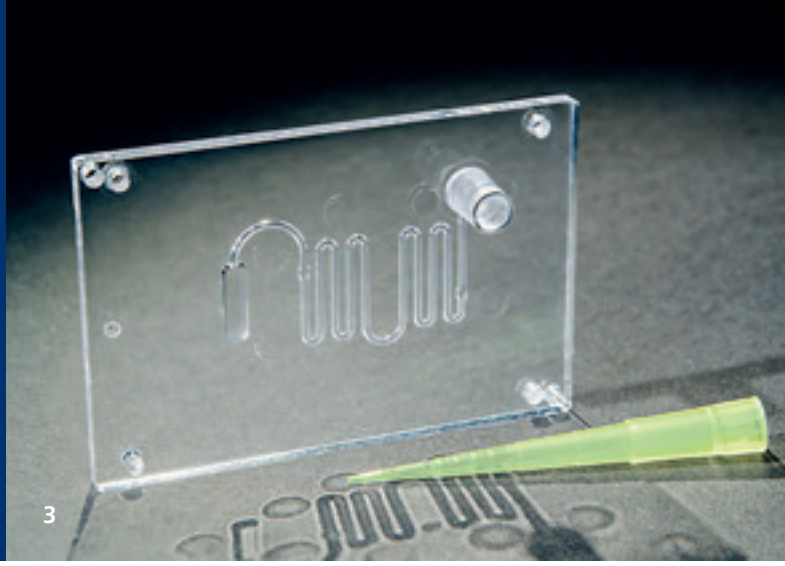
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Fraunhofer IMM offers its customers a comprehensive processing platform for the realization of microfluidic polymer devices starting from the design and manufacturing of first prototype samples for concept validation up to batch production of pilot series on small and medium scale.

The most frequently used methods comprise:

- **direct cutting in polymer substrates:** milling or laser machining are used for the realization of prototypes on small scale (in cooperation with the Precision Components Development and Fabrication Group and the Reactor and Component Design Group), an excimer laser is employed for precise mask-based ablation of channels down to a size of 5 µm with low surface roughness and for functionalizing the polymer surface, realization of interconnects and substrate cutting or drilling via CO_2 laser
- **hot embossing and injection molding:** custom designed tools and mold inserts are made in-house, high quality optical waveguide structures realized by using a hot embossing tool made by precision milling, fabrication of fluidic channels with a small cross section of 10 microns depth and 500 microns width via injection molding with a mold insert realized via a dedicated precision milling process in hardened tool steel
- **polymer joining technologies:** required for tight and reliable sealing of microfluidic structures with cover lids and on-chip integration of further components such as e.g. fluid connectors, valves and reservoirs. The portfolio includes ultra-sonic welding, thermal laser welding, solvent welding, lamination, gluing and chemically or plasma activated bonding which allow to achieve bond strengths that can withstand up to several bars of pressure, UV enhanced bonding used to cover 10 microns deep and 500 microns wide channels

We always think beyond the fabrication of single pieces using fabrication and assembly methods that are easily transferable to mass production.

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1 *Precision milling of a micro mixer*
2 *Die-sinking with the SonoDrive 300 (IMM development)*
3 *Close-up view of a die-sinking process*

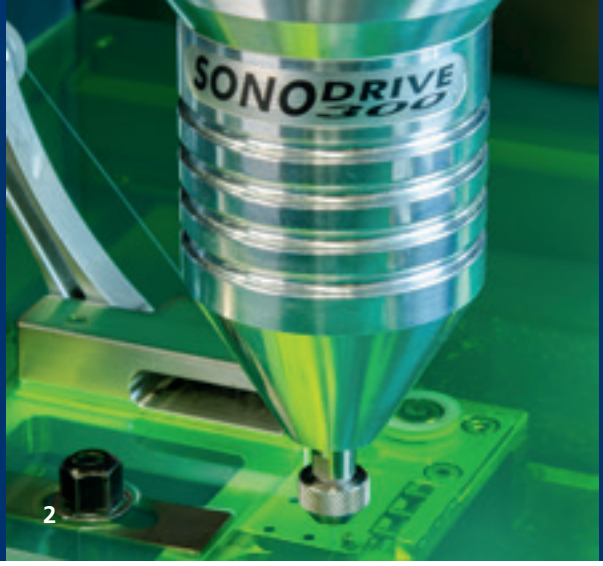
PRECISION COMPONENTS DEVELOPMENT AND FABRICATION

Complex, multifunctional but easy to handle – that's the product development challenge often faced today. Complete, intelligent systems require components made by using various materials and technologies. The combination of cutting-edge manufacturing processes and established machining equipment are Fraunhofer IMM's technological backbone. Combining procedures and processes from various technological fields allows breaking new ground in application development.

The Precision Components Development and Fabrication Group combines more than 20 years of experience in micro machining and electro discharge machining. The EDM part of the group stands for multi-axis die-sinking, wire electro discharge machining (EDM) and fine wire EDM as well as micro EDM-turning - always realizing tight tolerances at high quality surface finishing. Flexibly combining different processing technologies is the key to successful R&D work, prototyping and pilot lot production, allowing creating new machining strategies. The number of ways to realize microstructures and microstructured parts is manifold. Advanced and combined manufacturing in a continuous process chain is possible having optional tools such as vibrating electrode chucks, vibrating drilling devices, electrode dressing units and integrated high precision zero-point fixation at hand. The ideal combination out of the broad range of technologies is used for R&D work, prototyping and pilot lot production. The mechanical processing part of the group offers the possibility to machine a large variety of work piece materials from standard metal parts to special alloys and ceramics. This includes the high precision machining of hardened steel parts, e.g. mold inserts, and the realization of micro parts and micro EDM-electrodes. The fabrication technology portfolio beyond the group is completed by laser manufacturing (cutting, welding, ablation, micro drilling), photolithography, advanced silicon etching and thin film technology.

The precision components development and fabrication group understands itself mainly as a crosscutting service provider for the more application oriented R&D groups. However, it as well fosters its own development work aiming at further improving the available fabrication technologies.

> By merging R&D and manufacturing competencies under one roof, Fraunhofer IMM offers its partners customer-specific, microsystem technology-based solutions beyond commercially available standards.



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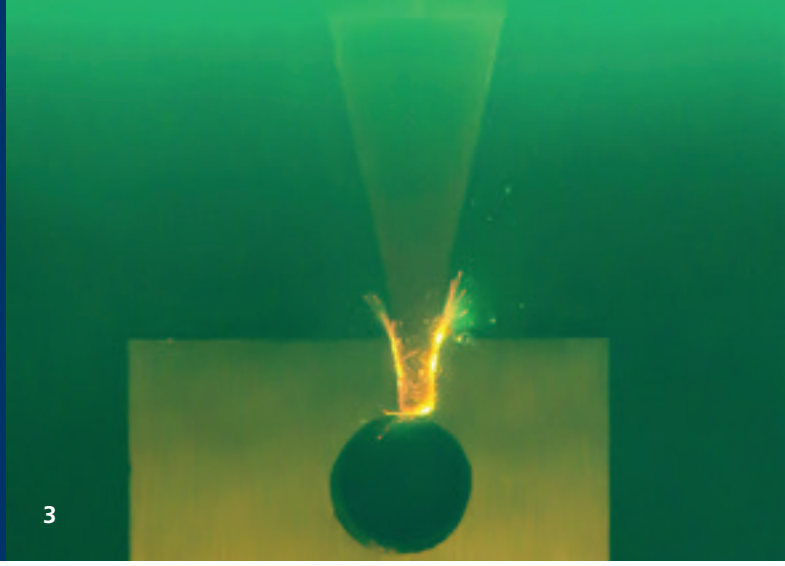
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Machinery and measurement tools available:

- **die-sinking EDM:** 4-axis CNC-controlled EDM die-sinking machines, 0.1 µm resolution, additional 2-axis CNC-table, rotation axis, vibrating electrode chuck, vibrating rotation spindle, µ-electrode dressing unit
- **wire EDM:** single wire machines with wire diameters 0.05-0.3 mm, additional CNC B-Axis high speed micro spinner devices, twin wire machine wire diameter 0.02-0.2 mm, high speed micro spinner device
- **ultra precision machining:** UP-lathe with additional Y-axis table or diamond turning and linear milling operations
- **3D CNC-milling system:** max. travel 500*350 mm, z-axis 610 mm, high-speed spindles, automatic tool change, high pressure cooling system with internal tool cooling option, minimal quantity lubrication system, laser tool measurement
- **2,5D CNC-milling system:** max. travel 500*260 mm, z-axis 160 mm
- **CNC lathe with driven tools:** 12 tool holder, 6 driven tool holder, various clamping systems, high pressure cooling system
- **3D CNC-optical measuring system:** max. travel 250*200 mm, z-axis 200 mm
- **profile projector:** Magnification lenses 50x, 200x, 500x

This equipment is complemented by a variety of further inspection tools and portable measuring instruments.

