Fraunhofer IMM

Annual report 2023/24

The power of freedom within scientific research

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Editorial

Freedom – a word that we often use carelessly, regardless of its powerful meaning. It is an elastic term that gains relevance especially when it is in danger. In times when freedom is suddenly no longer a matter of course for many, we are thinking more about what freedom means and, above all, what it means and can achieve for us personally.

The Federal Ministry of Education and Research is dedicating Science Year 2024, the year of the 75th anniversary of the Basic Law, to the topic of freedom.

Freedom means, among other things, having the opportunity to act in a self-determined way, without restrictions or constraints. It includes freedom of expression, freedom of choice and individual development.

A good education makes you personally and socially free. Free research and teaching are the cornerstones of good education. As the head of a research institute, it is particularly important to me, together with the entire management team, to create a working environment in which my employees can develop freely, make their own decisions and research freely. After all, our scientists are the driving force behind our successes. Only with the freedom to research own subject areas potential can be exploited and new insights gained. These findings are not only invaluable for us as an institute, but also for society as a whole. By supporting scientific freedom, we help our researchers to become pioneers in their field. They have the opportunity to devote themselves to their research projects with passion and dedication and thus contribute to solving global challenges.

Dear readers, in our previous annual reports we have already introduced you to some of our employees from all areas. Now I would like to give you a deeper insight into the research work of our scientists, which is full of passion, personal responsibility and innovative ideas.

Freedom and scientific research, an unbeatable combination – enjoy reading!

Yours,

Michael Maskos

»As the head of a research institute, it is particularly important to me, together with the entire management team, to create a working environment in which my employees can develop freely, make their own decisions and research freely.«

Prof. Dr. Michael Maskos,
Executive Director,
Fraunhofer IMM

Researchers in the spotlight

Many minds, various topics, one goal: Freedom of research to make the world a better place. On the following pages, we show you the brains behind our topics. Because behind each of these topics is a person who puts heart and soul into her or his research.

Biogas as a hydrogen carrier for fuel cells

Our reformer technology enables the highly efficient utilization of biogas, synthetic and fossil natural gas as a source of electricity and heat or as a hydrogen supply for fuel cell applications – available all over the world, today.

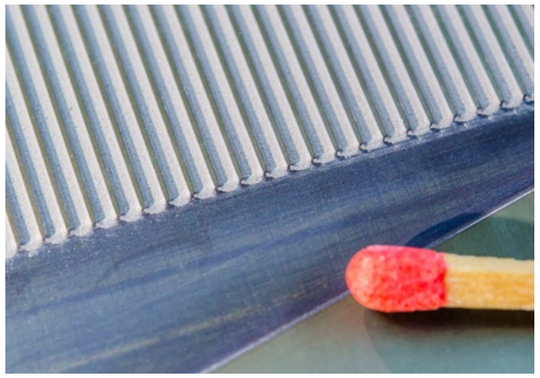
Generate sustainable energy with high flexibility – by using our reformer technology!

IMM technology vs. conventional plants

Combined heat and power plants convert natural gas into electricity using a combustion engine with additional utilization of the resulting waste heat. This task can be fulfilled much better in a coupled reformer-fuel cell system with modern catalytic converter technology:

- Without the emission of NO_x
- Without the use of large moving engine components, thus
- much less maintenance required and much lower noise emissions

Engine-based combined heat and power units have an optimum operating point, beyond which efficiency drops drastically. Unfortunately, many CHP units do not run at this load point. Because a fuel cell is less dependent on the system load, our system can work at partial load at high efficiency, unlike engine-based systems.
We are also highly focused on optimum performance combining the smallest possible size and the highest system efficiency by utilizing the energy contained in all process flows.



Why biogas?

- Methane is the carrier with the highest hydrogen content – up to 80 % hydrogen in dry reformate.
- Biomethane, a carbon dioxide-neutral source of energy, is already being fed into the natural gas grid.
- With today's biogas production capacity, up to 13 % of Germany's natural gas demand can be covered in future by using biomethane.

»Maximum flexibility using biogas on your path to sustainability!«

Dr. Christian Bidart,
Mobile and Decentralized
Energy Generation Group

Nanomedicine

We develop versatile nanoparticle systems for therapeutic and diagnostic applications as well as processes for the continuous micromixer assisted production of nanocarriers.

