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FRAUNHOFER INSTITUTE FOR MICROENGINEERING AND MICROSYSTEMS IMM

MAKING THE DIFFERENCE

2019/20

ANNUAL REPORT

2019/20

ANNUAL REPORT

EDITORIAL NOTES

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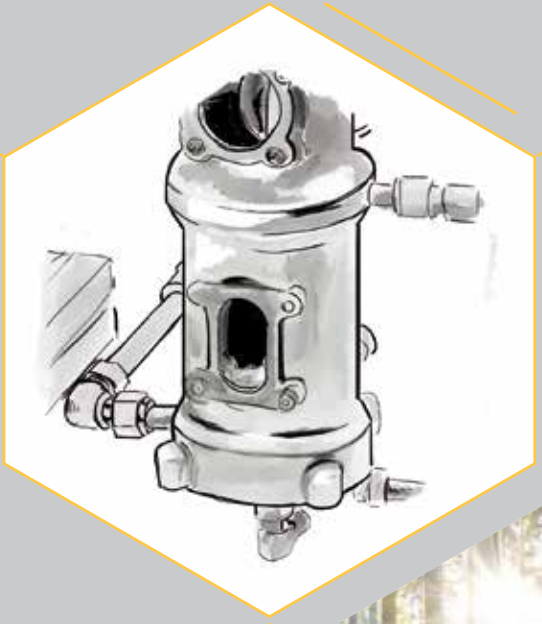
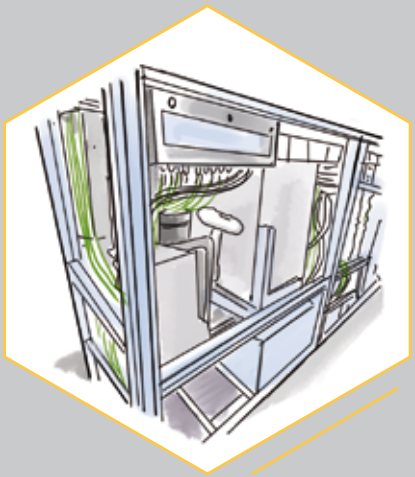
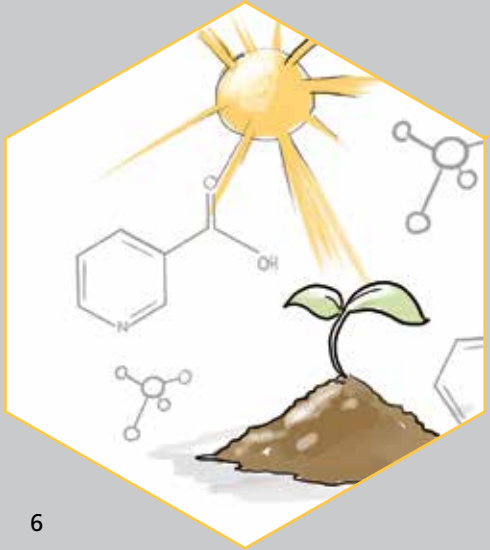






DEAR READERS

According to an official statistical survey in 2019 a share of almost 25 % of the German population worries about environmental hazards and climate change. Not without a reason more and more attention is now being paid to these topics at company and political levels. Buzz words like energy efficiency, renewable energy, carbon footprint or decarbonizaton gain some kind of omnipresence in media.

As one of the world's largest organizations for application-oriented research, the Fraunhofer-Gesellschaft is consistently pursuing sustainability as vital part of its governance. And sustainability is also the key driver for many R&D activities at Fraunhofer IMM which is directly reflected in two of our key strategic issues: sustainable chemistry and hydrogen-based energy generation.

Hydrogen is the central element in our work aiming at the development of technologies for a cleaner and more efficient energy supply in transportation and stationary applications. The use of light and electric current are two pillars to allow for environmental friendly chemical synthesis processes reducing the consumption of materials and reducing waste. Carbon dioxide is not only a poison for persons and climate, it is also a recyclable and valuable source to use for the production of energy carriers and some basic chemicals, thus contributing significantly to the goals of realizing an increasingly carbon dioxide neutral society.

To conclude this brief introduction to our annual report 2019/2020 let me slightly modify a few words that have recently been used by a young lady: No step is too small to make a difference! Enjoy your reading and follow our little Micro-B throughout the report to discover all our activities related to sustainability and also learn about our activities related to health that have the potential to make a difference.

PROF. DR. MICHAEL MASKOS
EXECUTIVE DIRECTOR FRAUNHOFER IMM

PROFILE

FRAUNHOFER INSTITUTE FOR MICROENGINEERING AND MICROSYSTEMS IMM

Our scientists are engaged in research and development in the fields of **Energy, Chemistry and Diagnostics.** The emphasis is on hydrogen-based energy supply, sustainable chemistry and process analysis as well as personalized diagnostics and liquid biopsy. We provide solutions for hydrogen supply relying on a compact and dynamic approach that is well suited for mobile applications. Doing so we use catalytic processes and, increasingly, renewable fuels. We use structured reactors and continuous processing to precisely control and intensify chemical processes. We create efficient solutions for the extraction and enrichment of relevant biomarkers for automated and personalized precision diagnostics in the laboratory and also on site. With our development work we achieve an essential contribution to the societal challenges ››secure, clean and efficient energy‹‹, ››climate action, environment and resource efficiency‹‹ as well as ››health‹‹.

In the Business Field Hydrogen Based **Energy** Supply our focus lies in the area of compact and dynamic hydrogen supply for fuel cells, including the reforming of natural gas, LPG, methanol, ethanol, propylene glycol, gasoline, kerosene and diesel for stationary as well as mobile applications in the field of propulsion and auxiliary power supply also for cars, trucks, aircraft and leisure vehicles. The portfolio comprises the construction of highly compact microstructured reformer reactors, the associated catalyst technology, process simulations for the overall fuel processor and the overall system, the construction of complete fuel processor systems and their coupling with fuel cells and finally the automation of systems with and without fuel cells.

The Business Field Sustainable **Chemistry** deals with the improvement and sustainable design of chemical production processes using in-house technologies. These technologies enable precisely

controlled continuous chemical processes with increased resource and energy efficiency and foster modular and flexible production concepts e.g. facilitating the adaptation to a raw material base changing towards more renewables. Moreover, regeneratively produced excess electricity can be used to produce valuable chemicals with a high efficiency and selectivity applying electrochemical microreactors. Photochemical microreactors with optimized use of light allow for green paths in organic synthesis and material use of CO_2. Services provided for our customers and partners cover lab chemical process development in the area of flow chemistry, the development and realization of specialized flow reactors (with an increasingly use of additive manufacturing technologies) up to production scale, and further support in transferring the results in chemical production and application e.g. by the establishment of demonstrators at pilot scale level.

In the Business Field **Diagnostics** we develop technical solutions for microfluidic-based analysis systems to be applied in life sciences, medical research and diagnosis comprising the detection of pathogens in natural body fluids (such as whole blood, plasma, serum, sputum and urine) as well as the analysis of organic samples. Our microfluidic processes and techniques allow to overcome limitations with respect to fast, locally available and precise diagnostic tests that still exist for near patient, on-site testing, operating inside and outside the established large central laboratories. The approaches enable the provision of in-depth diagnostic parameters that are so far unused. Sample preparation is a vital part of our activities when developing the corresponding microfluidic cartridges and functional systems.

QUALITY POLICY

As 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. Communicating openly 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 adapted to changing requirements and improved. 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 (2019)

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.

RESEARCH NETWORK

BMBF Project Partners // TU Eindhoven // European Technology Platforms // EU Project Partners // BAM Bundesanstalt fuer Materialforschung und -Pruefung // Dechema // Process-Net // DWV // DGO // Microtec Südwest // N.ERGHY // Cluster Nanotechnology

COOPERATIONS AND STAFF EXCHANGE

University of Mainz // Max Planck Institute for Polymer Research Mainz

REGIONAL NETWORK

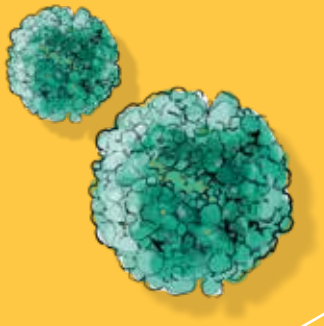
STUDENT RESEARCH PROJECTS AND DISSERTATIONS

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 // University of Stuttgart // University of Duisburg-Essen

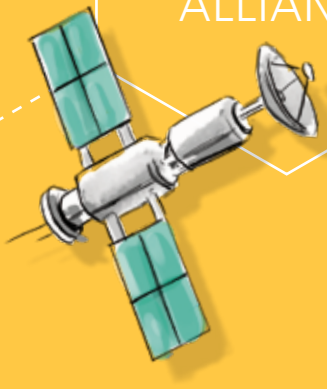
NETWORKS

AMA // IVAM // Dual Career Network Rheinmain // Mainz Research Alliance e.V. // Cluster Indiviualized Immuneintervention (CI3) e.V.

ASSOCIATIONS AND ALLIANCES WITHIN FRAUNHOFER



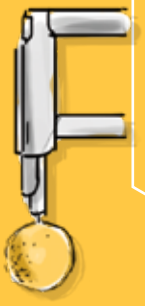
FRAUNHOFER **SPACE** ALLIANCE



FRAUNHOFER **NANO-TECHNOLOGY** ALLIANCE

FRAUNHOFER **ENERGY** ALLIANCE

FRAUNHOFER **ADDITIVE MANU-FACTURING** ALLIANCE



FRAUNHOFER GROUP **MATERIALS**

Joseph von Fraunhofer

FRAUNHOFER-GESELLSCHAFT

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

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

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 74 institutes and research institutions. The majority of our 28,000 staff are qualified scientists and engineers, who work with an annual research budget of 2.8 billion euros. Of this sum, 2.3 billion euros is generated through contract research. Around 70 percent of Fraunhofer's contract research revenue is derived from contracts with industry and publicly funded research projects. The remaining 30 percent comes from the German federal and state governments in the form of base funding. This enables the institutes to work on solutions to problems that are likely to become crucial for industry and society within the not-too-distant future.