To preserve and extend our core competencies, we practice a continuing education of our employees and train junior staff to become precision mechanics.

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1 *Touch screen of a DSP on-line monitoring system*
2 *Touch screen of the PanPlex device*
3 *Smart circuit board for process monitoring*

PROTOCOL DESIGN AND SYSTEM INTEGRATION

The trend towards miniaturization has become well established in medical diagnostics as well as process analytics and will be further continued. Buzzwords like point-of-care-testing, Industrie 4.0, real-time measurement and big data dominate headlines and discussions. Although concrete measures not too seldom remain rather vague, one thing seems to be crystal clear – the need for generating data, rapidly and reliably, in time and increasingly on-site. One strategy to meet this demand is to downsize measurement systems to compact and thus portable devices using a microfluidic approach.

The Protocol Design and System Integration Group is more or less the final instance at Fraunhofer IMM being responsible for providing a fully functional system as project result – a dedicated device including electronics and software. As such, all the skills required for system engineering, system integration, automation and design/engineering with respect to electronics, firmware, software are gathered in this group, which is closely interacting with the method development and microfluidic components and assembly experts in house. Complete biological, chemical and electromechanical validation of the entire systems under real conditions is included. At the end of the line, there is either an easily adaptable lab-on-a-chip based platform technology or a stand-alone system available to perform single or multi-parameter measurements to identify some kind of analyte (for instance biomarkers, DNA, living cells, bacteria, viruses or other hazardous compounds) with the purpose of detecting, monitoring or primarily generating data – on-line, in-line or off-line. Combining advanced sample preparation methods (one example among others is the so-called "Liquid Biopsy") with sensitive measurement technologies (e.g. nucleic acid or immunodiagnostic based) allows for a complete, automated sample analysis (sample in - answer out).

> The increasing demand for smart/intelligent sensors, analytical systems for process monitoring and point-of-care systems as well as for instruments for pandemic studies is the stimulation for our daily work.

Due to a broad coverage of all necessary core technologies (integration of bioassays, chip design and manufacturing, systems engineering, prototype and apparatus engineering, optics and sensor technology, electronics and software) the initial application idea can be rapidly developed into a fully functional demonstrator. The application fields are diverse and range from CBRN detection, process monitoring, environmental monitoring to infection control, active agent testing, diagnostics and individualized therapy.

2


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Some applications focussing on patient-side diagnostics, process analytical technology (PAT) and lab automation are:

- **isolation of circulating tumor cells (CTC) from blood:** isolation of CTCs from 7,5 ml blood to single wells in µl-droplets, fully automated system, unprecedented CTC recovery, magnetic separation of CTCs
- **micro flow cytometry:** counting bacteria and detecting cells in microfluidic systems, using self-aligning disposable flow cells and robust / calibration free detection
- **mobile platform for versatile point-of-care testing:** complete and compact system for pandemic surveys, fully automated sample preparation, PCR amplification and assay incorporated, integrated analysis software
- **lab-on-chip for rapid liver monitoring:** µ-fluidic chip incorporating sampling, sample preparation and analytical methods for liver function tests
- **continuous glucose measurement:** sensor based on transmission spectroscopy in the near infrared range (NIR), measuring continuously and providing the required accuracy over the entire physiologically relevant concentration range
- **oil monitoring on-line in machines/motors:** smart and compact IR-detection system for lubricants, simultaneous in-line detection of water, soot, TAN, oxidants
- **simultaneous and continuous µ-titration on a chip:** microfluidic titration for stand-alone measurements or on-line process monitoring, continuous determination of equivalent points while substantially reducing reagent consumption

We miniaturize tests and enable our customers to apply individual therapeutic or situation specific analytical approaches. Although we are following a micro-fluidic approach, we can even handle large sample volumes.

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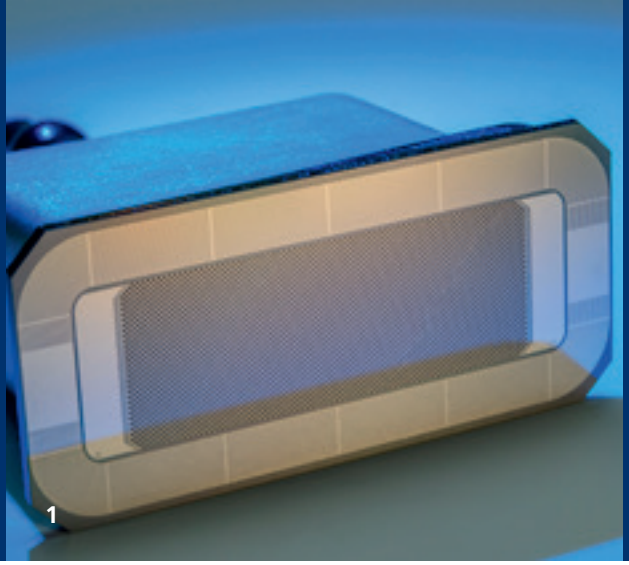


1 *Helium sensor*
2 *Wafer with bolometers for the plasma examination*
3 *Close-up view of the bolometers*

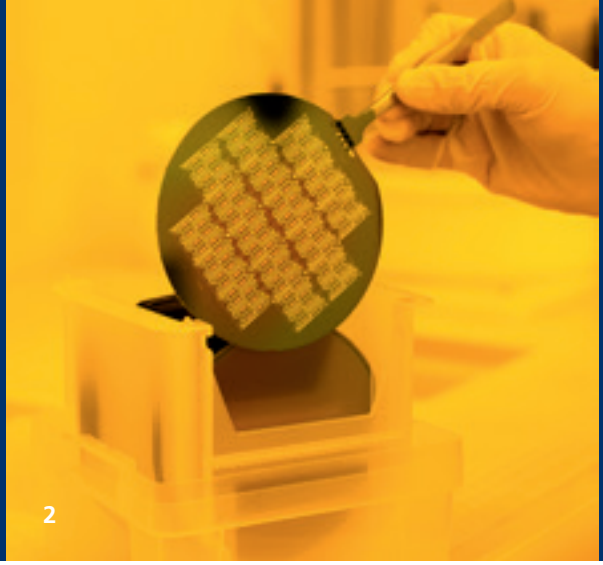
SENSOR DEVELOPMENT AND FABRICATION

Use and impact of sensors in industry and across our everyday societal use scenarios are steadily growing. Roughly, 100 sensors are measuring approximately a dozen of physical properties in a car. Although this is only one prominent example, this already makes obvious, that accuracy, reliability and to a certain extent robustness are properties being mandatory for many of the use cases.

The Sensor Development and Fabrication Group at Fraunhofer IMM has devoted its work to the realization of innovative sensors and system components according to the customers' needs relying on silicon and thin film technology. Solutions elaborated are far beyond the common state-of-the-art with respect to functionality, performance and demand to fabrication technology. In some cases even concerning very harsh environmental conditions such as changing thermal loads up to 450 °C together with high radiation levels, high shock loads or rocket launch. Thus, clients and partners from research receive customized solutions matching their special technical measurement issues. The service portfolio comprises design and simulation, process development, realization of demonstrators for the verification of feasibility as well as pilot series in documented quality for further validation by the customer in product use.

Examples for application developments performed on direct customer's order or in the course of research partnerships are three-axial tactile sensors for the measurement of pressure and shear forces with piezo resistive transducers, flow rate sensors for gases and liquids as well as a density sensor for liquids based on a microfluidic U-tube resonator. Furthermore, helium and hydrogen detection via highly selective thin film membranes, bolometer sensors for fusion research with high radiation and temperature resistance, microelectrode structures for electrochemical analysis, flexible and rigid multichannel microelectrode probes for neural recording and stimulation as well as micro optical components such as flow-through cells have already been developed. The most extreme precision requirements were managed in the realization of an ultra-precise double-slit chip for an environmental monitoring application.

> Our customers come from industrial instrumentation and analytics, medical device manufacturing, biodiagnostics, aerospace and cutting-edge research.