We developed a device for dynamic light scattering (flowDLS), with which the particle size can be continuously determined during production.

What are the advantages of a modular continuous process?

A modular continuous nanoformulation process increases productivity, quality, scalability and reproducibility and makes the process cost-efficient. It also reduces the risk of contamination and human error by reducing manual intervention and enabling innovation. In terms of advanced manufacturing, modular continuous processes can integrate advanced technologies such as real-time online analytics, automation and process optimization tools to drive innovation in nanoformulation.

How do we ensure reproducibility in the production of nanoformulations?

Continuous processes ensure consistent mixing and reaction conditions, resulting in more uniform and high-quality nanoparticles. Further, advanced monitoring and control systems in modular setups allow for precise control of process parameters, leading to improved reproducibility and reliability of the nanoformulations.

Core competencies

- Development of nanoformulations
- Process development
- Analytical services
- Microstructured moules for formulation, downstream processing and online analytics

Customer benefits

- Cost and time savings
- Faster time-to-market
- Flexible production quantities (“on demand”)
- Innovation advantage
- Modules for Continuous Manufacturing (CM) and Process Analytical Technology (PAT)

»We have micromixing modules for various development stages from screening to production scale (1 mL to 100 L) without parallelization!«

Dr. Regina Bleul,
Head of Nanomaterials
for Cancer Therapy Group

Lab-on-chip PCR and isothermal amplification

Microtechnology, macropotential: nucleic acid analysis of the future. We develop customized, microfluidic-based on-chip amplification solutions for individual applications.

We offer a technological portfolio which can be composed and adapted to a major range of nucleic acid analysis, such as pathogen detection, analysis of cell-free DNA or genetic testing.

Our technology

- Fast reaction times: Microfluidic-based technologies enable fast and efficient amplification processes.
- Low reagent consumption: By using tiny liquid channels, the consumption of reagents can be minimized.
- High sensitivity: Microfluidic-based technologies enable the highest sensitivity in the detection of nucleic acids.
- Automation: The integration of microfluidic processes into automated systems enables easy handling and scalability of nucleic acid amplification.
- Compact size: Microfluidic systems are compact and portable, allowing and can be used directly at the point-of-need.

Customer benefits

Using microfluidic-based nucleic acid amplification technologies, freely selectable sections of any DNA strand can be amplified and detected in a highly specific manner. In principle, all samples containing cells from animals, plants, fungi, microorganisms, or cell-free nucleic acid, can be used. Research at the IMM focuses on strategies for reducing, simplifying and automating the necessary sample preparation steps.

- Reliable analysis: Microfluidic-based technologies offer precise control over reaction conditions, resulting in high accuracy and reproducibility of results.
- Time and cost efficiency: Automated microfluidic-based technologies enable fast, material-saving amplification processes and minimize the workload.
- Safety and flexibility: The integration of microfluidics in automated systems allows simple, user-friendly and flexible handling of the technology.

»Transfer your desired molecular biological analysis to a microfluidics cartridge, optimize your laboratory processes in research and diagnostics and exploit new fields of application!«

Dr. Verena Grützner,
Infection and Cancer
Diagnostics Group

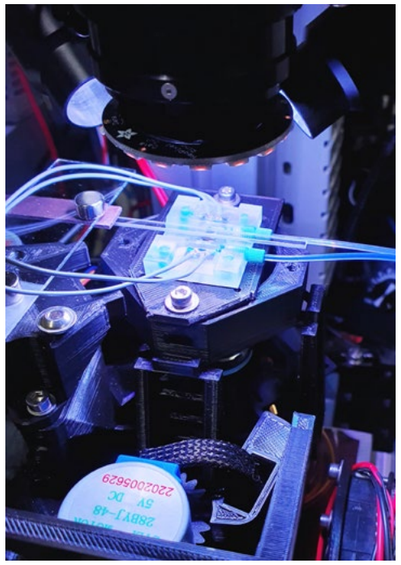
Bioprinting – Targeted cell dispensing in minimal volume microdrops

Our technology dispenses single cells, encapsulated in the smallest possible liquid volumes, to avoid dilution in drug-testing and enable high-proximity cell-by-cell bioprinting with a resolution that enables direct intercellular connections.