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

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

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

FRAUNHOFER-GESELLSCHAFT IN NUMBERS (2019)

74
INSTITUTES AND RESEARCH UNITS IN GERMANY

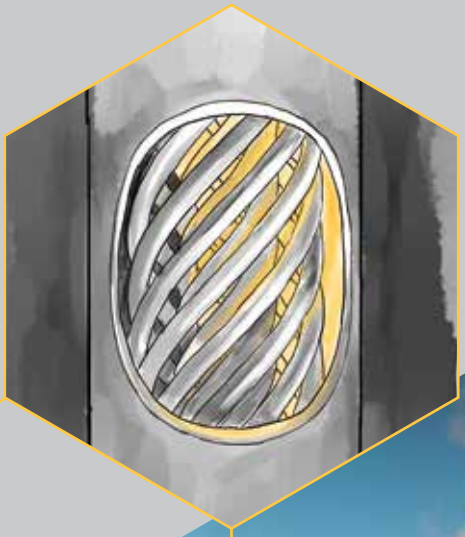
28.000
STAFF

2,8
BILLION EURO RESEARCH BUDGET

2,3
BILLION EURO CONTRACT RESEARCH

30%
CONTRIBUTED BY THE GERMAN FEDERAL AND STATE GOVERNMENTS

70%
INDUSTRY AND PUBLICLY FINANCED RESEARCH PROJECTS

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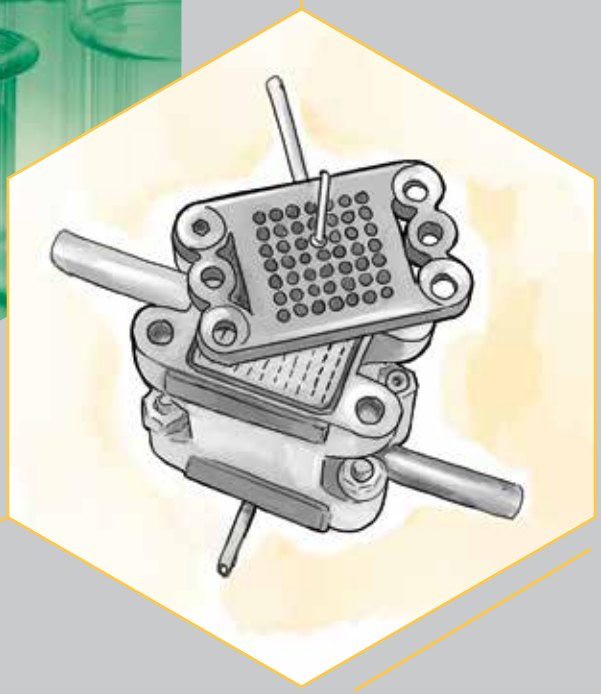
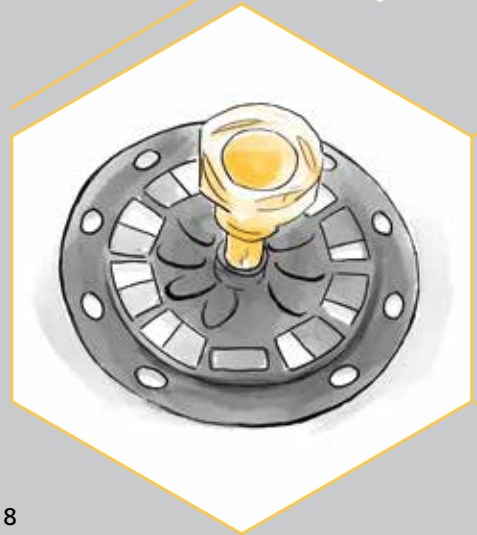




BUSINESS FIELDS

Our society faces a number of challenges that require both, targeted investment in research and innovation and top-notch organizations that are able to transform the money spent into a tangible benefit for people. No single player can be ubiquitous. But in our business fields we strive for making the difference dealing with hydrogen-based energy supply, sustainable chemistry and personalized diagnostics.

1 *Fuel processor for diesel (as part of an APU)*

HYDROGEN BASED ENERGY SUPPLY

In the scope of the energy transition alternative energy generation pathways are becoming increasingly important. Due to the fluctuating availability of renewable sources energy storage will become inevitable in future. The capacity of chemical energy storage is orders of magnitude higher than that of batteries. Hydrogen is one of the best known examples while alcohols such as methanol and ethanol, synthetic hydrocarbons such as methane (natural gas) and higher molecular weight liquid hydrocarbon mixtures as a substitute for kerosene need as well to be taken into account. Nonetheless the extraction of hydrogen from different energy sources through catalytic conversion, called fuel processing technology, will foreseeably become one of the central processes of future energy technology.

Since the beginning of the millennium, Fraunhofer IMM has evolved to be the most powerful non-university research unit worldwide working in the field of fuel processing. This is backed by a large number of projects in industrial contract research and public funding in the area of compact and dynamic hydrogen supply for fuel cells, including the reforming of natural gas, LPG, methanol, ethanol, propylene glycol, gasoline, kerosene and diesel for stationary as well as mobile applications in the field of propulsion and auxiliary power supply also for cars, trucks, aircraft and leisure vehicles. The portfolio comprises the construction of highly compact microstructured reformer reactors, the associated catalyst technology, process simulations for the overall fuel processor and the overall system, the construction of complete fuel processor systems and their coupling with fuel cells and finally the automation of systems with and without fuel cells.

What makes us unique?

- The use of a scalable reactor concept based on microstructured plate heat exchangers being coated with catalysts
- A portfolio of highly active and long-term stable, robust catalysts for the special application area of fuel processing technology for fuel cells
- A manufacturing technology for the cost-effective production of large numbers of reactors
- Handling of all process steps up to the complete system including the fuel cell

FLAGSHIP PROJECT:
FUEL CELL BASED COMBINED HEAT AND POWER UNIT

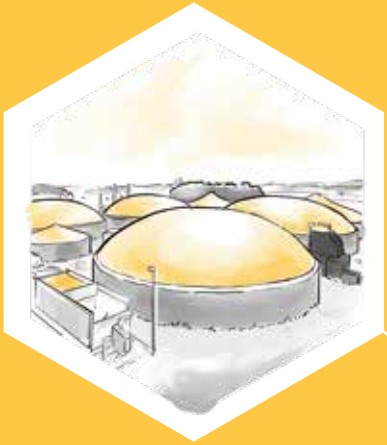
The prototype of our fuel cell combined heat and power (CHP) unit promises to be an adequate solution for all applications in need of an efficient and, preferably, at the same time ecological and perspectively at least CO_2 neutral electrical energy and heat supply. With a power equivalent of 50 kWel and an overall efficiency of the CHP unit expected to exceed 95 % a technology basis has been created that explicitly will address industrial applications and small residential areas. The system efficiency is less dependent from the load scenario in place as it would be the case when relying on combustion engines in the CHP unit. Additionally, the maintenance requirements are reduced by extensively avoiding moving parts. CO_2 neutrality can easily be achieved by connecting the unit to a biogas plant.

The system was entirely designed at Fraunhofer IMM and contains catalyst formulations that were all developed in-house. The required reactors for the fuel processor have been constructed and built at Fraunhofer IMM. Heat integration allows for highly dynamic operation of the system. Relying on low temperature PEM fuel cell technology guarantees reliability and durability. The fuel cells and system control components are third-party products but the system control was programmed in-house.

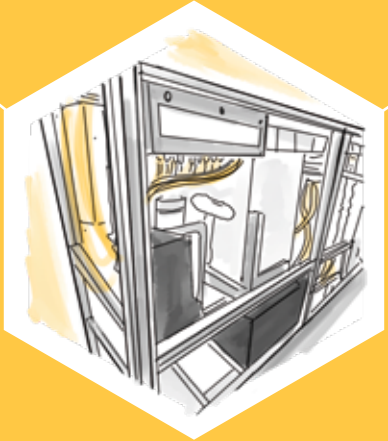
Currently the system is in trial operation for intensive technical experiments and to ensure a reliable operation later on.

Substantially financed by the Ministry of Science, Education and Culture of the State of Rhineland-Palatinate

The goal:
CO_2 neutral electrical energy and heat supply with power equivalents allowing to address large scale application scenarios in a variety of areas in work and life.



BIOGAS PLANT



COMBINED HEAT AND POWER UNIT

RESIDENTIAL AREA

1 *Modular microreactor built by additive manufacturing*

1

SUSTAINABLE CHEMISTRY

The chemical and pharmaceutical industry faces global competition and this increasingly in the context of energy transition, a changing raw material base and climate change. Moreover, society increasingly voices the expectation that production and consumption need to become more resource-saving, environmental-friendly, socially acceptable, in total, more sustainable. Chemical industry is the base of many value chains and often the most important driving force for innovations in other fields. As Europe's most important chemical producer Germany especially faces the public as well as competitive pressure to establish a sustainable chemistry.

The Business Field Sustainable Chemistry deals with the improvement and sustainable design of chemical production processes and process analytics using in-house technologies. These technologies enable precisely controlled continuous chemical processes with increased resource and energy efficiency and foster modular and flexible production concepts e.g. facilitating the adaptation to a raw material base changing towards more renewables. Moreover, regeneratively produced excess electricity can be used to produce valuable chemicals with a high efficiency and selectivity applying electrochemical microreactors. Photochemical microreactors with optimized use of light allow for green paths in organic synthesis and material use of CO_2.

Services provided for our customers and partners cover lab chemical process development in the area of flow chemistry, the development and realization of specialized flow reactors (with an increasing use of additive manufacturing technologies) up to production scale, and further support in transferring the results in chemical production and application e.g. by the establishment of demonstrators at pilot scale level.

What makes us unique?

- A wide range of microstructured mixers, heat exchangers and reactors allowing to precisely control chemical processes
- Scalability and modularity of the reactor concept as a premise for flexible production and reduced time-to-market
- A profound knowledge and experience base in the transfer of batch to continuous processes including the view towards pilot and production scale
- Industry relevant process know-how for special reaction classes like electro- and photochemical syntheses, syntheses of reactive intermediates and polymers, nanoparticle synthesis and encapsulation

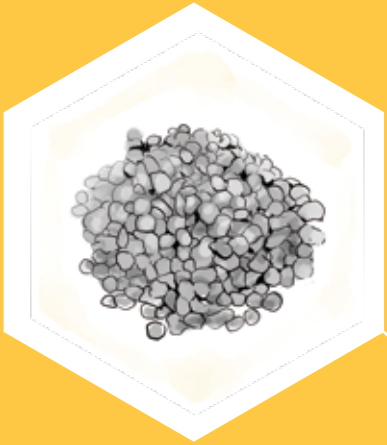
FLAGSHIP PROJECT:
PILOT PLANT FOR THE CONTINUOUS GRIGNARD SYNTHESIS

Grignard reagents are of high relevance in the chemical and pharmaceutical industry for carbon-carbon coupling reactions. In the synthesis of the top 50 active pharmaceutical ingredients, about 10 percent of the synthetic pathways contain one or more Grignard reactions.

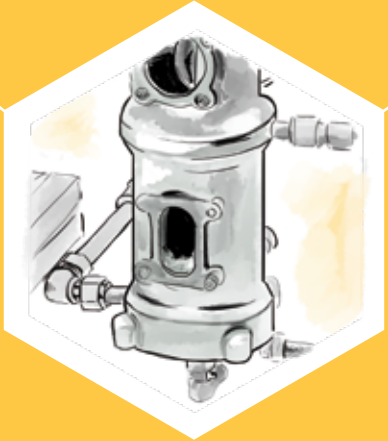
The continuous synthesis process that has been developed at Fraunhofer IMM currently covers throughputs from the lab-scale to the pilot-scale allowing access to production capacities in the order of 100 tons per year. Relying on a patented, innovative reactor concept and process implementation, a number of typical challenges can be overcome. As the synthesis of Grignard reagents is highly exothermic in many cases, an excellent thermal management is required to allow for safe processing of such highly reactive intermediates. Our approach includes a continuous supply of magnesium turnings and their integrated mechanical activation. Incubation times are decreased and the use of auxiliary reagents for a safe reaction start can be omitted for most cases. So the main features of a flexibility in production, improved safety, and a better and faster product formation are the reasons why producers and users of Grignard reagents are interested in this novel process.

Currently, a modular pilot plant for the continuous synthesis of various Grignard reagents up to a liquid throughput of 20 l/h is being extensively tested. Apart from extending the activities towards further organometallic compounds, the next logical steps in making this technology available to industry are extensive co-operations with industrial partners to evaluate applicability and cost benefits to a number of Grignard reagents in their portfolio as well as bilateral industrial projects to expand the available throughputs from pilot scale capacities to even larger production outputs. Such efforts are already on the way or in the pipeline.

The goal:
Flexible and parallel provision and processing of reactive intermediates in a resource efficient way and at a scale that allows to address chemical and pharmaceutical production.



MAGNESIUM TURNINGS



GRIGNARD PILOT REACTOR

GRIGNARD PILOT PLANT

1 *Fully autonomously working high-speed moving plug real-time PCR module*

DIAGNOSTICS

The cause, course and treatment of a disease such as cancer, autoimmune disorders, diseases of the central nervous and the respiratory system, are significantly influenced by individual genetic attributes and living conditions. Modern medicine increasingly recognizes and addresses these differences between human individuals and terms this concept 'personalized medicine'. Due to the tumor heterogeneity personalized approaches are especially relevant for cancer therapy. This is as well reflected in the ››national decade against cancer‹‹ proclaimed by the German federal government to set the focus on the uniqueness of every human individual. Patients are expected to significantly benefit from precisely targeted therapies based on a personalized initial and companion diagnosis and a quasi-continuous monitoring of disease progression.