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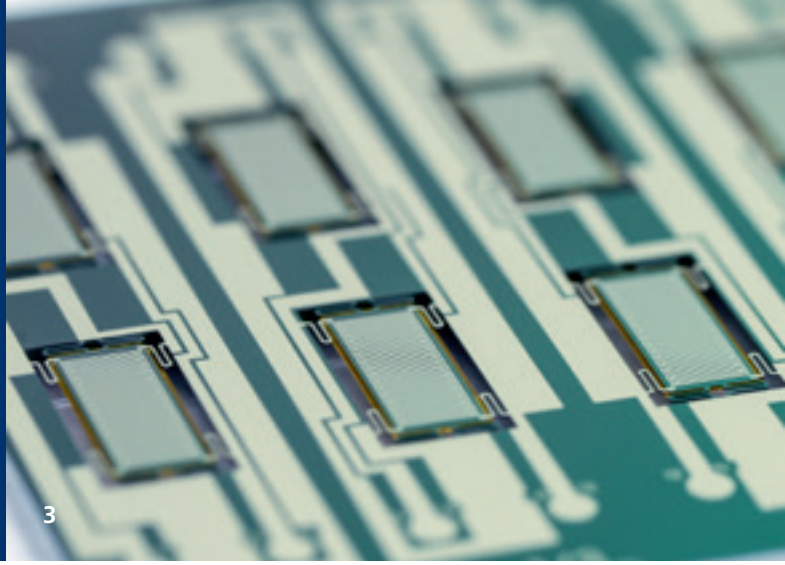

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Fraunhofer IMM has a high-performance cleanroom process line at disposal including comprehensive metrology for quality inspection and control.

Some of the dedicated MEMS specific processes used at highest level for application deployment are the following:

- thick-layer resists and resist spray coating for realizing and processing of 3D topologies by means of **UV lithography**
- wet and dry **chemical deep structuring of silicon** including SOI wafer processing
- film **stress optimized PECVD and LPCVD** processes, for instance for realization of thin, self-supporting functional elements and free-standing membranes
- multitarget and **reactive gas sputtering**, for instance for the deposition of alloys and oxidic functional layers
- **micro electroplating and electroforming** of, for instance, noble metals such as gold and platinum with a layer thickness of up to several 10 µm or, respectively, low-stress copper and nickel deposits up to a thickness of several millimeters
- **assembly and packaging technologies**, for instance flip-chip and wire bonding for electrical contacting or creation of silicon-silicon and silicon-glass stacks on wafer level

Both, the skills and expertise of our process engineers and a well-equipped cleanroom facility for silicon micromachining, assembly and metrology provide the basis to transform innovative ideas into new product applications.

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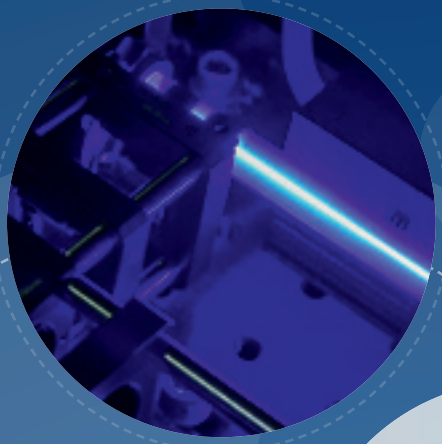

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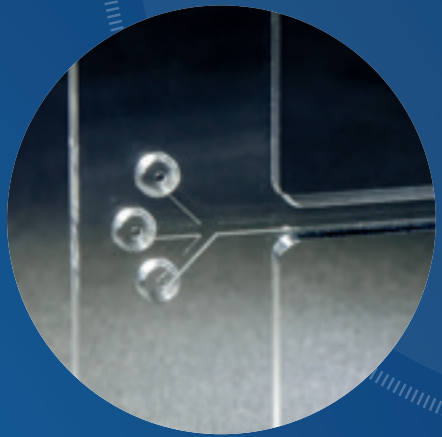

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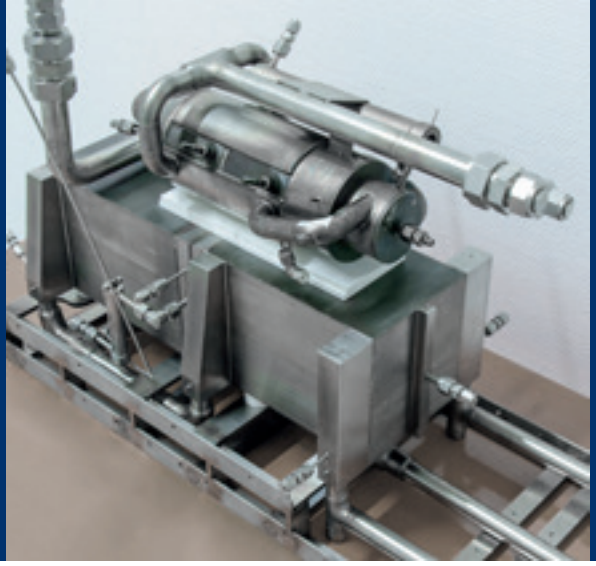


Propylene glycol fuel processor

GETPower

GALLEY ENERGY TROLLEY POWER

Current efforts are directed towards the increase of the environmental compatibility of aviation while reducing the CO_2 and noise emissions. In the framework of previous projects, a mobile power supply for passenger aircraft based on propylene glycol as fuel has been developed together with the lead company Diehl Aerospace GmbH. The overall goal was to relieve the aircraft main turbine and the auxiliary power unit (APU) from the task of producing electricity for passenger convenience. As the galleys are one of the main consumers of electricity in the aircraft, a trolley was chosen as a mobile unit, which can be docked to the galley, and in this way ensures its energy supply.

The goal of the GETPower project series is the further development of the already existing reformer system, to achieve an optimized integration of the entire system into a standard trolley and, thus, to get as close as possible to a scenario which can be realistically applied in aviation. This includes work with respect to possible input fuels, construction materials and system design, but as well aims to develop a cost model for diverse business cases. At the end, GETPower will contribute to improve energy supply and management in the aircraft cabin by implementing an innovative and safe network solution in the sense of a "more electric aircraft".

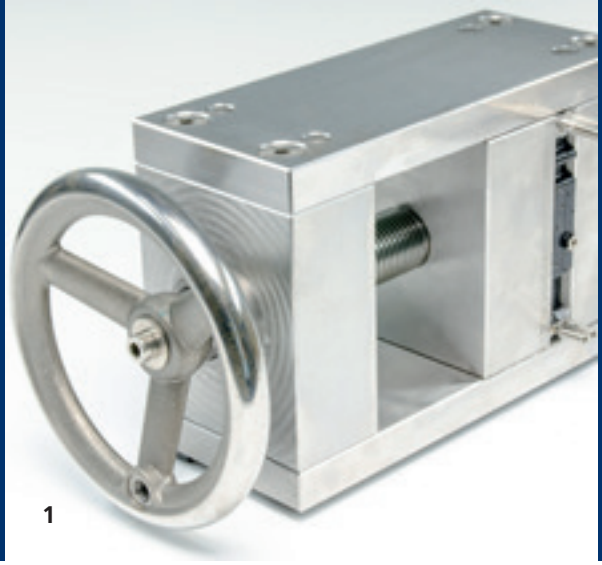
Project GETPower / 2, funding references:
BMWi, 20K1514A / 20Y1710

Fraunhofer IMM contribution

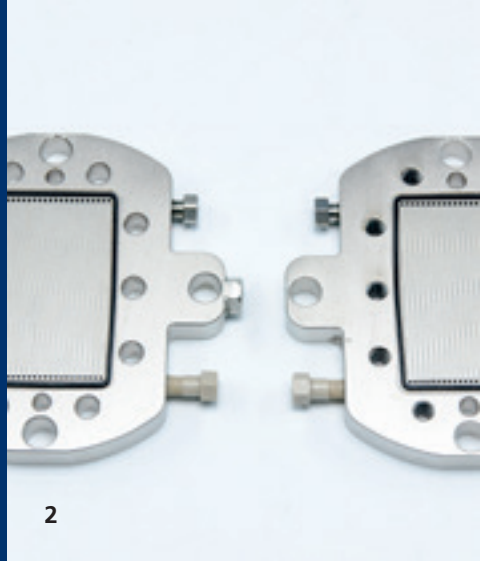
- Extension of the concept towards further renewable fuels already used in aviation such as ethylene glycol and glycerin
- Realization of reformer components made of lightweight material to the extent possible allowing to further reduce weight of the whole setup
- Cost reduction with respect to the fabrication of the reactor technology by applying embossing, stamping and 3D printing
- Simulation calculations with respect to the thermal and mechanical wear and tear to improve the overall system design
- Improvement of the thermal system management

Fraunhofer IMM competencies

- Extensive experience in design, construction and fabrication in the field of fuel processors
- Development of catalysts and catalyst coatings ideally suited for use in microstructures being optimally adapted to reactor type and scale of process
- Availability of test equipment for the determination of the performance and stability of catalysts
- Development of several auxiliary power units based on fuel cells using methanol, ethanol, LPG, gasoline and diesel
- Realization of the worldwide first reformer system using propylene glycol as fuel in the framework of the DIANA project.