Cells survive the printing process with a viability of 90 %, which has been confirmed by fluorescence microsopy and proliferation tests.

IMM technology at a glance

- The dispensing rate can be adjusted according to the respective requirements.
- The drop-on-demand can be integrated into third-party systems.
- We rely on a scalable, silicon-based manufacturing process. This enables us to achieve consistent quality and tool-independent design flexibility. Manufacturing precision is particularly important for micrometer-level structures like ejection nozzles.



Customer benefits

- Benefit from high-quality results thanks to superior dispensing speeds.
- Expect dispensing technology that can be adapted to your specific requirements.
- Save costs with a sterilizable and reusable dispensing chip.

The ORCAS principle

The ORCAS principle combines the minimum requirements needed for successful single cell printing with the long-term goal of organ printing. The five requirements address the deficits of competing methods. Our technology fulfils all five ORCAS criteria for the first time.

- One cell at a time – cell-by-cell assembly, different cell types
- Resolution – precision placement for direct cellular interaction (< 10 µm spacing)
- Cell-on-demand – best-in-class single-cell dispensing rate
- Aseptic – autoclavable dispensing chip
- Survival – viability of cells and predefined spheroids

»Our technology simultaneously fulfills all five ORCAS requirements, which is unique in bioprinting!«

Klaus Kögler,
Infection and Cancer Diagnostics Group

Diesel fuel as a hydrogen carrier for fuel cells

Hydrogen, power and heat – with high efficiency and proven availability. Our reformer technology enables the highly efficient utilization of diesel fuel and synthetic diesel as a source of electricity and heat or as a hydrogen supply for fuel cell applications – available all over the world, today.

IMM technology vs. conventional diesel generators

Diesel generators convert diesel fuel into electricity using an internal combustion engine, possibly with additional utilization of the resulting waste heat. This task can be fulfilled much better in a coupled reformer-fuel cell system with modern catalytic converter technology:

- Without the emission of NO_x
- Without the use of large moving engine components, thus
- much less maintenance required and much lower noise emissions
- With a significantly lower heat signature (important for military and surveillance applications)

Motorized diesel generators have an optimum load point, beyond which efficiency drops rapidly. Because the efficiency of a fuel cell is less dependent on the system load, it can also be operated at partial load (away from the optimum load point) with high efficiency, unlike the engine system. Our focus is also on optimum performance with the smallest possible size and system efficiency by utilizing all material flows. This enables us to achieve an overall system efficiency in the range of 35 %, which is 10 % more than for combustion engines of a comparable size.

Uniquely high power range of our diesel reformer systems up to 25 kW – easily scalable up to 100 kW through modularization!

Application areas

Diesel fuel, which can be replaced in future by sustainable synthetic fuel (Fischer-Tropsch fuel), has the highest energy density of all fuels. This is important for mobile applications, where tank volume is just as important as international availability:

- Military applications
- Surveillance tasks
- Yachts
- Off-road travel mobile

We bring our customers' applications onto the road – thanks to our innovative, vibration-resistant catalytic converter coating processes!«

Dr. Gunther Kolb,
Head of Energy Division

On-site bacteria detection in water

We realize the automated preparation of water samples and the qPCR analysis of microorganisms in a mobile device. This allows the direct on-site detection of pathogens from large amounts of water samples (e.g. one liter) in a time frame of one hour.

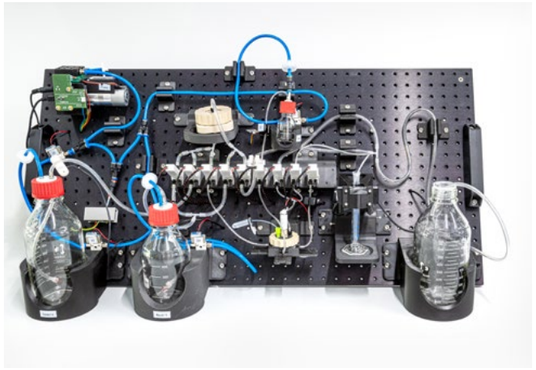
Instant action: If required, cleaning measures or decontamination can be triggered immediately; if not required immediate release for use.