For more than two decades Fraunhofer IMM develops technical solutions for microfluidic-based analysis systems to be applied in life sciences, medical research and diagnosis comprising the detection of pathogens in natural body fluids (such as whole blood, plasma, serum, sputum and urine) as well as the analysis of organic samples. Our microfluidic processes and techniques allow to overcome limitations with respect to fast, locally available and precise diagnostic tests that still exist for near patient, on-site testing, operating inside and outside the established large central laboratories. The approaches enable the provision of in-depth diagnostic parameters that are so far unused. Sample preparation is a vital part of our activities when developing the corresponding microfluidic cartridges and functional systems.

What makes us unique?

- The breadth and depth of our microfluidic system competence for the automated preparation and analysis of human samples
- Extensive experience in the miniaturization of lab preparation methods, their integration with microsystems, including measurement methods for sample analysis, such as PCR, nucleic acid extraction and purification, immunoassays or ELISAs
- The capability to isolate and position single cells directly from billions of other cells
- A technique for the dispensing of single cells guaranteeing a good morphological quality and allowing a further cultivation of these cells

FLAGSHIP PROJECT: LIQUID BIOPSY

The sampling of body fluids, especially blood, is widely accepted as a gentle procedure by the majority of the people. This makes liquid biopsy to a diagnostic method of choice, especially as one single blood sampling could be used to check as many relevant parameters as possible (circulating tumor cells, cell-free nucleic acids, exosomes and/or proteins).

For about ten years liquid biopsy is now in the focus of Fraunhofer IMM's R&D activities, especially with respect to the isolation and characterization of circulating tumor cells (CTCs). The current status quo we have achieved comprises a microfluidic-based system for the enrichment of CTCs from a 7.5 ml whole blood sample and isolation of single cells for subsequent analysis. Technical and optical expertise is particularly required for the isolation of the cells, where the cells are detected and, with real-time data analysis, automatically separated by a high-precision dispensing pulse. The highly efficient process from blood sample to isolated and living cells works with a recovery rate of more than 70 %. Using a polymer based and disposable microfluidic cartridge meets the requirements of cost efficient fabrication and prevents cross-contamination between different patient samples.

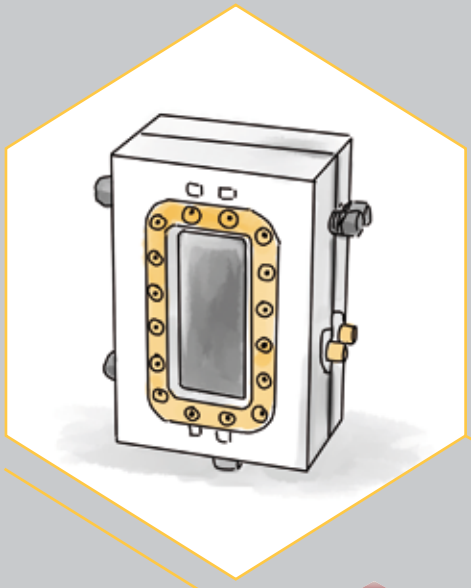
Currently, selection quality and robustness of the technology are being continuously improved. In parallel project partners run real patient samples in fully operational prototypes of IMM technology in their lab and use the isolated CTCs for their cancer research.

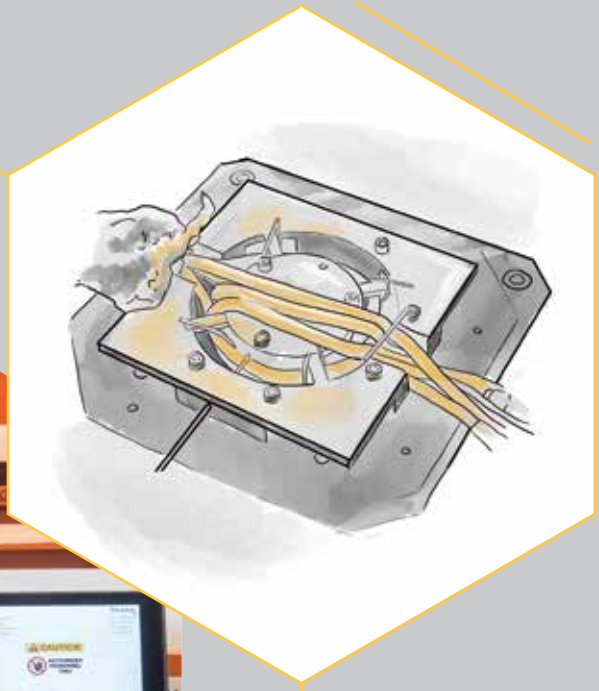
The goal:
Analyzing a variety of relevant biomarkers from one single standard blood sample giving access to novel diagnostic procedures.

BLOOD SAMPLE

ANALYSIS SYSTEM

MULTI PARAMETER DIAGNSOTICS



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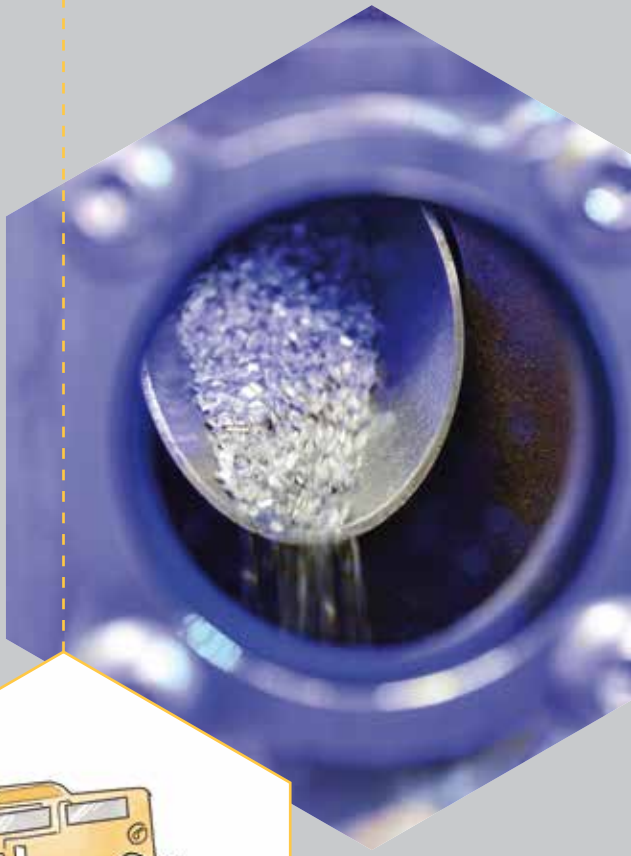
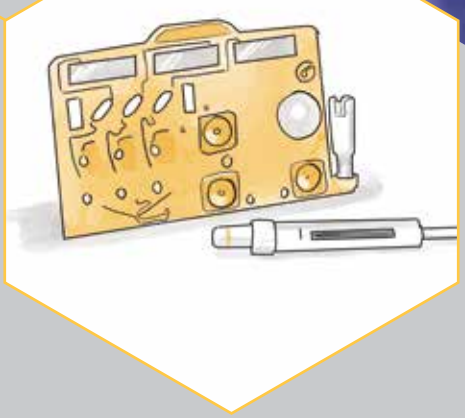
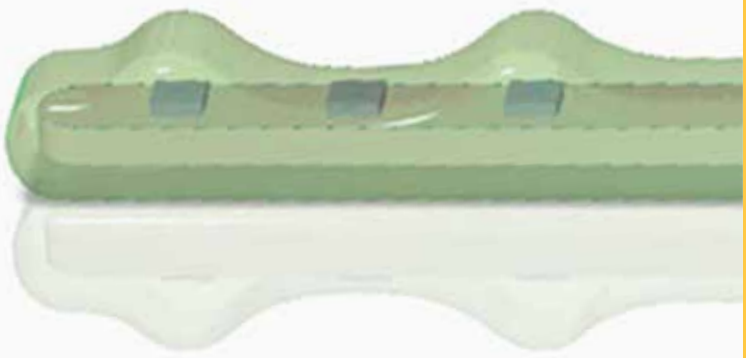




PROJECT HIGHLIGHTS

We decided to present three of our most promising projects as so called flagships in the business field section of this report. Although we expect that these three beacons will develop the most powerful ››luminosity‹‹ in the near future, there are of course many more projects to present. In the following pages we have gathered a cross-section of activities related to health, environment, energy and sensor technology.



1 *CAD of MEMS-Force Sensor*
2 *Modular microreactor for flow chemistry built by additive manufacturing*

1

A NEUROPROSTHESIS TO RESTORE THE VAGAL-CARDIAC CLOSED-LOOP CONNECTION AFTER HEART TRANSPLANTATION

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. This leads to a significantly altered modulation of the rate- and load-contractility relationship of the donor heart. Or more simply: the patient is less efficient and resilient than before.

The aim of NeuHeart is to address this very important clinical problem by developing a disruptive hybrid bio-electronics platform based on

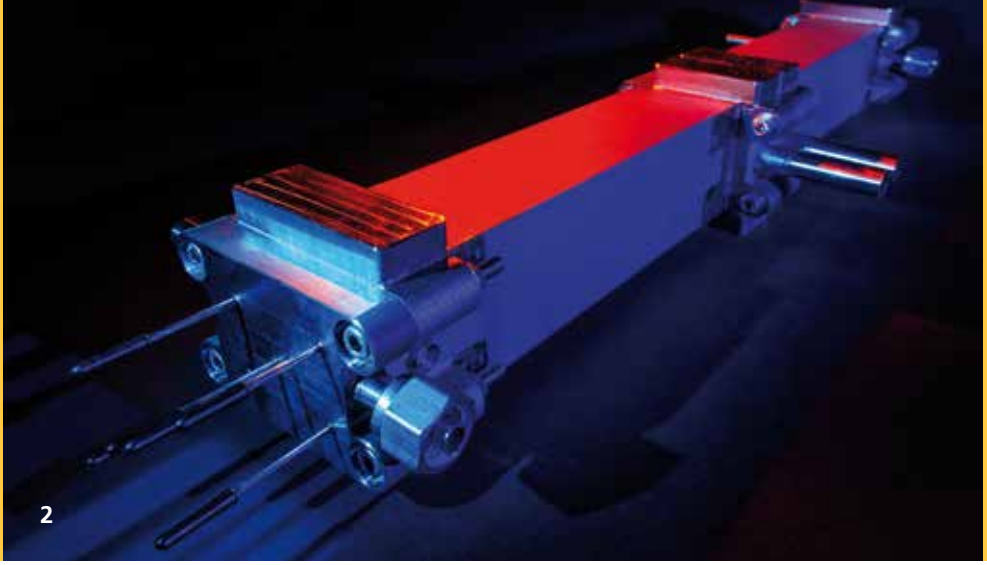
- a closed-loop neuromodulation of the vagus nerve (VN) using a regenerative neural interface
- implanted artificial sensors to record sensory information
- advanced models of the cardiovascular system to optimize the VN stimulation strategies.

The NeuHeart »cardiac smart neuroprosthesis« will artificially re-establish the vagal control in a denervated heart, re-enabling the cardiac-vagal connection, thus providing a highly reliable control of the neuroprosthesis over a long period of time. NeuHeart opens up new frontiers to fundamental research of the heart transplant science, helping in the treatment of heart failure and heart transplantation consequences. In addition, NeuHeart proposes a novel implantable treatment paradigm that could extend its application to a wider range of clinical heart diseases, patients with neurodegenerative diseases (e.g. Parkinson's), or to promote the development of advanced neurological control and repair devices and neurotherapeutic applications.