1 *Electrochemical microreactor*
2 *New plate design of electrochemical reactor*



ELMIFLEX

FLEXIBLE ELECTROCHEMICAL MICROREACTOR CONCEPT FOR THE ELECTRIFICATION OF ORGANIC SYNTHESIS

Goals of the emerging area of green chemistry are to save energy and to reduce the use of hazardous chemicals as much as possible. Besides energy generation and energy storage the range of applications includes organic electrochemistry. A further benefit when applying electrochemical procedures is the direct use potential for sustainably generated excess energy. In this context, organic electrochemistry is currently experiencing some kind of renaissance allowing reactions without „substantive" reagents that would have to be separated in their used form from the reaction products.

In the development of the reactor concept an approach based on housed plate stacks is followed. The required stability and pressure tightness is achieved by pressing of the stacks. One electrochemical cell consists of two plates allowing parallel or serial operation of up to ten cells in the same housing.
Due to a small electrode spacing a thin-gap cell in principle allows for low ohmic resistances, low energy losses, short diffusion paths, effective heat control, homogeneous mass and power distribution, greatly reduced need for conducting salt and shorter residence times.

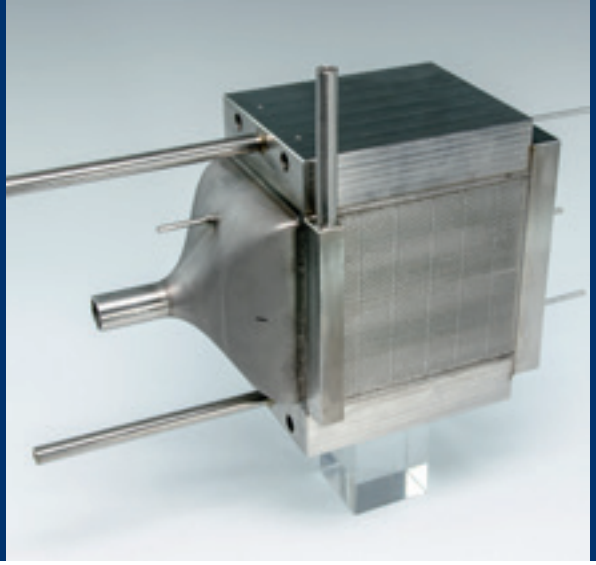
Fraunhofer IMM contribution

- Further development of the microreactor concept with respect to the broadest possible applicability for diverse electrochemical conversions in varying throughputs
- Realization of a prototype of the electrochemical reactor system including modular design allowing the variation of throughputs by a factor of 10 while guaranteeing an easy exchange of electrode materials
- Usability for temperatures down to -70 °C, high pressure stability up to approx. 50 bar
- Validation of the prototype for two sample reactions
- Evaluation in a continuous processing chain including on-line analytics

Fraunhofer IMM competencies

- Fundamentals of a flexible electrochemical microreactor concept allowing to address the challenges of precision, reproducibility and modularity available; pioneering electrochemical microreactors developed as early as 1998
- Simulation capabilities with respect to flow distribution
- Optimized processing chain for structuring, coating and joining
- Use of additive fabrication technologies for metallic components

Project ELMIFLEX, funding reference:
State of Rhineland-Palatinate, 15412-52 123-7 / 40 (9)



Laser welded methanation reactor

ICOCAD

INNOVATIVE CONCEPT FOR CARBON DIOXIDE UTILIZATION AS SIDE STREAM OF INTEGRATED BIO-REFINERY CONCEPTS

Due to increasingly tougher environmental legislation new processes, using less energy and materials, being less polluting in terms of by-product generation and eliminating the need for treatment of waste, are required. Germany is Europe's biggest biogas producer as it is the market leader in biogas technology. Even a very rough calculation by rule of thumb shows that there is an economically very interesting amount of CO_2 to be converted into methane related to this sector.

The objective of the ICOCAD project is to develop innovative reactor technology for the methanation of carbon dioxide, separated from biogas plants and integrated bio-refineries, and to verify its suitability through pilot scale testing and plant concept development. This includes the construction of a prototype reactor, which will be installed in an already existing plant environment. The second aim of ICOCAD is the development of innovative, durable, poisoning and coking resistant catalyst formulations for the methanation of the carbon dioxide to methane utilizing hydrogen from water electrolysis. The applied reactor technology allows modular reactor design, which can easily be adjusted to the individual size and demands of the carbon dioxide and hydrogen sources. Due to thin layers of catalyst, the new plate heat exchanger reactor design is beneficial with respect to increasing the thermal and mechanical stability of catalysts.

Project ICOCAD, funding reference:
FNR, 22400215

Fraunhofer IMM contribution

- Development and test of the noble metal containing catalyst formulations: catalyst design, preparation and characterization; evaluation of catalyst activity
- Durability and stability testing of the noble metal containing catalysts
- Design of the pilot reactor allowing to minimize the system start-up time; catalyst coating of the microstructured reactor plates; sealing of the reactor by laser welding
- Support of pilot scale reactor integration and field testing – joint development of plant concept

Fraunhofer IMM competencies

- Extensive experience in catalyst design and catalyst coating technologies, including support and preparation methods
- Reactor design and development of plate heat exchangers for heterogeneously catalyzed gas phase reactions at larger scale, especially for energy-related applications
- Testing facilities for the determination of the performance and stability of catalysts by means of cutting edge on-line measurement technology

MethGas test rig

METHGAS

DEVELOPMENT OF A DECENTRALIZED PLANT CONCEPT FOR THE CONVERSION OF RENEWABLE ENERGY CARRIERS INTO NATURAL GAS

Natural gas supply is primarily coupled to the natural gas grid. Off-grid systems for heating, energy generation and natural gas fueling can be supplied by liquefied natural gas. Assuming a sufficiently high acceptance, the boil-off related loss in liquefied natural gas tanks is not a major problem. In application scenarios with less frequent use the heat input related losses, however, can easily call the economic feasibility in question. In such cases, a mobile plant would be required, that allows the conversion of a liquid energy carrier, which can be stored as long as required, into natural gas.

The objective of the METHGAS project is the development of catalysts and of a decentralized plant concept to provide natural gas with conventional specifications from renewable energy sources such as alcohols. In order to increase the compactness of the decentralized plant microstructured reactors are used. Methanol is converted into synthesis gas using a steam reformer based on a microstructured plate heat exchanger technology allowing an optimum energy transfer between exothermic and endothermic process steps. Subsequently, the methanization of the carbon oxides containing synthesis gas into a methane rich gas mixture takes place. Finally, the unconverted hydrogen and carbon dioxide have to be separated by pressure swing adsorption.

Project METHGAS, funding reference:
Foundation for Innovation Rhineland-Palatinate,
961-386261 / 1191

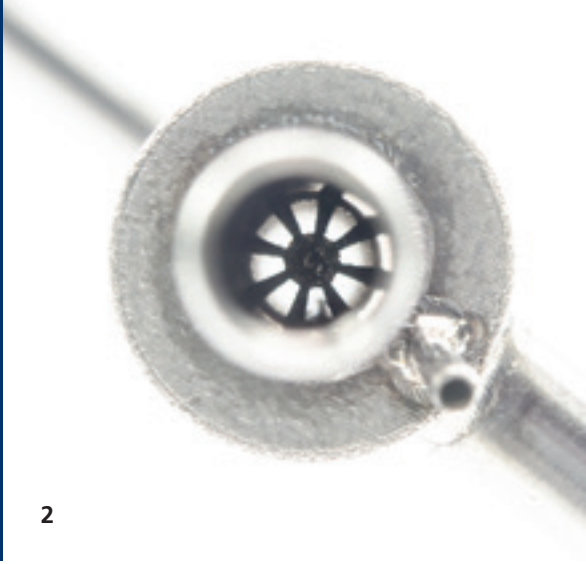
Fraunhofer IMM contribution

- Further development of the catalyst for the steam reforming of methanol
- Development of a catalyst for the methanization of carbon oxides being able to tolerate small amounts of non-converted alcohol
- Activity and long-term stability test of the catalysts achieving at least a 2,000 hours lifetime
- Refinement of the simulation model for the plant
- Verification of the concept via the design and realization of and via performing tests with the demonstration plant (system start-up, partial load, full load)