The InBaDtec device

The device is designed following the ISO/TS 12869:2019, and also especially ISO/TS 12869-2:2024. It is highly automated so that the end user only has to load the water sample (100 ml to 1 l) and the consumables. The device itself concentrates the bacteria in the sample and analyses the amount by qPCR. The quantitative result will be delivered in one hour. The device can be customized for other specific applications such as bacteria or virus detection in swimming and bathing water, or wastewater, as well as food and beverage industry, pharmaceutical industry, and so on.

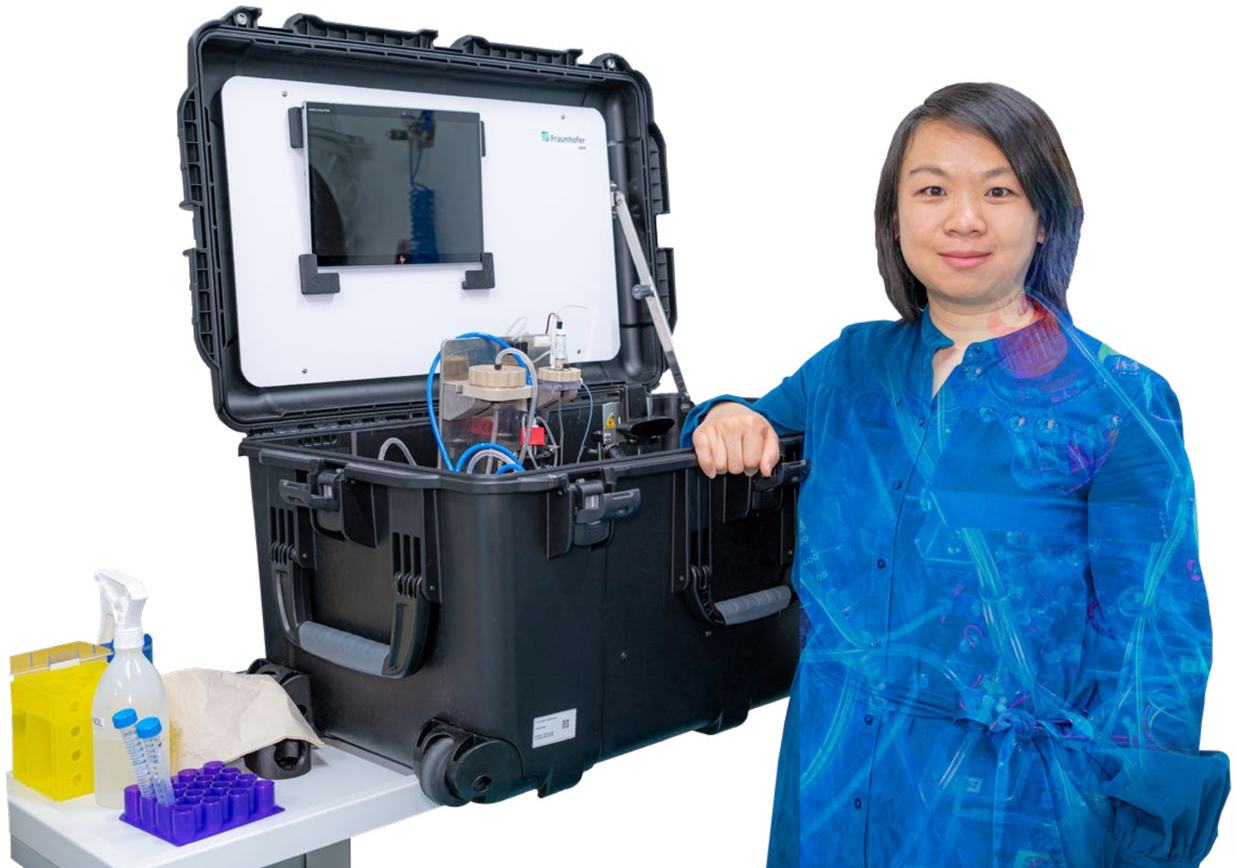
Benefits at a glance

- Easy to use: All the fully automated hardware and software has been designed to be user-friendly.
- Precision you can trust: The analysis method is based on qPCR, which guarantees the accuracy and specificity. In addition, we have also integrated an optional live/dead discrimination function to avoid false positive results.
- Affordable excellence: No more costly test methods. We are constantly striving to further reduce the costs per test.