Fraunhofer IMM contribution

- Leading the work package that is dealing with the design and realization of the implantable MEMS force sensor device required to monitor the activity of the myocardial muscle
- Implementation of the MEMS fabrication process and realization of the MEMS sensor devices as well as first version of readout electronics
- Integration and packaging
- Experimental evaluation of MEMS sensors with heart phantom

NeuHeart, funding reference: Future and Emerging Technologies (FET), grant agreement number 824071



2

INNOVATIVE CHEMOENZYMATIC INTEGRATED PROCESSES

The chemical industry represents one of the largest economic sectors worldwide and in Europe. Providing modern products and materials and enabling solutions in virtually all sectors, the chemical industry is a wealth-creation sector and represents a great value for the European economy. According to officially published numbers, the European chemical industry, including pharmaceuticals, is having a considerable impact on environment due to their carbon dioxide emissions. As the concern on climate change and environmental issues steadily increases, the focus of manufacturing industries has been gradually shifting towards the development of alternative greener, safer and sustainable processes. In this context, biocatalysis (using enzymes) offers immense opportunities for developing sustainable processes.

The INCITE project targets novel integrated upstream and downstream processing paths involving flow chemistry and membrane technology in chemoenzymatic processes in real industrial settings aiming at a sustainable, safe and energy-efficient production of commodity and fine chiral chemicals. Compared to traditional chemical synthesis processes, these chemoenzymatic processes have clear advantages of greater efficiency, higher product quality, higher safety and smaller environmental footprint.

The project focusses on the two demonstration cases

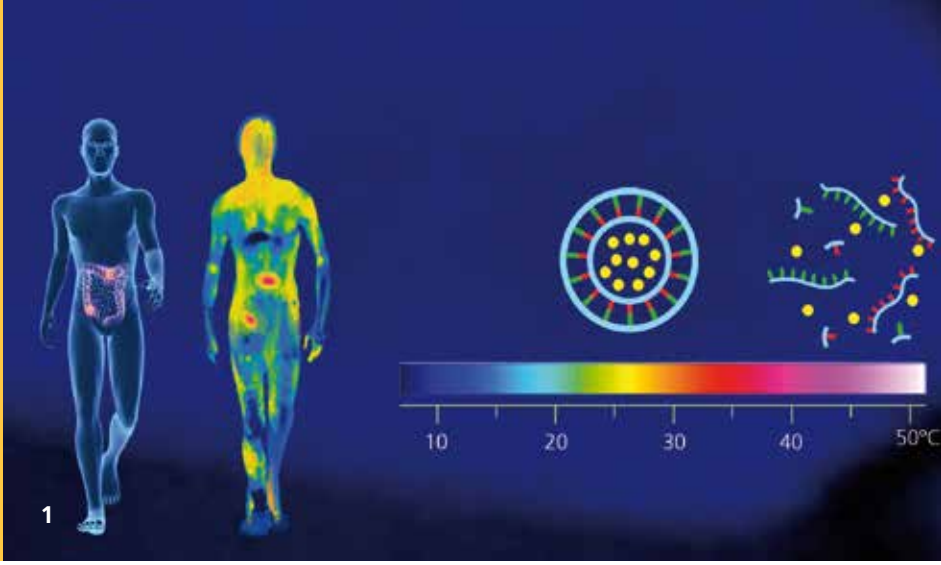
- esterase-catalyzed production of a chiral molecule used as starting material for the production of agrochemicals in the field of crop protection and public health,
- solvent-free synthesis of oleochemical esters using lipase enzymes,

and anticipates a minimum decrease of 20 % in greenhouse gases emissions as well as minimum of 40 % resource and energy efficiency gains.

Fraunhofer IMM contribution

- Leading the work package process innovation
- Particular expertise in flow reactors process optimization, flow reactor development and realization and flow reactor subunits realization
- Support of plant design for precursor synthesis step in the agrochemical project line transferring this process from lab scale to demonstration scale covering further process optimization in lab-scale, development and realization of flow reactors (and eventually also separators) in demo-scale and the design and realization of selected subunits for the demo plant
- Establishment of a flow chemistry step for the photochemical racemization in the agrochemical project line

INCITE, funding reference: H2020-NMBP-ST-IND-2018-2020/H2020-NMBP-SPIRE-2019, grant agreement number 870023



1 *Concept biomimetic thermoresponsive nanomaterials for cancer therapy*
2 *Polymer microfluidic cartridge for point-of-care testing of tuberculosis*

REVOLUTIONIZING CANCER THERAPY WITH BIOTRANSFORMED NANOMATERIALS

Cancer is one of the leading causes of death worldwide. The number of patients will continue to rise with increasing demographic change. In Germany, about one in four people die from the consequences of cancer. Cancer is thus the second most frequent cause of death after cardiovascular diseases. Classic chemotherapies, which usually expose patients to byeffects due to the insufficient specificity of the drugs which have toxic side effects, still account for the majority of first-line therapies. An important goal of nanomedicine is therefore to make the treatment of this disease safer and more efficient.

BioCarrierFutur will take advantage of the fact that all tumors have one characteristic in common: due to the high cell division rate, their temperature is 1 to 2 degrees Celsius higher than the surrounding tissue. The temperature is a parameter that can be controlled relatively easily, for example by local overheating in the tumor (hyperthermia therapy). The project aims to realize a system for temperature-switchable drug release. For this purpose, nature serves as a model to develop novel biomimetic polymers that serve as carrier systems for the formation of thermoresponsive, supramolecular structures. These nanotransporters are designed to decompose at increasing ambient temperature and release trapped active ingredients in a targeted manner. This solution idea transforms biological principles into a programmable material for the construction of a functional drug carrier system.

In the future, nanotransporters will be used to encapsulate the highly toxic drugs in the diseased tissue and release them by remote control. This not only promises a significant improvement in the efficacy and tolerability of established therapies, but would also open up new ways for the targeted transport of sensitive active ingredients such as biotherapeutics. The successful proof of concept will enable the acquisition of further research funds and create the basis for a far-reaching exploitation, also beyond the use in cancer therapy.

Fraunhofer IMM contribution

- Definition and organization of synthesis methods and analytical procedures for the production of suitable polymers or their supramolecular structures in water
- Modification of commercially available block copolymers by photoreactions
- Identification of suitable polymers as well as their chemical parameters
- Development of a functional proof-of-concept system

BioCarrierFutur, funding reference: Fraunhofer internal

2

CREATING A COST-EFFECTIVE, ULTRAFAST, DNA-BASED TUBERCULOSIS TEST

Tuberculosis (TB) is one of the top 10 causes of death worldwide. It is caused by bacteria (Mycobacterium tuberculosis) that most often infects the lungs. TB is a widespread infectious disease that is particularly common in developing countries, but in principle occurs in every part of the world. About one third of the human population is thought to carry the pathogen. About 10 % of these carriers can develop active TB during their lifetime. What makes TB an urgent global health problem is the multidrug-resistant tuberculosis (MDR-TB), a form of TB caused by bacteria that do not respond to isoniazid and rifampicin, the two most powerful, first-line anti-TB drugs. Multidrug-resistant TB (MDR-TB) is on the rise and remains a public health crisis and a health security threat globally.

One person infected with TB can typically infect 10-15 others and current TB testing methods require weeks to deliver a diagnosis. Slow diagnosis can lead to patients being placed in respiratory isolation unnecessarily or put on ineffective therapies. Fast and accurate diagnosis makes it possible to treat patients right away and can help put an end to the spread of TB.

The goal of the project is to use cutting-edge technology to create an easy, safe to use and extremely fast test for TB that is based on DNA detection. Current DNA-based detection of TB can take several hours.

The future PITBUL system's USPs

- Real-time PCR in 2 to 15 minutes
- Reaction volumes 4 to 50 times higher than any current system, for increased sensitivity
- High multiplexing degree for cost-efficient testing
- MDR TB markers stemming from recent cutting-edge research data
- Cloud-based PCR-software
- High-performance cartridge-based system, adaptable to other multiplex assays
- Two-tailed qPCR TB assays to detect a broader span of strains

Fraunhofer IMM contribution

- Development of concepts for reagent storage, the actuation of sample liquid inside of the cartridge and other necessary microfluidic operations (splitting/mixing of sample aliquots, high multiplexing capacities etc.)
- Lyophilization and reagent storage integration
- Evaluation of assembly and bonding procedures for the individual cartridge components

PITBUL, funding reference: EU grant agreement no. 768889

1 *Methgas test rig*
2 *Methgas stainless steel afterburner*

1

2

POWER-TO-X – HOW TO USE RENEWABLE SURPLUS ENERGY

Transforming the energy sector by increasing renewable energy generation requires strategies for storage technologies, grid flexibility and demand side management. Power-to-X comprises a variety of options to meet these challenges and is to be understood as an umbrella term for different processes, technologies or applications to convert primary energy (preferably from renewable sources) into an energy carrier, heat, cold, product, or raw material.

Primarily Fraunhofer IMM operates in the application fields of power-to-gas, power-to-fuel and power-to-chemicals. We cover the entire technology chain from catalyst development and stability testing, process simulation, system design and control to development of low-cost fabrication techniques, reactor construction and complete system integration and testing. A portfolio of long-term stable catalyst formulations is at hand for use in various heterogeneously catalyzed gas-phase reactions. The catalytic coatings can be optimally adapted to reactor type and process scale. A specially developed screen printing process for initial batches or piloting allows the micrometer precise insertion of the catalyst into the microchannels.

All issues dealing with the use of carbon dioxide as a material will ultimately be judged by the so-called climate neutrality that implies the production of the required hydrogen by relying on regenerative energy production. From the technical point of view, each new application requires either the development of a novel catalyst formulation or at least an optimization of existing formulations with respect to selectivity and activity. At the same time, the catalysts need to be stabilized for the real process environment and the optimum utilization of material and heat cycles in the entire system need to be considered to guarantee an optimum process efficiency.

Fraunhofer IMM's activities

- Development of an innovative reactor technology for the methanation of carbon dioxide in the side stream of a biorefinery
- Development of mobile plants for the conversion of used cooking oils and pyrolysis oil into biodiesel and synthetic fuels respectively
- Realization of reactors for methanol synthesis from synthesis gas
- Methanol-to-gasoline; production of synthetic gasoline from synthesis gas via methanol
- Realization of a 50 kW reactor for the conversion of carbon dioxide from biogas into methane

Internal projects

3 PEEK double falling film microreactor for photo chemistry

4 Double falling film microreactor built in test plant for photo chemistry

3

4

DOUBLE FALLING FILM MICRO-REACTOR BUILT IN TEST PLANT FOR PHOTOCHEMISTRY

Greenhouse gases such as carbon dioxide are suspects of being co-responsible for global warming. Even though the carbon cycle is virtually closed when using biomass for energy production, the utilization of generated CO_2 is a highly topical sociopolitical question. In case of a successful utilization, especially when applying alternative sources of energy such as wind energy, hydropower or solar energy, the ecobalance can sustainably be improved. Decarbonization is a term that increasingly appears in position papers, industry roadmaps and climate action plans. Fostering the circular economy is part of the possible transformation paths that have been investigated in the framework of the roadmap towards a climate neutral chemical industry in Germany in 2050.