Fraunhofer IMM competencies

- Design and construction of microstructured reactors for gas phase reactions
- Plate heat exchanger approach to allow a modular construction approach
- Extensive experience in catalyst design and catalyst coating technologies
- Project experience with respect to the methanol reforming process
- Selective methanization of carbon monoxide in the presence of large amounts of carbon dioxide

1 *Modular microreactor made by laser sintering*
2 *Heat exchanger made by laser sintering*



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Additive Manufacturing

PROGRESSIVE PROCESSES IN THE FABRICATION OF MICROSTRUCTURED DEVICES

The integrated approach for device, process and system development in combination with the utilization as well as (further) development of progressive techniques for the fabrication of microstructured devices is essential for sustainable success in Fraunhofer IMM's business fields Energy & Chemical Technology and Analysis Systems & Sensors. These processes include laser ablation, laser welding and cutting, vacuum brazing, electro erosive processes as well as precision mechanical processing, embossing, rolling, rotary stamping and wet chemical etching. For a couple of years now, the fabrication technologies mentioned before are complemented by generative processes, especially by using selective laser melting (SLM). SLM is used for the cost efficient realization of special devices with microstructures preferably made of stainless steel or other corrosion resistant metals. This on the one hand gives access to devices, which either could not be realized in the conventional way or could be realized accepting higher efforts. On the other hand, a cost efficient realization of small series of devices frequently required becomes possible.

Cooperating with renowned manufacturers and doing our own research we have built-up the required expertise to generate a production-ready design for the devices. Future goal is to implement catalysts or oxidic catalyst supports during the generative fabrication process of the reactors. Fraunhofer IMM is member of the working group lightweight construction of the Transfer Initiative Rhineland-Palatinate intensively dealing with additive manufacturing and member of the working group micro process engineering of ProcessNet. Application fields for the mostly microstructured devices, especially the chemical reactors, partially or completely fabricated by generative processes, mainly focus on fine and specialty chemistry and energy technology.

Fraunhofer IMM's efforts to exploit the enhanced possibilities offered by generative fabrication processes are strictly application driven:

- Highly exothermic solid-liquid reactions
- Electrochemical reactions
- Heterogeneously catalyzed gas phase reactions
- Power to liquid processes
- Production of fuels and chemicals from renewable resources
- Heat exchange including condensation and evaporation

3D printing will perspectively also gain importance in biomedical applications where the functionally complex production of organs or organ models in a most ordered way is targeted.

Internal project

1 *Device for nanoparticle determination by the sizing of dynamic light scattering*

2 *Device for nanoparticle determination using the Tyndall effect*

Static and Dynamic Light Scattering

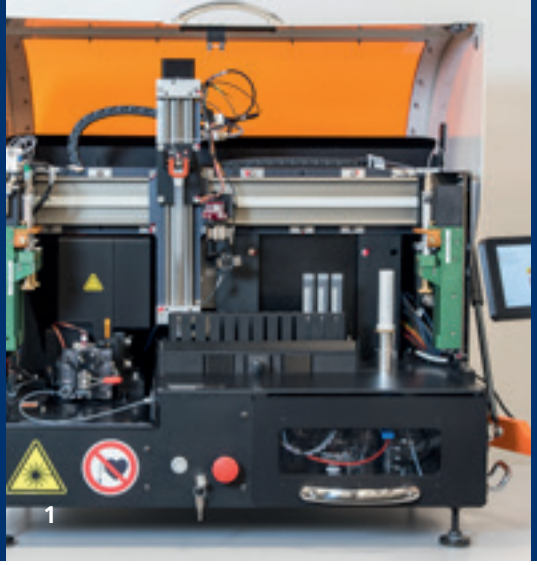
CHARACTERIZATION OF NANOPARTICLE CONTAINING DISPERSIONS

Laser scattered-light analysis is widely used in industry for quality control purposes. Dynamic light scattering (DLS) and static light scattering (SLS) both allow an easy characterization of dispersions. As the methods are not relying on any special property of the analyte, they are applicable to a wide spectrum of analyte materials and solvents.

As there still is a lack of fast and cost effective in-line/on-line particle sizing devices based on the DLS method, Fraunhofer IMM has developed, patented and implemented a new technique for measuring DLS continuously and in flow in a fully integrable and easy-to-use instrument. Compared to currently available approaches this system has achieved a substantial advantage, as it is able to suppress the influence of additional particle movement caused by the sample flow using efficient digital image processing before the calculation of the particle size is started. Thus, no constant flow conditions are required as long as the flow is laminar. The current optical and fluidics setup allows the determination of particle sizes at high flow rates of up to 200 ml/min. The use of low-price image sensors, laser diodes and standard computer hardware as they are found in consumer electronics contributes to moderate system costs. The flow DLS device auto-calibrates to different particle sizes and concentrations as well as to different flow velocities. The instrument can be connected to an industrial process control system by a serial interface.

Internal project

One of the quality attributes of nanostructured materials is that individual nanoparticles are not segregated and subsequently relieved into the environment. Therefore, the water solubility corresponding to OECD Test Guideline No. 105 has to be checked. The test requires, amongst others, "the check of the presence of colloidal matter by examination of the Tyndall effect". The light scattering devices actually available on the market either lack sensitivity for low concentrations of small particles or they are very expensive and need a highly qualified operator to interpret the results. Therefore, a proof-of-principle demonstrator has been developed which is suitable for product monitoring and for the cost-efficient, easy to use and highly sensitive determination of nanoparticle contents in aquatic colloids. The demonstrator allows for the determination of the average particle size and the corresponding concentration of synthetic amorphous silica nanoparticles with a diameter down to five nm in aquatic colloids. It is suitable for in-site characterization and for product monitoring both in a certified stationary and in a mobile test laboratory.



1 *CTCelect device, 2nd gen. with open hood*
2 *CTCelect device, second generation*

CTCelect

ISOLATION OF CIRCULATING TUMOR CELLS FROM PATIENT BLOOD

The scientists at Fraunhofer IMM have already come a long way in preliminary projects. In cancer research, tumor cells circulating in the blood are seen as an important source of information on the progress of the disease and possible therapeutic approaches. As part of the Ci3 Cluster for Individualized Immune Intervention, a microfluidic flow cytometer with integrated single cell dispenser (CTCelect) was developed that can fully automatically isolate tumor cells from a patient's blood sample. Each isolated tumor cell can then be examined for its genetic and molecular biological properties. This allows conclusions on how different tumor types respond to a treatment so that drugs can be specifically developed. The processes were optimized using model systems so that the fully automatic flow from blood to individual cells could be reliably tested.

In the further course of the project, the aim is to validate and characterize the previously implemented process of enriching and isolating freely circulating tumor cells on real clinical samples. Another focus will be on the investigation and overcoming of major non-technical innovation hurdles. For this purpose, a demonstration device with associated assay will be set up in order to collect the requirements of the clinical users. The clinical user, the Institute for Translational Skin Cancer Research at the University Hospital Essen, will test the optimized system for its robustness, error tolerance and user-friendliness on clinical samples related to the isolation and further characterization of circulating carcinoma and melanoma cells. The Fraunhofer Institute for Systems and Innovation Research ISI will determine the technical and non-technical requirements of future users of the system. In addition, the Karlsruhe Institute will carry out an analysis of the target markets and an assessment of market acceptance, as well as examining key legal and ethical aspects.

The verification and evaluation of the real data obtained in the course of the project is of great importance for the continuation of the work and the achievement of the set goals.

Project CTCelect, funding reference:
BMBF, 03VP01061

Fraunhofer IMM contribution

- Standardized liquid biopsy procedure to be tested under clinical conditions
- Systematic testing in model systems to prove the basic functionality of the concept
- Optimization of detection and dispensing unit
- Characterization of the "by-catch"

Fraunhofer IMM competencies

- Transfer of standard assays into a microfluidic chip-based environment
- Processing of large volume samples in a microfluidic environment
- Broad project expertise in on-site diagnostic applications

1 *Micorofluidic cartridge*
2 *PanPlex device, 2nd gen.*

PANPLEX

POINT-OF-CARE SYSTEM FOR THE RAPID DIAGNOSIS OF INFLUENZA SUBTYPES

Facing an epidemic or pandemic outbreak, a precise and rapid identification of infected people is required to be able to reliably estimate the risk potential. In the course of a joint research project we have developed a mobile, autonomously working platform for near patient diagnostics of influenza together with R-Biopharm GmbH. Using this platform the infection status of the patient as well as the subtype of the influenza virus can be determined.