The device is integrated into a portable case and can therefore be brought to the point of use by the operator!«

Dr. Sisi Li,
Head of Bioanalytics in
Industrial Media Group



Organometallics in flow

Organometallic chemistry has been in use for over 100 years and is well known. The easily scalable, demand-oriented synthesis and direct subsequent conversion of organometallic compounds in flow has reached market maturity in industrially relevant throughputs.

Save time, money and energy by using our flexible, scalable and patented technology.

IMM technology vs. conventional processing

The main advantages of scalable and continuous organometallic reagent synthesis are the increase in safety due to the comparatively small reactor volume, the improvement in product quality due to the process window used and the flexibility in the production of precisely desired and required reagent quantities.

Additional benefits are:

- Savings on cleaning, product changes and reconditioning
- Reduced time to market
- Access to the entire class of organometallic compounds and a wide range of subsequent reactions

The continuous process

The halide solution is continuously pumped through the reactor from the bottom to the top, while the metal is also continuously fed into the reactor depending on consumption in order to maintain the high metal surplus that is so important for product quality. This creates a truly continuous process in the liquid and solid feed. Unwanted side reactions, in particular Wurtz coupling, are suppressed by the use of a large metal excess, very short residence times in the range of a few minutes and narrow residence time distributions.

We increase the efficiency of our customers' carbon carbon bond formations!«

Dr. Gabriele Menges-Flanagan,
Flow Chemistry Group

Emulsification and encapsulation technology

We have the expertise and technical facilities to optimize emulsion-based formulations and accelerate our customers' product development. We offer a complete range of R&D services for encapsulation including customer-specific development/optimization of formulations on lab to mini-plant scale and the construction and manufacturing of plant modules for emulsification and encapsulation. Accordingly we provide technical support up to commercial production.

IMM technology vs. available technology

Our technology can be applied for processing of emulsion-based and solution-based systems up to 350 °C and 100 bar.

IMM´s technology is based on microstructured components and enables a precise control over the formulation process, being the basis for customized and reproducible product properties. It is applicable for a broad range of materials and can cover different methods for formulation of droplets or capsules in a size range from 100 nm to 50 µm. The technology combines emulsification, reaction, purification, and solvent evaporation. Up to eight components can be simultaneously emulsified/encapsulated, thereby recycling and re-use of solvent (if applicable) is possible. Moreover, the technology is modular and scalable.

Technology advantages

- Individual solutions for all product and formulation requirements
- Capsules with different release profiles
- Continuous and scalable or batch-wise operation

Our customers' advantages

- Reduced processing and working time
- Reduced process, energy and working costs
- Technical support on any stage of product development cycle (lab, mini-plant or production scale)
- Benefit from the whole Fraunhofer network as source of detailed and comprehensive analysis of the products

»Use our emulsification and encapsulation technology to boost your product!«

Dr. Anna Musyanovych,
Head of Micro- and Nanoparticle Engineering Group

Continuous synthesis of fine chemicals

Technology platform for the next stage of fine chemical production in continuous flow reactors with heterogenized and process-specific catalyst combinations.

Realistic sustainability with Green Chemistry in continuous flow!

IMM technology vs. conventional batch processes

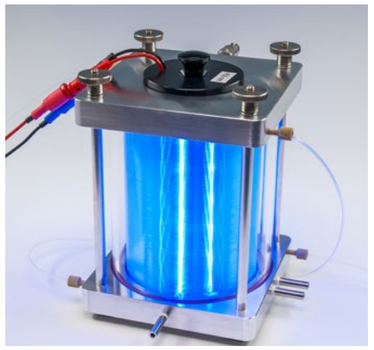
Fine chemicals for the pharmaceutical or agrochemical market are usually obtained from chiral molecules with a high degree of purity. Currently, such compounds are synthesized in batch processes with homogeneous catalysts, which leads to a complex and time-consuming process and purification sequence. Our approach: cascade reactions for the heterogeneously catalyzed synthesis of chiral fine chemicals in a continuously operated reactor system.