CarbonCat is a project for fundamental research in the fields of organic chemistry and reactor and light engineering providing a strong base for various applications. Utilizing CO_2 as alternative carbon source the consortium directly aims at reducing the dependence on fossil raw materials like mineral oil. The project will provide

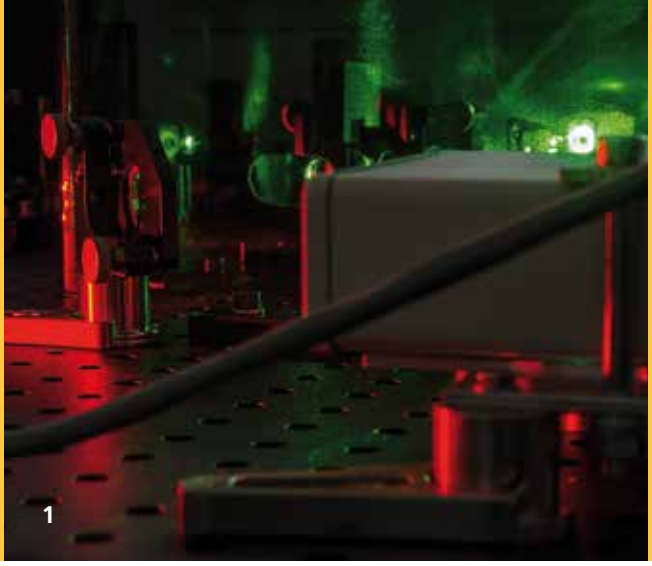
- pioneering development of a microreactor system by which the potential of novel catalyst materials shall be evaluated to achieve an innovative transformation of CO_2 into valuable C1 compounds like methanol under sustainable conditions
- new and important insights into catalyst development with diamond materials being chemically modified and optimized for acting as photocatalyst using visible light from LED illumination as energy source
- trendsetting advancements in reactor engineering for continuous flow photochemistry allowing the intense contacting of solid diamond catalyst, water and carbon dioxide gas with visible light.

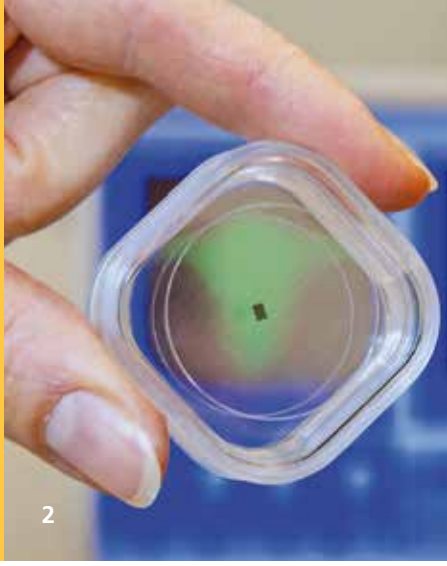
Fraunhofer IMM contribution

- Expertise in the development and exploration of microstructured reactors
- Realization of a continuously operating reactor plant with the novel diamond photocatalyst as a core
- Physical adaptation of the diamond material applied in the microreactor
- Detailed investigation of the photocatalytic process in continuous operation mode

CarbonCat, funding reference: German Federal Ministry of Education and Research (BMBF) funding code 033RC009A.

1 Optical set-up for the laser treatment of a silicon target
2 Silicon target on which the nanoscale 3D structure should grow





NANOSCALE 3D STRUCTURES MADE OF METALS USING A FEMTOSECOND-LASER

For years, Germany is a forerunner when dealing with the development and application of laser-based technologies for the generation of nanostructures in photoresists. The realization of tiniest structures at nanometer scale is gaining more and more importance in a variety of technical applications. Adding a third dimension to the structures while simultaneously decreasing the structure size to the order of magnitude of the light wavelength opens up the possibility to address interesting phenomena such as the targeted manipulation of light to realize novel optical components or surface functionalization to yield novel sensing elements.

Vapor deposition of metals is a well-known technology used to create functional layers made of metals. This includes laser-based vapor deposition using metal precursors. The aim of the project LAMETA is to scale down the resolution limit to the nanometer scale by combining two-photon absorption with commercially available metal precursors and, thus, to provide a process that will allow producing fully three-dimensional nanostructures directly, on any substrate, without elaborate lithographic processes requiring special photoresists.

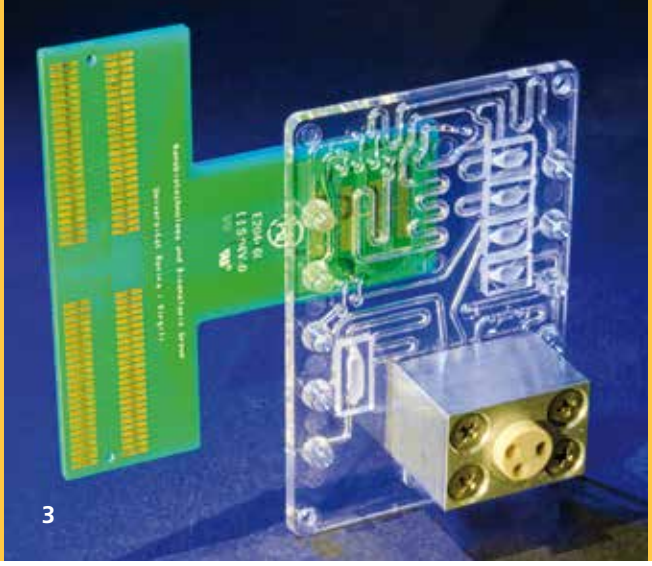
In the framework of the project, it is intended to enable new applications in the field of plasmonics by

- investigating the resolution limit of the process
- realizing suitable functional demonstrators to allow a targeted interaction between light and the periodical metal structures.

Fraunhofer IMM contribution

- Elaboration of process windows for the deposition process using a femtosecond laser oscillator
- Transfer of the deposition to the third dimension
- Optimization of structure sizes in the range of 100 nm for plasmonic applications at wavelengths from near infrared to visible light
- Demonstration of the process via two functional models, a passive optical component and a plasmon resonance based sensor

Project LAMETA, funding reference: Federal Ministry of Education and Research, 13N14948



3 *Exemplary microfluidic cartridge with integrated electronics*

EARLY DETECTION OF CERVICAL CANCER IN HARD-TO-REACH POPULATIONS OF WOMEN BY PORTABLE POCT

Cervical cancer is the 4th most common type of cancer in women worldwide. 85 % of affected women come from developing countries where regular screening is not available and the risk of developing cervical cancer is correspondingly higher. The preventive vaccination against human papillomavirus and the early detection of precancer in screening programs has shown to be successful in reducing cancer incidence and mortality. However, various challenges hinder the global implementation of such programs, in particular the non-participation of women in screening. This illustrates the lack of consideration of ethnic, cultural and resource differences between various population groups in current cervical cancer screening.

ELEVATE will conduct social science investigations to identify hard-to-reach women in Belgium, Brazil, Ecuador and Portugal, to address their barriers to screening and to design strategies to make primary care more accessible to them. This will be complemented with fundamental and technological research to develop an efficient and marketable test for the combined genomic and proteomic detection of HPV infections in those populations at high risk.

The future test will be

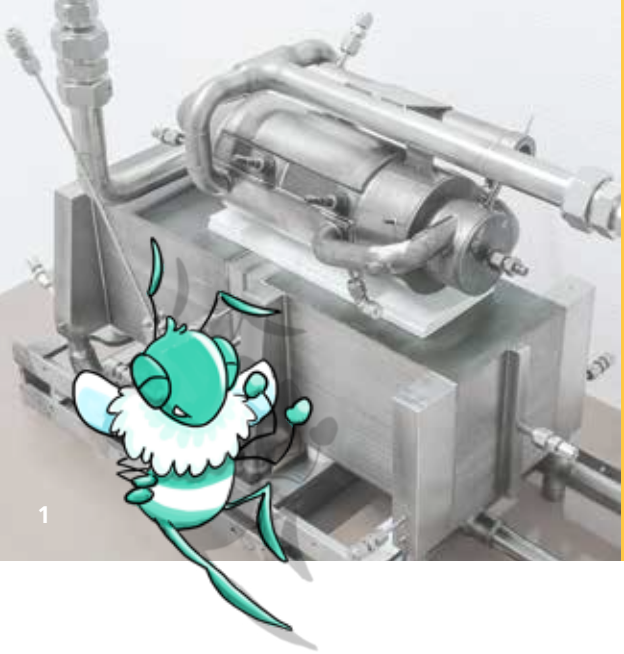
- portable
- cost-effective
- compatible with self-sampling
- point-of-care with rapid and easy-to-understand results, without relying on electrical outlets or trained health personnel.

Another integral part of the project is to infer and disseminate the societal and economic implications of the developed strategies using a hard-to-reach community-based participatory research.

Fraunhofer IMM contribution

- Identification of system requirements
- Interfacing with instrumentation
- Design, fabrication and testing of the microfluidic cartridges for combined proteomic/genomic HPV screening
- Integration of sample preparation and electrode

ELEVATE, funding reference: Horizon 2020 EU grant agreement no. 825747



1 *Propylene glycol fuel processor*
2 *Plant for component testing of fuel processor system*

ENERGY SELF-SUFFICIENT AIRCRAFT KITCHENS RELIEVE ENGINES AND ENVIRONMENT

Within the scope of earlier projects, a mobile power supply for passenger aircraft based on propylene glycol as fuel was developed together with the lead company Diehl Aerospace GmbH. The aim was to relieve the aircraft's main turbine and auxiliary power unit (APU) from the task of generating power for passenger comfort in order to meet future aviation requirements. Since the galleys are one of the main power consumers in the aircraft, a trolley was chosen as a mobile unit that can be docked to the galleys and supplies them with power. In the medium term, energy-autonomous galleys (MAGIC®) are to be created in this way, and in the long term even entire energy-autonomous cabins (DACAPO®).

In the prior projects DIANA and GETpower, the functionality was successfully demonstrated in a laboratory demonstrator and then a galley oven with a fuel cell-battery hybrid system coupled with a reformer was operated completely with classical aircraft on-board power supply.

In GETpower2, the focus is now on

- the utilization of the thermal energy generated
- the optimized integration of the entire system into a standard trolley
- the integration of such a trolley into a galley
- the associated impact on aircraft levels and certification conditions
- the operational aspects, including logistics and maintenance concepts.

By using a sustainable, biodegradable fuel as well as efficient and clean fuel cell technology, renewable energy is introduced into aviation. In the future, the additional energy generated on board will offer passengers more comfort on board through additional cabin functions. At the same time, this will relieve the existing on-board power supply system and thus the engine generators, resulting in lower kerosene consumption.

Fraunhofer IMM contribution

- Simulation of fuel processor system to assess the impact of changes in the architecture of the reformer system on the overall system
- Investigation of alternative fuels with regard to their suitability
- Investigation of lightweight construction, repair options and recycling of the fuel processor system
- Optimization of the trolley's thermal integration
- Development and test of the reactors, integration into the complete fuel processor system and testing of it
- Realization of a test setup for the fuel processor system for testing under the required environmental conditions

GETpower2, funding reference: 20Y1710

FRAUNHOFER IMM VS. CORONA

As part of the Corona Intervention Fund of the Carl-Zeiss-Stiftung, we are integrating a commercially available SARS-CoV-2 RT-PCR assay into a rapid analysis device that has already been developed into a prototype. The test system, which was originally developed for the detection of viral diseases of the respiratory tract in a BMBF-funded project, has an analysis time of less than 30 minutes and a handy size for rapid detection on-site.