The working principle of the detection system is the PCR-based nucleic acid amplification. The patient material is collected with a swab and initially put into a sample container. Subsequently, it is transferred into the buffer solution comprised. After lysis the buffer is transferred into several reaction chambers in which the multiplex detection reactions take place. The fluorescence that occurs in the course of the assay is recorded via detectors included in the system and then finally is analyzed. The result allows drawing conclusions with respect to the bare existence of influenza viruses as well as to their subtypes. The system itself is very compact, light and robust; the design is in the size of a shoebox. All process steps including sample collection and preparation as well as amplification of the target DNA are automated. Detection and analysis of the optical signal is integrated. All reagents are stored in the cartridge in a long-term stable way.

As the system is designed as a platform technology, it can easily be adapted to specific process requirements with respect to various viruses, bacteria or other nucleic acids by modifying the detection reaction and the temperature profile.

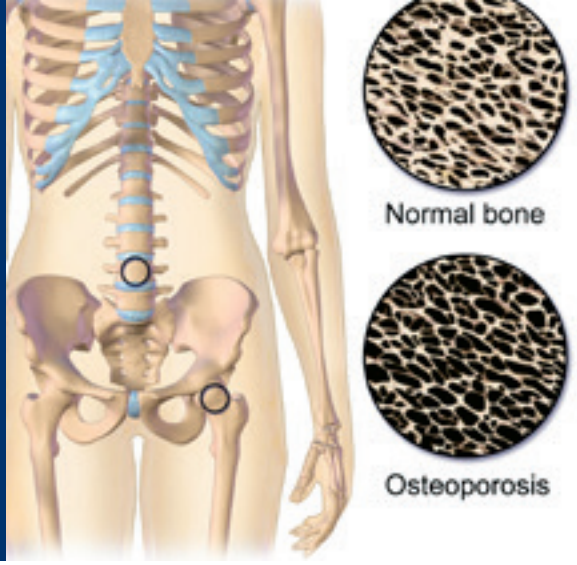
Fraunhofer IMM contribution

- Realization of a microfluidic test cartridge ideally adapted to the processing of the biological samples and the biochemical detection reaction, suited for mass fabrication
- Realization of an operating device (lab demonstrator) including rapid heating and optical multiplex detection
- Integration and fine tuning of the diagnostic test into a fully functional demonstration system

Fraunhofer IMM competencies

- Long-standing experience in the realization of microfluidic systems for nucleic acid based testing
- Broad expertise in the detection of pathogens with or without amplification
- Realization of an enzymatically optimized microfluidic real-time PCR multiplex system for near patient testing of respiratory diseases

Project PANPLEX, funding reference:
BMBF, 13N13846



Osteoporosis

PoCOsteo

POINT-OF-CARE IN-OFFICE DEVICE FOR IDENTIFYING INDIVIDUALS AT HIGH RISK OF OSTEOPOROSIS AND OSTEOPOROTIC FRACTURE

Facing an increasingly ageing society, diseases like osteoporosis (porous bone) including the resulting complications become more and more prevalent. The manifestation of this disease is usually drastic and often includes a fracture of the osteoporotic bone. Early detection of individuals at risk of osteoporosis and, in consequence, the early start of a suitable treatment may drastically improve the current situation by reducing the burden for affected individuals and the high medical care cost for the society. Until recently, little or no measures for prevention or early detection of osteoporosis were taken.

The aim of PoCOsteo is the development, clinical validation and preparation for commercialization of a point-of-care tool for bone disease prevention, detection and treatment. The analysis of Bone Turnover Markers (BTMs) is supposed to be the key route providing the required sensitivity/specificity to effectively determine the onset of osteoporosis in an early stage and to accurately monitor the evolution during treatment. In order to reach the goals of the project various technologies such as molecular medicine, nanobiotechnology, microfluidics, material sciences and biochemistry need to be joined. The PoCOsteo project thus aims to integrate proteomics and genomics technology into a functional single PoC device and to validate the final instrument by comparing the results with the current state-of-the-art. The final device is supposed to be used by physicians to identify individuals at high-risk of osteoporosis and osteoporotic fracture, to provide them with personalized care, and monitor the treatment process more efficiently.

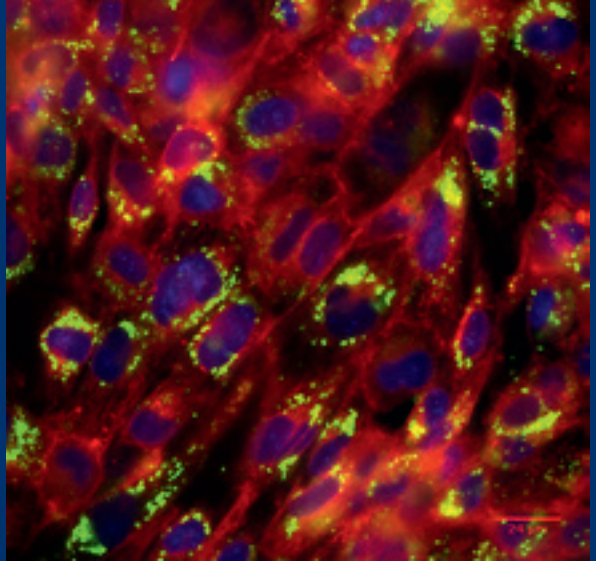
Fraunhofer IMM contribution

- Leading the work package "microfluidic manifold development"
- Design, fabrication and testing of the microfluidic cartridges and integration of sample preparation and electrodes
- Identification of system requirements and the interfacing with instrumentation

Fraunhofer IMM competencies

- Microfluidics and microsystem design, fabrication and rapid prototyping of microfluidic polymer systems and systems integration
- Transfer of chemical and biological assays into microfluidic manifolds
- Microfluidic sample preparation
- Small scale production using injection molding

Project PoCOsteo, funding reference:
Horizon 2020, 767325



Fluorescence microscopy of human brain endothelial cells with ingested fluorescent polylactide nanoparticles

NanoBBB

DEVELOPMENT OF A TEST SYSTEM WITH A DYNAMIC BLOOD-BRAIN BARRIER MODEL

In case of severe neuro degenerative illnesses such as Alzheimer's and Parkinson's disease but as well of brain tumors or traumatic brain injuries therapy today is usually limited to the alleviation of symptoms whereas the actual cause of the disease is not combatted and the progression cannot be stopped. Key for a successful therapy is the passage of active ingredients across the blood-brain barrier (BBB) and, thus, the effective introduction of neuro pharmaceuticals or active substances based on peptides, proteins and other macromolecules respectively. A novel and promising therapeutic approach is based on the packaging of such active substances in small polymeric nano carriers the surface of which can be modified to achieve very specific properties (targeted and local release, delay times …). However, to carry out systematic investigations up to now realistic model systems as well as the corresponding BBB passing nanoparticles (NP) are missing.

Goal of the project was the development of a dynamic BBB model which is optimally representing the real physiological condition (blood, pulsation, flow rate, shear forces …), monitoring the barrier function and allowing to identify those NP properties that allow for an actual passage across the barrier without damaging the barrier. The selectivity of the NP for specific target structures can be achieved by an appropriate functionalization. This was supposed to be achieved by developing NPs being capable of specifically binding endogenous proteins allowing to procure an effective passage across the BBB.

Project NanoBBB, funding reference:
BMBF, 13N13529

Fraunhofer IMM contribution

- Synthesis of nanoparticles with different functionalities allowing the BBB passage
- Characterization of nanoparticles: size, size distribution, charge, shape/morphology, colloidal stability in the presence of blood proteins
- Use of the nanoparticles in a cell model: first in vitro examination with respect to absorption / membrane passage and toxicity of the particles
- Use of the particles in a dynamic blood brain barrier model to verify the BBB passage under close to reality conditions
- Identification of adsorbed blood proteins and conclusions with respect to particle parameters allowing for a BBB passage

Fraunhofer IMM competencies

- Synthesis of nanoparticles from different materials with varying sizes and surface modification
- Mini emulsion polymerization
- Particle characterization (TEM, dynamic light scattering, zeta potential, protein corona,…)
- Biological characterization of particles (toxicity, proliferation, apoptosis, fluorescence based flow cytometry, fluorescence microscopy,…)

#WHATSNEXT?