- Hardly any changeover times
- Cost savings through mild reaction conditions
- Better process control using micro process engineering and flow chemistry methods
- Less effort in the downstream process thanks to heterogeneous catalysis
- Higher yield and improved selectivity
- Use of sustainable components with reduced use of precious metals

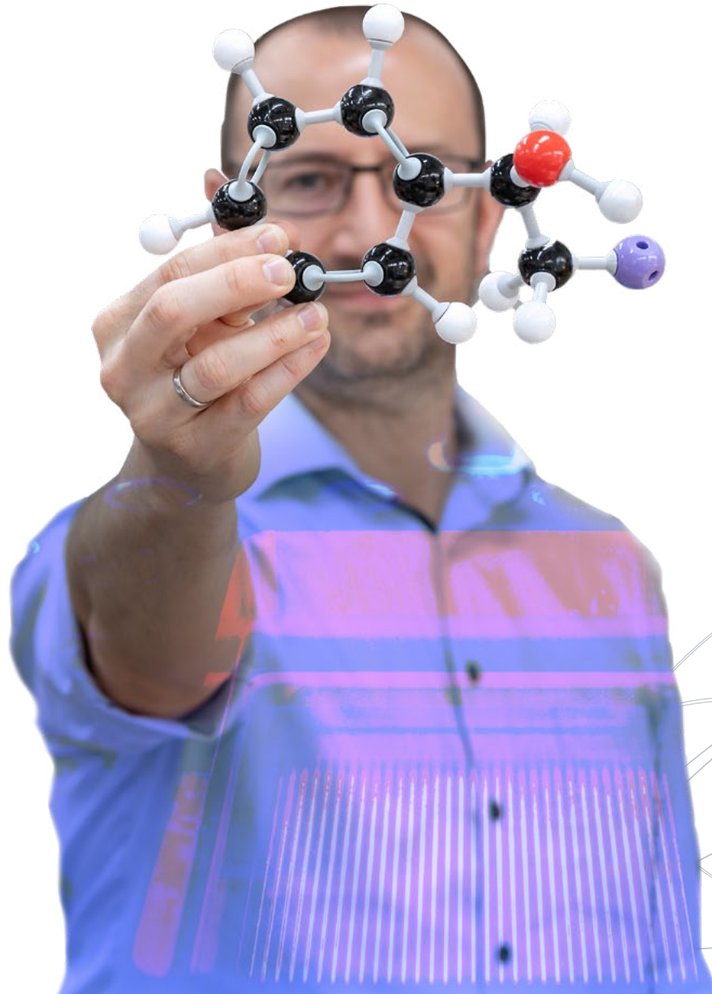
Our services

We offer developments and feasibility studies in the following areas:

- Material development and upscaling in the field of catalysts
- Reactor development for cascade processes
- Plant and process development



Hire a scientist including laboratory for a comprehensive consultation with real experiments!«



Dr. Thomas H. Rehm,
Head of Sustainable
Chemical Syntheses Group

Methanol as a hydrogen carrier

Hydrogen availability – anywhere, anytime. Using methanol as an energy source, our reformer technology enables a decentralized, off-grid supply of green hydrogen and green electricity.

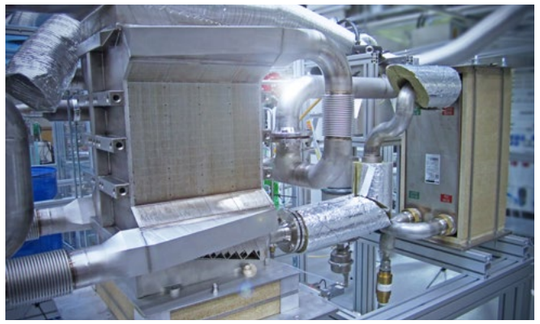
We increase the efficiency of our customers application – with patented IMM catalysts and reactor concepts.

IMM technology vs. conventional reformer reactors

The focus of conventional reactors is on large-scale plants with long, continuous production cycles, few load changes and maximum cost optimization. Our focus is on optimal performance in the smallest possible size, system efficiency by recycling all material flows and flexibility in operation.