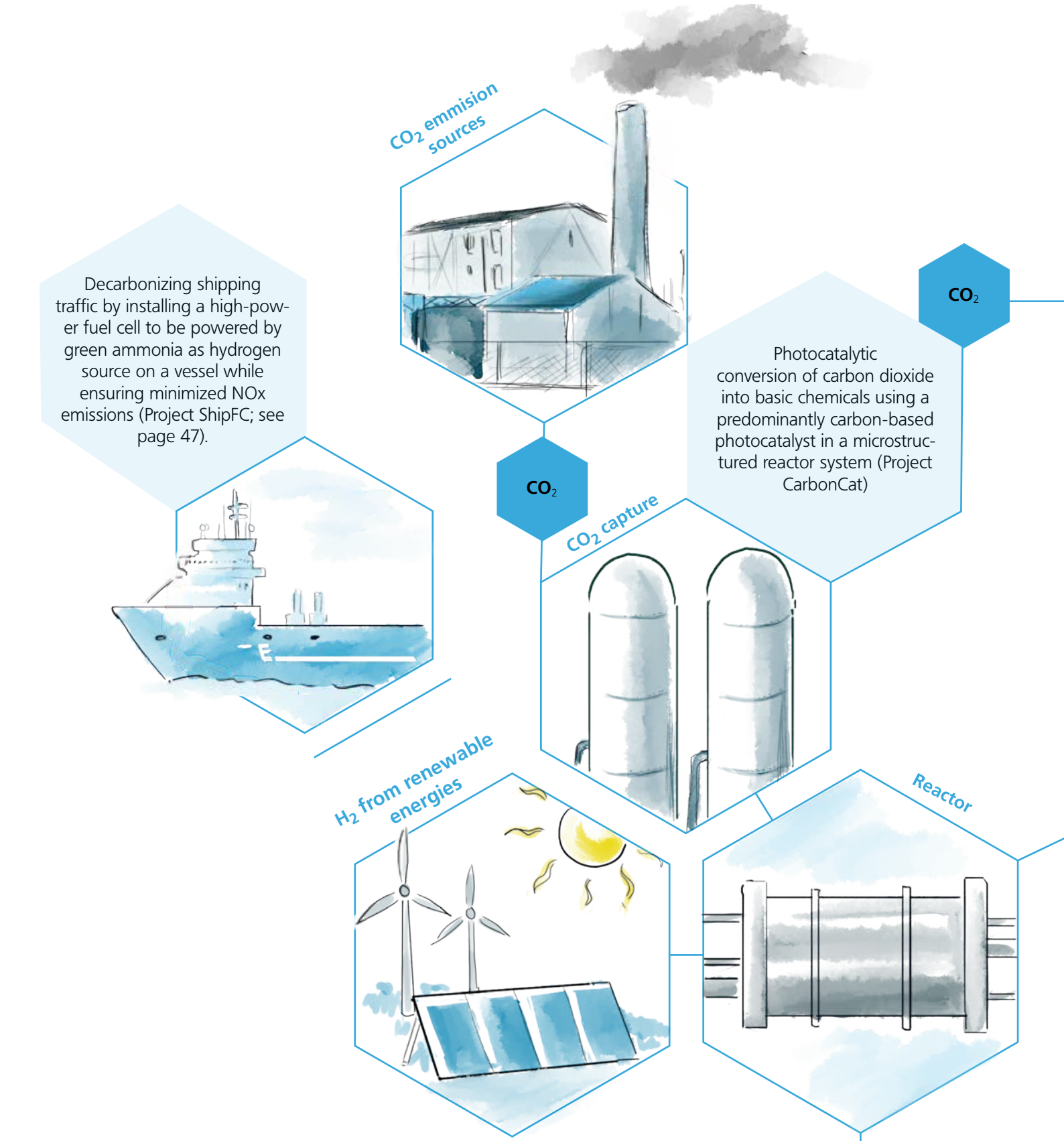
The project CODECT deals with the concerted early digital detection of the Covid-19 transmission based on routine laboratory tests via digitally AI supported diagnostics. Rapid blood tests can be collected anywhere while the routines themselves are supposed to be run in the lab environment. Target group are mainly those patients that are already infected but still symptom-free giving the best chance to break the chain of infection in a very early stage.

This project is funded by the
Carl Zeiss Foundation

The CODECT project is supported by the Fraunhofer Internal Programs under Grant No. Anti-Corona 840237

GUIDING SUBJECTS

At first glance the entire activities of Fraunhofer IMM might be perceived as a ››bouquet of colorful flowers‹‹. In fact, the absolute majority of our project work is clearly subordinate to a priority setting having in mind some of the most urgent issues to be addressed by R&D providers. That's what we call our guiding subjects in which we join our forces and have the knowledge base to make the difference for the benefit of society.

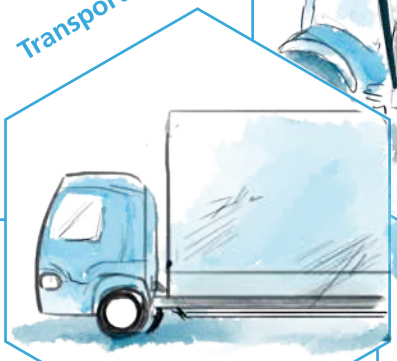


DECARBONIZATION

Our Federal Climate Protection Plan stipulates a dramatic reduction of greenhouse gases until 2050. This includes a turnaround towards a low carbon industry and society. Possible approaches are avoiding/reducing carbon dioxide (CO_2) emissions, the capture of CO_2 to be recycled for further usage while retaining the carbon neutrality of the production process, and the storage of waste CO_2 usually from large point sources. Fraunhofer IMM's activities currently mainly focus on the utilization and avoidance of CO_2.

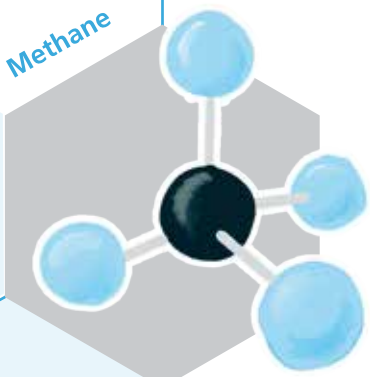
Agriculture

Transport



Living

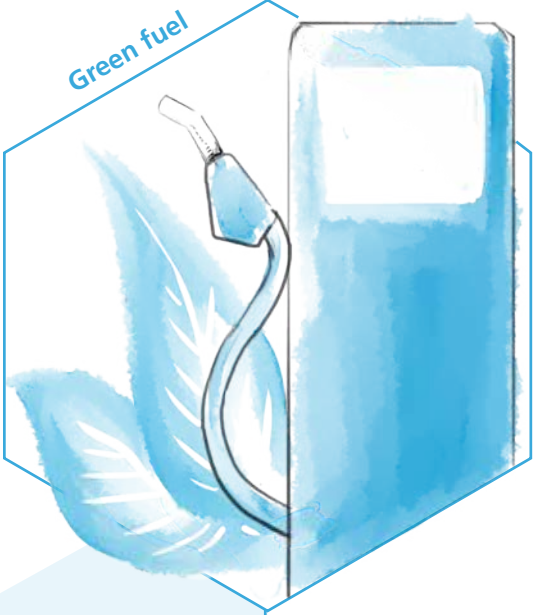
Methane



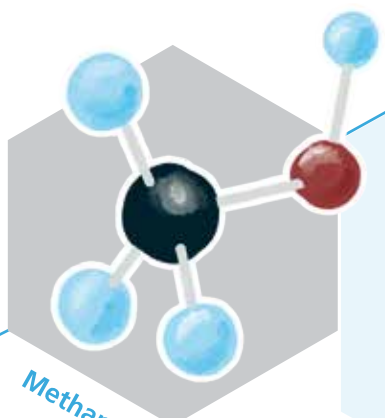
Innovative reactor technology for the methanation of carbon dioxide as side stream of integrated bio-refinery concepts (Project ICOCAD)

Conversion of carbon dioxide from biogas into methane using hydrogen which is regeneratively produced via electrolysis; 50 kW reactor installed at biogas plant (Fraunhofer internal cooperation)

Green fuel



Development of a mobile plant for the conversion of used cooking oils into biodiesel (Project Biodiesel)



Methanol

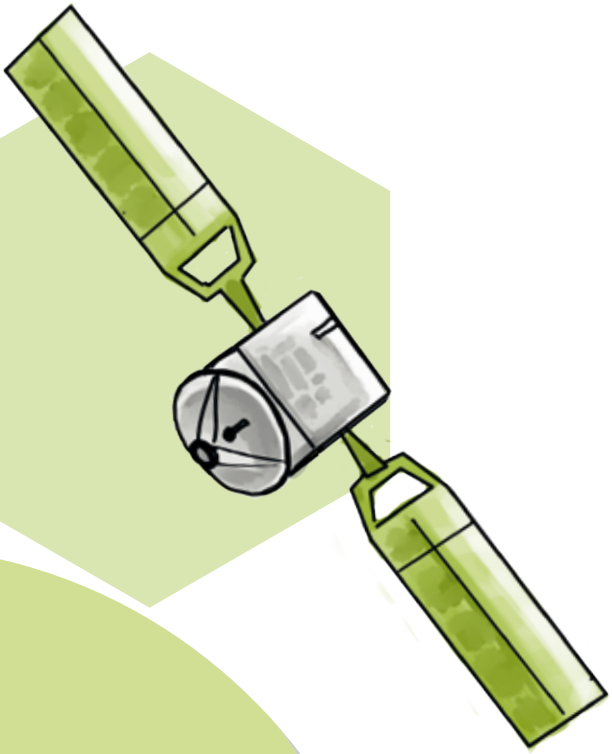
Development and demonstration of novel intensified unit operations which can be integrated into economic and sustainable biorefineries for the production of second generation biofuels, intermediates and high value products (Project SUPRABIO)

Development of a miniplant for the conversion of pyrolysis oil into synthetic fuels (Projects BIOGO)

ENVIRONMENT

Protecting our environment is much more than dealing with greenhouse gas emissions. It is widely agreed that the era of endless affordable resources is coming to an end and that access to raw materials and clean water cannot be taken for granted. Biodiversity and ecosystems need our special attention. In this context Fraunhofer IMM is contributing with a wide range of activities developing applications with respect to environmental monitoring and resource efficiency.

Development and manufacture of a slit module with an ultra-precise double slit chip as core element for EnMAP (Environmental Mapping and Analysis Program). EnMAP is a German satellite mission that aims at monitoring and characterizing the Earth's environmental and climate changes based on imaging spectroscopy.



Transition to a more flexible and sustainable chemistry by taking novel integrated upstream and downstream processing paths involving flow chemistry and membrane technology in two chemo-enzymatic processes to an industrial level. The target products include commodities and fine chiral chemicals for crop protection, agrochemicals, public health, feed/food or cosmetics. (Project INCITE, see page 29)

Further development of a reformer system for a mobile power supply in passenger aircrafts based on propylene glycol as fuel 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)

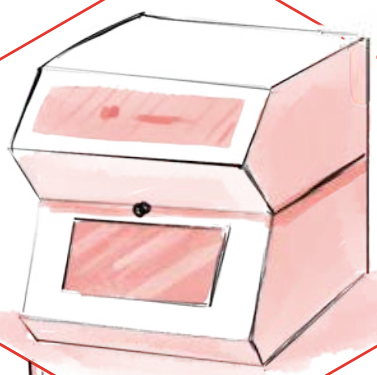
Standardized, modular, highly functional and mobile container environment allowing the fast transformation of various raw materials into valuable chemicals and fuels saving time and costs with maximum flexibility and diversity. (EcoTrainer)

Development of selected innovative and energy-efficient chemical reaction processes using novel microwave, ultrasound and plasma systems as well as environmentally friendly catalysts, to finally demonstrate them in industrial environment. (Project MAPSYN)

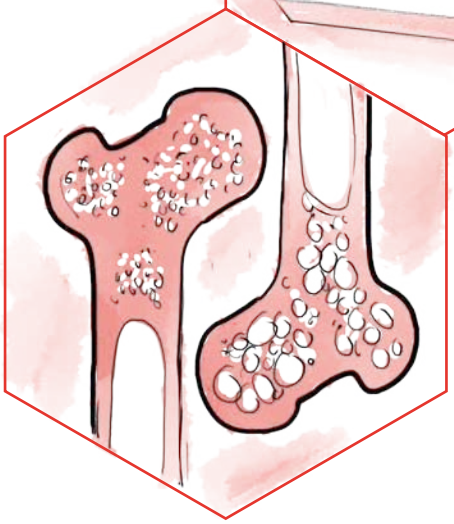
Development of a prototype of a reformer and fuel cell-based combined heat and power unit with an electrical power equivalent of 50 kW aiming at a climate-neutral energy supply. (Project BlockCell, see page 21)

POINT-OF-CARE TESTING

Development of a point-of-care system for the rapid diagnosis of influenza subtypes (Project PanPlex)