BLOCKCELL

Development of a natural gas-driven cogeneration unit based on reformer and fuel cell technology with an electrical total capacity of 50 kW

A reformer reactor is currently integrated with a water-gas shift reactor, a preferential oxidation reactor, evaporators, heat exchangers and the corresponding low temperature PEM fuel cell technology in a containerized environment to a compact, fully automated fuel processor/ fuel cell power generation unit with short start-up time. The entire system will be characterized by a high efficiency of the catalytic processes. The reactors are designed to tolerate conditions of up to 800 °C reaction temperature.

INTEGRATE

Wireless sensor network for decentralized data acquisition

The smart platform will enable the in-situ measurement of different variables allowing for the parallel acquisition and storage of a large number of physical values with simultaneous low effort and flexible scalability. The use of WPAN protocols allows for easy integration into existing networks. The platform supports end-to-end communication. An application-specific detection of anomalies in the data with subsequent network-wide reactions are implemented in each node and do not require a central control unit.

NEUHEART

Neuro prosthesis to restore the vagal-cardiac closed-loop connection after heart transplantation (H2020 – grant agreement 824071)

A heart transplant can significantly increase life expectancy of heart failure patients but unfortunately exercise capacity and health-related quality of life of patients are still limited. The most common approach involves the complete explantation and surgical denervation of the native heart. Main project goal is to address the fundamental clinical problem of the resulting modulation of rate- and load-contractility relationship of the donor heart via a bioelectronic solution based on the closed-loop neuromodulation of the vagus nerve.

BIO-CARRIERFUTURE

Revolutionize cancer therapy with innovative biomimetic polymer nanomaterials

Exploiting the fact that due to the high rate of cell division tumor tissue generally displays a 1-2 °C higher temperature than the surrounding tissue, a thermoresponsive supramolecular carrier system will be developed to solely and specifically release anticancer drugs into the tumor tissue. This project transforms biological principles into a programmable nanomaterial creating an innovative functional drug delivery system.

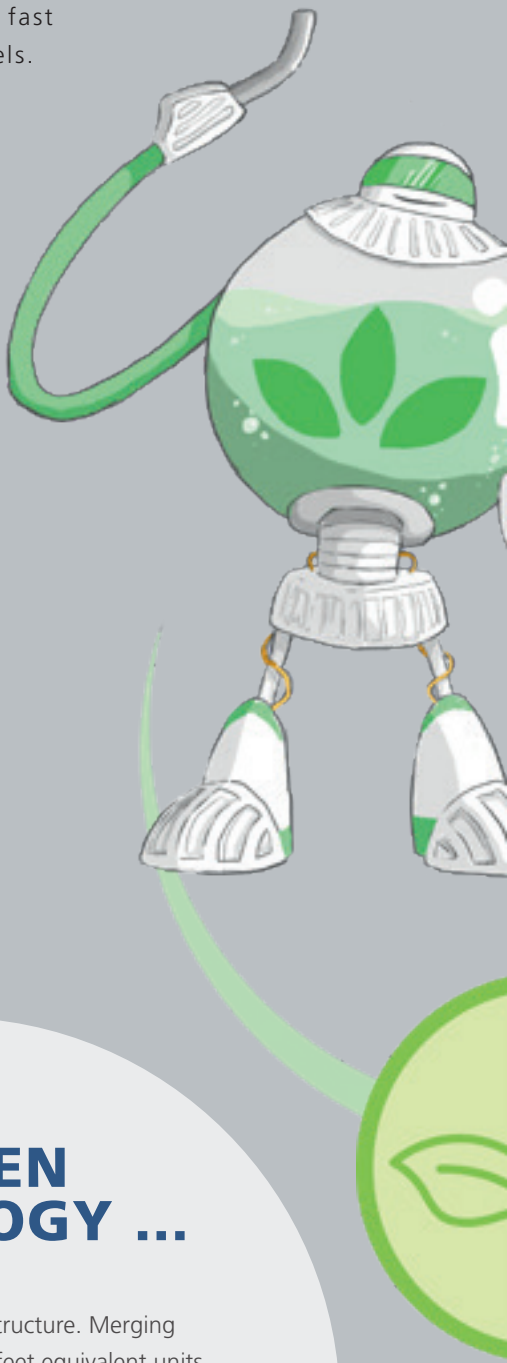
REACTIVE INTERMEDIATES

In-situ production of Grignard reagents with continuous process control

Nowadays, about 10 % of the top 50 API syntheses contain one or more Grignard reactions. Having proven at lab scale that the Grignard reagent formation can significantly benefit from a continuous process we now strive for a scale-up by a factor of 50 to show the industrial relevance of the process at pilot plant scale. This includes the direct conversion of the Grignard reagent in a second subsequent process step. Central element will remain the continuous provision of a large excess of Magnesium including its activation.

ECOTRAINER

Standardized, modular, highly functional and movable cubicle allowing the fast TRANSFORMATION of various raw materials into valuable chemicals and fuels.



SAVING TIME AND COSTS ...

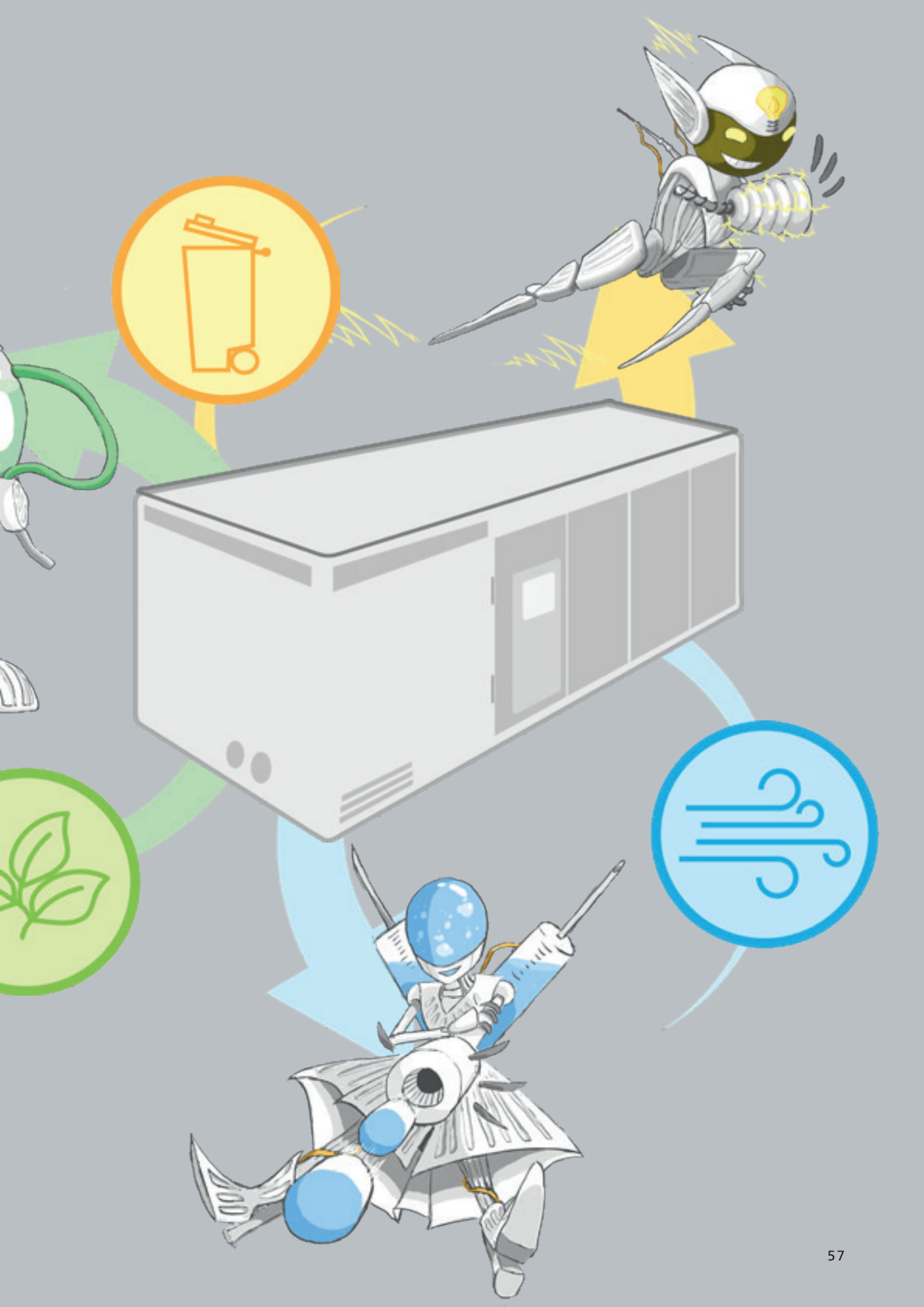
... is the mantra to keep in mind being supported by the intrinsic advantages of the approach. Drastically decreased development times for new products and processes as well as a reduced complexity of the development process allow for a fast transfer into production.