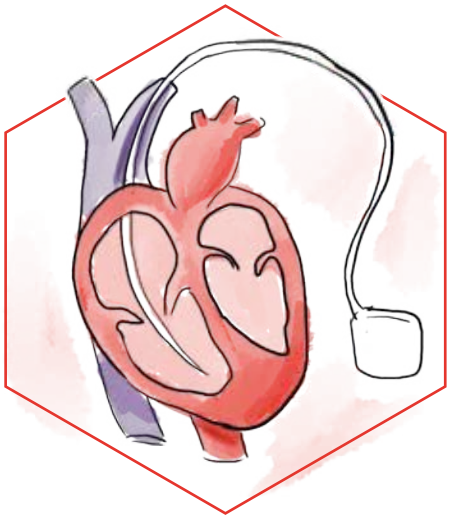
Implementing sample preparation into a diagnostic health platform for the ultra-fast point-of-care testing for tuberculosis (TB) as well as emerging TB resistance markers (Project PITBUL, see page 31)



Implementing sample preparation and sensors into a portable and point-of-care HPV testing device for the early detection of cervical cancer in hard-to-reach populations of women (Project ELEVATE, see page 35) and into a point-of-care in-office device for identifying individuals at high risk of osteoporosis and osteoporotic fracture (Project PoCOsteo)

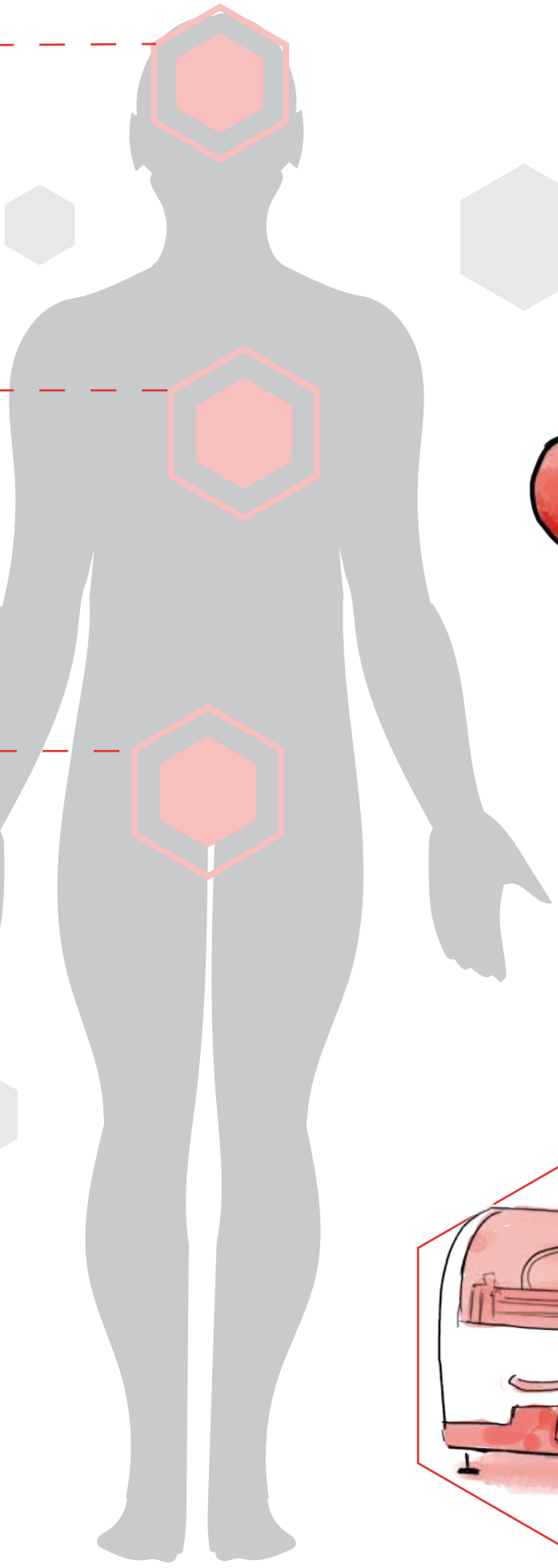
THERAPY

Neuroprosthetic applications dealing with restoring motor functions after severe spinal cord injury (Project NEUWalk) and realizing an implantable MEMS force sensor device required to monitor the activity of the myocardial muscle in a neuroprosthesis allowing restore the vagal-cardiac closed-loop connection after heart transplantation (Project NeuHeart, see page 28)



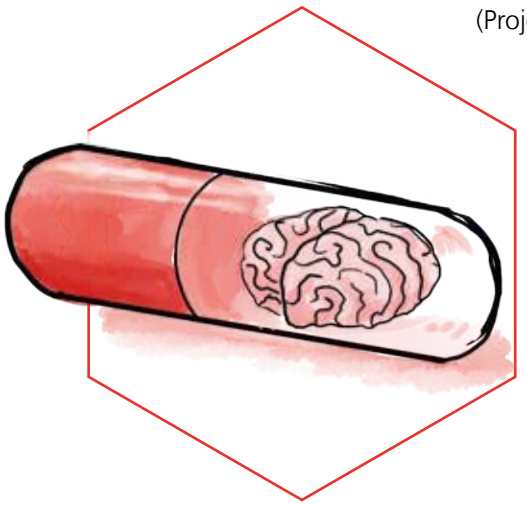
HEALTH

As chronic and infectious diseases, pandemic threats and antimicrobial resistances are on the rise, it is of utmost importance to find new ways to prevent diseases or at least their spread, to develop better diagnostics and to establish more effective therapies, in an increasing number of cases personalized therapies. Fraunhofer IMM's project portfolio especially comprises activities directed towards personalized diagnostics, point-of-care testing, targeted drug delivery and, to some extent, therapeutic approaches.



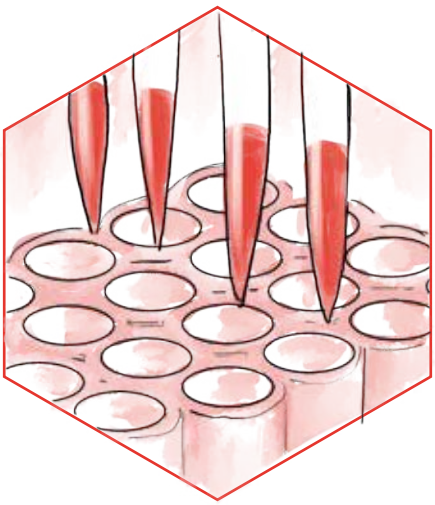
TARGETED DRUG DELIVERY

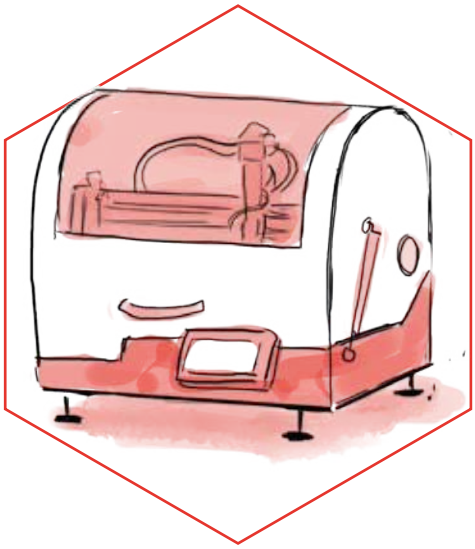
Dealing with functio-
nal carrier systems for tempera-
ture triggered drug release in cancer
therapy using a programmable material
(Fraunhofer internal project) and with the
development of a close-to-real dynamic
blood brain barrier model allowing to
identify those nano particles properties that
enable an actual passage across the barrier
without damaging the barrier.
(Project NanoBBB)



PERSONALIZED DIAGNOSTICS

Identification and
isolation of further
biomarkers such as
exosomes using liquid
biopsy (Fraunhofer
internal project)

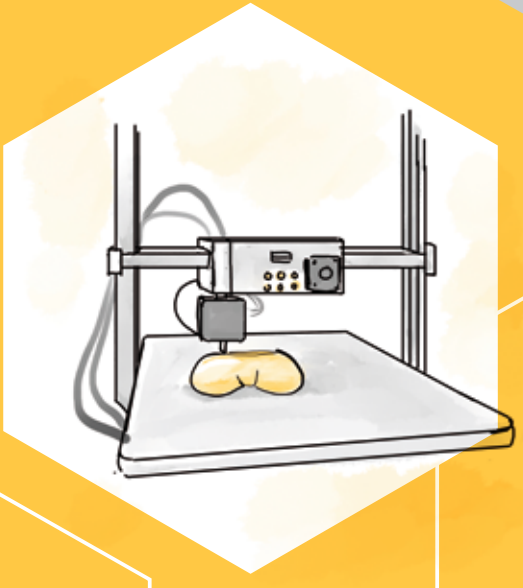




Series of
projects dealing with
the isolation and characteriza-
tion of circulating tumor cells
cumulating in a project that
currently deals with the isolation
of tumor cells in real patient
samples (Project CTCelect)

WHAT'S NEXT

Understanding complex correlations, an orderly performing of experiments and, sometimes, trying to be smarter than nature itself is part of the daily business of a researcher. But being a scientist specially goes along with the commitment to go beyond the state-of-the-art and to tackle the society's needs of tomorrow already today, to always be one step ahead. Therefore we have dedicated ourselves to the following topics. **That's where we want to make the decisive difference in the nearer or distant future!**



SAVING LIVES BY ESTABLISHING A RELIABLE TECHNIQUE FOR THE PRINTING OF ORGANS

Current approaches usually rely on using some kind of bio-ink to produce an organ-like cell agglomerate that is expected to re-organize itself to a functional organ. We are working on a technology that allows to use more or less commercially available print-head technology to place single cells at a particular time, at a specific place and, at the same time, with high speed **and** high precision. This has the potential to significantly increase the success rate.

Initial activities funded by an internal program of the FhG

HEADING FOR MW FUEL PROCESSORS/REFORMERS TO ACHIEVE CLEAN ENERGY/HEAT SUPPLY

The search for an efficient and, preferably, at the same time ecological and perspectively at least CO_2 neutral electrical energy and heat supply is a recurring point of discussion. Fuel cell based combined heat and power units increasingly gain popularity due to their possible efficiency. While current commercial solutions primarily address single households we strive for CHP units that allow for a reliable supply of whole residential areas and companies using fuel processors based on our well established plate heat exchanger technology. A 50 kWel system is currently in trial operation at our premises.

Initial activities funded by the state of Rhineland-Palatinate

IMPLEMENTING AUTONOMOUS ANALYSIS TO PROVIDE REAL-TIME INFORMATION AT THE POINT-OF-ACTION

The improvement of product purity, energy and resource savings, safety and controllability as well as reliability require value-added and intelligent analysis tools in production processes. In this context artificial intelligence and autonomously operating analysis units gain increasing importance. Merging our capabilities in microfluidics and MEMS based sensor technology allows to overcome existing limits to combine sample preparation methods, resource efficient processing and optical/electrical sensor components into a highly integrated automated functional unit that is able to provide very specific information required for a continuous monitoring and feedback capable control.

Initial activities funded by the state of Rhineland-Palatinate

SUPPORTING THE ENVIRONMENT BY DECARBONIZING SHIPPING TRAFFIC

We participate in a maritime innovation project that has been awarded 10 million Euro funding from the European Union, looking to install the world's first high-power fuel cell to be powered by green ammonia as hydrogen source on a vessel. We are in charge to develop, design and manufacture catalysts as well as a compact catalytic afterburner, specifically dedicated to ensuring minimized NO_x emissions.
The 2 MW ammonia fuel cell system will be installed in Viking Energy in late 2023.