MAXIMUM FLEXIBILITY AND DIVERSITY ...

... become evident by a variety of possible raw materials (from plant debris, used oils and crop material to hydrocarbons) and the range of application fields (from energy technology, food technology and pharmacy/medicine to green chemistry). Feasible concepts like power-to-gas and power-to-chemicals are the interlink to the utilization of renewable energies.

PROVEN TECHNOLOGY ...

... meets established infrastructure. Merging Evonik's ISO-Container forty-feet equivalent units with Fraunhofer IMM's proprietary and specific microstructure-based process technology in the form of compact chemical reaction and plant concepts yields a customer specific refinement. The approach of flexibly configurable room cells paves the way for the subsequent piloting and production using the same infrastructure.



RISING STARS

YOUNG RESEARCH CLASS

The »Young Research Class« combines the career development of outstanding young scientists with the development of an original and forward-looking research project on a strategic theme that is defined annually by the Executive Board of the Fraunhofer-Gesellschaft.

“With the Young Research Class, the Fraunhofer Headquarters has offered us young scientists a unique opportunity to contribute our respective expertise to joint research projects across institute boundaries on the future topic of „programmable materials“. This period has so far not only generated new project proposals, but has also given rise to true friendships.”

Dr. Sibylle von Bomhard

TALENTA Start allows me to focus more effectively on my dissertation, scientific publications and lectures, thereby enhancing my scientific profile and visibility. In addition, the TALENTA grant enabled me to take my first project management courses, which is helpful both for my work at IMM and for my next career steps.

Lisa Bacher (TALENTA Start)

TALENTA »START«

TALENTA »start« is the program for all female university graduates who start their career with Fraunhofer. The aim is to provide candidates with orientation at the start of their careers in applied research and to enable them to acquire the necessary skills.

The participation in TALENTA Speed up gave me the opportunity to build up a completely new field of research aiming at nanotherapeutics here at IMM and to sharpen my scientific profile outside the institute.

Dr. Regina Bleul (TALENTA Speed up)

TALENTA »SPEED UP«

TALENTA »speed up« is designed for experienced Fraunhofer internal and external female scientists with motivation and potential to assume leadership or specialist responsibility. The focus is thus on female scientists who are about to take on a management position or a position in a specialist career, or who are planning to do so in the short or medium term. The objective is to systematically support the candidate in expanding her area of responsibility.

TALENTA offers me a network of encouraging women, a platform for the exchange of career information and inspired me to new research questions. Participating in the training programs brought me many new insights to identify and productively apply my leadership skills as well as provided me with opportunities to achieve my scientific business goals effectively and more easily. I am very grateful to be part of the TALENTA program.

Dr. Anna Musyanovych (TALENTA speed up)

EXTENSION BUILDING

ROOFING CEREMONY

Nearly one and a half years after the start of construction, on August 14, 2018 the time had come: Together with colleagues, guests from politics and business and the companies involved in the shell construction, we celebrated the roofing ceremony.
We were delighted to hear the appreciative words of Minister Prof. Dr. Konrad Wolf and the Executive Vice President Human Resources, Legal Affairs and IP Management of the Fraunhofer-Gesellschaft, Prof. Dr. Alexander Kurz. Many colleagues took the opportunity to be guided through the new building. The varied and tasty grill buffet as well as the cocktails from the fully-automated Fraunhofer IMM cocktail machine completed the picture.

“We are eagerly awaiting the end of the construction period and cannot wait to take possession of our new premises.”

When do you ever have such a party location? The charm of a shell construction combined with decorated bar tables, a delicious buffet and atmospheric lighting!

PROGRESS

The implementation of the construction is steadily proceeding. The roof is closed, the windows are built in and the actual time planning envisages the start of use by Fraunhofer IMM in May 2020. Currently the contract work focusses on advancing the interior construction with respect to the high-grade lab and technical facilities but also to provide a modern and inspiring working environment.

This construction project is funded by the Federal Ministry of Education and Research, the Ministry of Science, Education and Culture Rhineland-Palatinate and the European Regional Development Fund.

APPENDIX

FAIRS & EVENTS 2018/19

Fraunhofer IMM supports the process of acquisition through an intense presence at fairs and exhibitions, organizing 10-15 appearances per year. The focus lies on activities in Germany with a share of more than 50 % while the number of events in China is steadily increasing. Industry branch events of central importance are, for instance, the Hannover Messe, SENSOR+TEST, analytica and ACHEMA. In discussions with our scientists we regularly identify new exhibition opportunities which are offering an appropriate framework for our innovations.

Fair / Event	Period of time	City / Country
Europa in meiner Stadt	May 8, 2018	Germany / IMM
Ci3 Schaufenster	May 24, 2018	Germany / IMM
ACHEMA	June 11 – 15, 2018	Germany / Frankfurt
ACHEMA Evonik booth	June 11 – 15, 2018	Germany / Frankfurt
ACHEMA FlowChemistry Pavillion	June 11 – 15, 2018	Germany / Frankfurt
SENSOR+TEST	June 26 – 28, 2018	Germany / Nuremberg
CHFCE (China International Hydrogen and Fuel Cell Conference & Exhibition)	July 26 – 28, 2018	China / Beijing
Open House	October 18, 2018	Germany / IMM
Compamed	November 12 – 15, 2018	Germany / Dusseldorf
FC EXPO	February 27 – March 3, 2019	Japan / Tokyo
Hannover Messe	April 1 – 5, 2019	Germany / Hannover
Open House	April 9, 2019	Germany / IMM
AchemAsia	May 21 – 23, 2019	China / Shanghai
SENSOR+TEST	June 25 – 27, 2019	Germany / Nuremberg

CONFERENCES 2018/19

Fraunhofer IMM regularly presents results from its innovation fields and from current research projects to a specialist audience. Our scientists are well-received guest speakers at international conferences. We as well regularly invite external scientists from industry and research to join our in-house colloquia. This intensive exchange of experiences and knowledge between industry and research serves not least to initiate international cooperations.

Conference / Event	Period of time	City / Country
Jahrestreffen Reaktionstechnik 2018	May 7 – 9, 2018	Würzburg / Germany
Transporter - und Barrieretage 2018	May 7 – 9, 2018	Bad Herrenalb / Germany
12th International Conference on the Scientific and Clinical Applications of Magnetic Carriers	May 22 – 26, 2018	Copenhagen / Denmark
GPE 2018 - 6th International Congress on Green Process Engineering	June 3 – 6, 2018	Toulouse / France
3. Mühlheimer Wasseranalytisches Seminar (MWAS 2018)	September 12 – 13, 2018	Mühlheim an der Ruhr / Germany
Single Cell Europe Conference	September 19 – 21, 2018	Prague / Czech Republic
MSE 2018 - Materials Science and Engineering	September 25 – 27, 2018	Darmstadt / Germany
IMRET 2018 - International Conference on Micro Reaction Technology	October 21 – 24, 2018	Karlsruhe / Germany
DECHEMA Tagung Spurenstoffe und Krankheitserreger im Wasserkreislauf	October 23 – 24, 2018	Frankfurt / Germany
XXIII International Conference on Chemical Reactors (CHEMREACTOR-23)	November 05 – 08, 2018	Ghent / Belgium
8th NRW Nano Conference	November 20 – 22, 2018	Dortmund / Germany
NMRPM 2019 – Quantitative NMR Methods for Reaction and Process Monitoring	January 31 – February 1, 2019	Kaiserslautern / Germany
4th Munich Point-of-Care Testing Symposium	March 11 – 15, 2019	Munich / Germany
52. Jahrestreffen Deutscher Katalytiker	March 13 – 15, 2019	Weimar / Germany
IWMPI - 9th International Workshop on Magnetic Particle Imaging	March 17 – 19, 2019	New York City / USA
Deutsche Plattform Nanobiomedizin Annual Meeting 2019	March 27, 2019	Frankfurt / Germany

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BINDING OF NANOPARTICLES TO AMINATED PLASMA POLYMER SURFACES IS CONTROLLED BY PRIMARY AMINE DENSITY AND SOLUTION PH
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9| Papavasiliou, J.; Schütt, C.; Kolb, G.; Neophytides, S.; Avgouropoulos, G.:
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25| Löb, P.:
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45| Onyema, H.:
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