Funded by the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875156 (receiving support from the European Union's Horizon 2020 research and innovation program)

WHAT MAKES THE DIFFERENCE

What really makes a good team? All team members share a vision, are well organized and feel a collective responsibility. Roles are clearly defined in a friendly and respectful working environment allowing an open and transparent communication at any time. The look beyond the own horizon is natural. Sounds too good to be true? Well, there is always some room for improvement but basically that is exactly what makes our employees special and why we decided, beginning with this report, to regularly devote some lines to persons you already might know and those who usually stay in the background ... persons who make the difference.

We asked seven people...What is your contribution to the success of Fraunhofer IMM? And what drives you?

1. The service provider:

Uwe Tschernich,
Central Administrative Services Group

- I help in the institute where I can: from small handicraft activities to the maintenance and care of the outside area, from goods receipt and goods issue up to office work, everything is included.
- No day is the same and it motivates me again and again when I can make work more pleasant for my colleagues or save the institute money by negotiating more favorable conditions with service providers or doing smaller jobs myself.

2. The lab technician:

Ivette Krollmann,
Precision Microfluidics Group

- My contribution? I'd say I breathe life into microfluidic systems. My job is the circuit design as well as the manufacturing of electronic components for the control of microfluidic systems.
- What I like about my job is that there are always new challenges due to new projects. Thanks to the versatile, multifaceted work in different teams, I am always learning and expanding my horizons.

3. The engineer:

Carmen Schwind,
Microsystems for Biology and Medicine Group

- I make sure that biological laboratory standards are transferred into our fully automated microfluidic systems by writing assay procedures with our self-developed software. This is how systems like our CTCelect for personalized cancer research are created.
- What drives me every day? My job is my hobby, I love what I do. Here at Fraunhofer IMM, I appreciate the very varied work, the homogeneous working group, the compatibility of family and career. And: Whenever I need help, my colleagues are there for me.

4. The workshop employee:

Marc Weritz,
Microfluidic Components and Microfabrication Group

- What I like about the production of prototypes is that every project presents a new challenge. I continuously optimize production, solve technical problems and advise my colleagues on feasibility.
- In addition, I have a friendly relationship with many of my colleagues and I really enjoy my job. That's why I also like to educate myself privately, for example to be up to date in CAD design.

5. The student:

Nicolai Schwarz (doctoral thesis),
Microsystems for Chemical Analysis Group

- My doctoral thesis is focusing on the development of process windows for deposition of metallic nanostructures from the gas phase, using a femtosecond laser. The influence of different parameters on the deposition process is observed by systematic experiments. My fundamental work enables a new approach for the development of plasmonic sensors on the nanometer scale. The implementation of such ideas strengthens the technological lead of IMM in international competition making us pioneers in an innovative field.
- I like working at Fraunhofer IMM because the scientific exchange with colleagues from the different departments is very fruitful and everyone is helpful. I admire the technical know-how that has been accumulated here over the years and I am glad to be a part of it and to be able to contribute my part.

6. The scientist:

Gabriele Menges-Flanagan,
Flow Chemistry Group

- Internally, I have continuously advanced my research topic ››Reactive Intermediates‹‹, realized a pilot demonstrator and thus enabled IMM to acquire larger-volume industrial cooperations.
- What I really appreciate at the Institute is the multidisciplinarity of colleagues and the opportunity to be both active in the laboratory and involved in the big picture. My motivation is that ››my‹‹ developments can actually be of benefit to industry and society.

7. The designer:

Christian Hofmann,
Group Leader Reactor- and Component Design

- I like to say jokingly that I give the scientists something to play with. I turn their ideas into simulations and 3D designs, plan and supervise production right up to the assembly and commissioning of devices and components.
- It is not without reason that I have been working at IMM for over 20 years. Here I can work independently and still be part of an interdisciplinary team. The internal infrastructure is ideal and we have a great working atmosphere.

EXTENSION BUILDING

We have been eagerly awaiting the first tangible visual results of our new building project for five years. A »real« building from the outside, but what does it look like inside? Follow us on a small leap into the future and look forward with us to all the things that will come at the beginning of next year!

Inventing the future
in our new and ultramodern
LABORATORIES.

Getting inspirations in our
COMMUNICATION & EXHIBITION
area while enjoying a good
cup of coffee.

Making the best
possible impression right from the
start with our spacious
FOYER.

Working on
really big ideas in our new
TECHNICAL CENTRE.

APPENDIX

TRADE FAIRS & EVENTS 2019/2020

Trade fair/event	when	where
11th European Congress of Chemical Engineering	September 15–19, 2019	Italy/Florence
Compamed	November 21–28, 2019	Germany/Dusseldorf
15th International Hydrogen & Fuel Cell Expo	February 26–28, 2020	Japan/Tokio
Quantum Dot Forum	March 11–13, 2020 (CANCELED)	USA/California
Pharma Forum	March 12, 2020 (CANCELED)	Germany/Mainz
Girls' Day	March 26, 2020 (CANCELED)	Germany/Mainz
Analytica	March 31–April 3, 2020 postponed to October 19–22, 2020	Germany/Munich
China International Medical Equipment Fair	April 9–12, 2020 (CANCELED)	China/Shanghai
Hannover Messe	April 20–24, 2020 (CANCELED)	Germany/Hannover
IFAT (World's Leading Trade Fair for Water, Sewage, Waste and Raw Materials Management)	May 4–8, 2020 (CANCELED)	Germany/Munich
2nd Flow Chemistry and Continuous Processing Conference	May 11–12, 2020 (only virtual)	USA/Boston
Sensor + Test	June 23–25, 2020 (CANCELED)	Germany/Nuremberg
Microfluidics & Flow Chemistry Europe 2020	June 25–26, 2020 postponed to September 10–11, 2020	Netherlands/Rotterdam

CONFERENCES 2019/2020

Conference	when	where
Jahrestreffen Reaktionstechnik 2019	May 7–9, 2019	Würzburg/Germany
Konferenz Netzwerken	May 28, 2019	Bad Herrenalb/Germany
Nanomed Europe 19	June 17–19, 2019	Braga/ Portugal
ICOSCAR6	September 11–13, 2019	Bad Herrenalb/Germany
2nd International Conference on Nanomaterials Applied to Life Sciences	January 29–31, 2020	Madrid/Spain
3rd Workshop on Modelling of Biological Cells, Fluid Flow and Microfluidics	February 9–13, 2020	Vratna/Slovakia
10th Workshop of Chemical and Biological Micro Laboratory Technology	February 26–28, 2020	Ilmenau/Germany
Flow Chemistry and Continuous Processing Conference (only virtual)	May 11–12, 2020	Boston/USA
Microfluidics & Flow Chemistry Europe 2020	June 25–26, 2020 postponed to September 10–11, 2020	Rotterdam/Netherlands
6. Internationales Commercial Vehicle Technology Symposium Kaiserslautern (POSTPONED)	September 8–10, 2020	Kaiserslautern/Germany

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EFFECTS OF SUPPORT COMPOSITION ON THE PERFORMANCE OF NICKEL CATALYSTS IN CO2 METHANATION REACTION
In: Catalysis Today (2019)

02| Ziogas, A.; Hofmann, C.; Baranyai, S.; Löb, P.; Kolb, G.:
NOVEL FLEXIBLE ELECTROCHEMICAL MICROREACTOR AND ITS VALIDATION BY THREE MODEL ELECTROSYNTHESES
In: Chemie Ingenieur Technik 92 (2020) 5, 513-524

03| Rehm, T.H.:
REACTOR TECHNOLOGY CONCEPTS FOR FLOW PHOTOCHEMISTRY
In: ChemPhotoChem 4 (2020) 4, 235-254

04| Ortega, C.; Kolb, G.:
DME-TO-HYDROCARBON OVER AN MFI ZEOLITE. PRODUCT SELECTIVITY CONTROLLED BY OXYGENATES UNDER THE KINETIC REGIME
In: Industrial and Engineering Chemistry Research 58 (2019) 51, 22893-22904

05| Shanmugam, V.; Neuberg, S.; Zapf, R.; Pennemann, H.; Kolb, G.:
HYDROGEN PRODUCTION OVER HIGHLY ACTIVE PT BASED CATALYST COATINGS BY STEAM REFORMING OF METHANOL: EFFECT OF SUPPORT AND CO-SUPPORT
In: International Journal of Hydrogen Energy 45 (2020) 3, 1658-1670

06| Heinß, N.; Alebrand, S.; Wittek, J.; Baßler, M.:
EQUILIBRIUM TRANSPORT VELOCITY OF DEFORMABLE CELLS AND RIGID SHERES IN MICRO CHANNELS UNDER LAMINAR FLOW CONDITIONS In: Microfluidics and Nanofluidics 24 (2020) 1, Article 3

07| Menges-Flanagan, G.; Deitmann, E.; Gössl, L.; Hofmann, C.; Löb, P.:
SCALABLE CONTINUOUS SYNTHESIS OF GRIGNARD REAGENTS FROM IN SITU-ACTIVATED MAGNESIUM METAL
In: Organic Process Research & Development 24 (2020) 2, 315-321

08| Fuhrmann, M.; Krivcov, A.; Musyanovych, A.; Thoelen, R.; Möbius, H.:
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In: Physica Status Solidi A - Applications and Materials Science (2020) , 1900828

09| Alberg, I.; Kramer, S.; Schinnerer, M.; Qizhi, H.; Seidl, C.; Leps, C.; Drude, N.; Möckel, D.; Rijcken, C.; Lammers, T.; Diken, M.; Maskos, M.; Morsbach, S.; Landfester, K.; Tenzer, S.; Barz, M.; Zentel, R.:
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In: Small (2020)

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In: Flow chemistry: Integrated approaches for practical applications; Chapter 12 ; Santiago, V.L.; Eduardo, G.-V. (Ed.): RSC (Royal Society of Chemistry), 2020, 388-415 (Green Chemistry Series Bd. 62)
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MICROMIXER SYNTHESIS OF SINGLE-CORE IRON OXIDE NANOPARTICLES WITH TUNABLE PROPERTIES
In: ISMAP - Ilmenauer Symposium „Medical Application of Magnetic Nanoparticles and Ferrofluids“, 3: Institut für Biomedizinische Technik und Informatik - TU Ilmenau 27.08.2019 - 28.09.2019. - Ilmenau

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VALIDATION OF A NOVEL FLEXIBLE ELECTROCHEMICAL MICROREACTOR BY ITS APPLICATION TO ELECTROORGANIC SYNTHESES
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15| Rehm, T.H.; Krüger, A.; Sahlmann, B.:
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16| Schramm, J.:
CONTROLLED PRODUCTION OF SILICA NANOPARTICLES VIA FLOW CHEMISTRY
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17| Berger, M.:
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18| Bacher, L.:
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19| Deichmann, J.-G.:
FURTHER DEVELOPMENT OF AN ON-CHIP DROP-ON-DEMAND AEROSOL GENERATOR FOR PLASMA SPECTROMETRY
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20| Baki, A.:
CONTINUOUS SYNTHESIS OF IRON-OXIDE NANOPARTICLES FOR BIOMEDICAL APPLICATIONS
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21| Onyema, H.:
ESTABLISHING A STEM CELL-BASED MODEL OF THE BLOOD-BRAIN BARRIER TO ANALYZE BARRIER PERMEATION OF NANOPARTICLES
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23| Ingenhorst, A.:
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24| Rösch, G.:
ISOLATION AND CHARACTERIZATION OF EXOSOMES FOR LIQUID BIOPSY
In: YSW - Young Scientists' Workshop IMM, 13
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26| Sommer, M.-J.:
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29| Musyanovych, A.:
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34| Deckers, C.; Rehm, T. H.:
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Zuwendungsgeber: BMBF
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38| Alebrand, S.; Arnold, A.; Brucker, C.; Spang, P.:
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Laufzeit: 01.05.2015 – 31.10.2018 Förderkennzeichen: 13N13529 Zuwendungsgeber: BMBF.- Projektträger: VDI Technologiezentrum GmbH. - Mainz, 2019

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42| Onyema, H.:
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45| Rösch, G.:
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