IMM catalyst vs. conventional catalyst

Fixed-bed catalysts, which are used in conventional reformers are inexpensive and available on a large scale – however they can only be used to a limited extent for small systems. The catalysts are not very active, thus requiring large quantities. They grind up under continuous vibrations, lose performance during longer periods of standstill, have a comparatively high CO selectivity and tend to self-ignite when contact with air occurs. These properties make them unusable for mobile applications – the patented IMM catalyst for methanol reforming has none of the problems mentioned.



Why methanol?

- Methanol is among the most hydrogen efficient carrier molecules with up to 75 % hydrogen content in the dry reformate
- Green methanol as a CO_2-neutral hydrogen source is readily available nowadays
- Methanol is easy to transport, store and handle – even by untrained operators

»Minimize the space requirements of your application – we hold the record for hydrogen production per liter of reactor volume since 2012!«

Dr. Jonas Schramm,
Head of Hydrogen
Technology Group

Liquid Biopsy – Microfluidic concepts for the isolation of biomarkers

Using our innovative microfluidic diagnostics platform for the automated screening of blood and tissue, we enable the analysis of a wide range of biomarkers from a single sample – mobile, flexible and fast.

Benefits of working with the IMM

- Our platform addresses a broad spectrum of applications that go beyond pure prognostics. We are researching the feasibility of basic tumor research through to mutation analyses and drug tests in tumor organoid cultures for personalized medicine.
- Short logistics and increased quality, as cells are freshly isolated according to a scientific and regulatory-oriented framework.
- Cooperation with the IMM offers a network expansion through a supra-regional interest in collaboration with the aim of finding personalized therapies for various types of cancer.

As our platform technology is very flexible, we help our customers to integrate target-specific immunoassays into their process automation.

Customer benefits

- Expand your portfolio (e.g., analysis of microorganisms, pre-natal diagnostics) with our innovative microfluidic diagnostic platform and open up new target markets in the long term.
- Reduce workload and simplify the operation of your solution thanks to flexible and automated integration of sample preparation inside or outside your solution.
- Strengthen your innovative power and bundle resources where they can unleash their efficiency: Through long-term joint further development of projects, we support you with our expertise from the project idea onwards, including risk analysis.

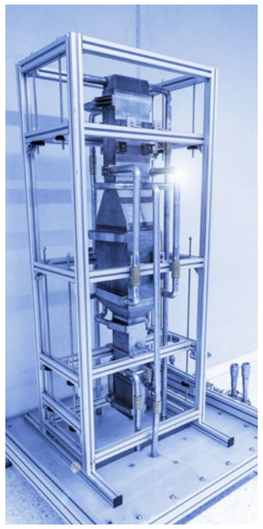
»Get the most out of your sample!«

Dr. Janis Stiefel,
Infection and Cancer
Diagnostics Group

Climate-neutral hydrogen generation by ammonia cracking

Hydrogen is the energy source of the future. Nevertheless, as the smallest and lightest element in the periodic table, hydrogen has a very low volumetric density, which makes transportation and storage inefficient. For this reason, hydrogen is initially transported in the form of ammonia, for example, and produced at the point of need using the cracking process.

Get faster and more efficient access to CO_2 neutral hydrogen by using our scalable and customizable technology.



Why ammonia?

Ammonia can be produced from green hydrogen and split into hydrogen and nitrogen without CO_2 emissions. Liquid ammonia contains more hydrogen per volume compared to liquid hydrogen. Furtheremore ammonia can be liquified at moderate pressure and room temperature. Both the storage and transportation of hydrogen in the form of ammonia is therefore a significant advantage thanks to the much higher volumetric energy density. Another advantage is that ammonia can also be used directly in combustion engines or turbines. In the future, ammonia could replace conventional fuels such as heavy fuel oil in shipping and contribute to reducing emissions.

Why IMM technology?

- Microstructured reactor technology and novel catalysts of world-record activity and high stability for maximum system efficiency and compactness (90 % size reduction).
- Enhanced system efficiency (90 %) by utilizing exhaust gases or off-gas for reactor heating. No additional fuel or electricity needed.
- Scalable, adaptable and fully integrated systems to deliver hydrogen for fuel cells, combustion engines or turbines.

Produce hydrogen from ammonia and achieve your climate targets with IMM ammonia cracking technology!«

Dr. Tobias Weißenberger,
Catalyst Technology Group

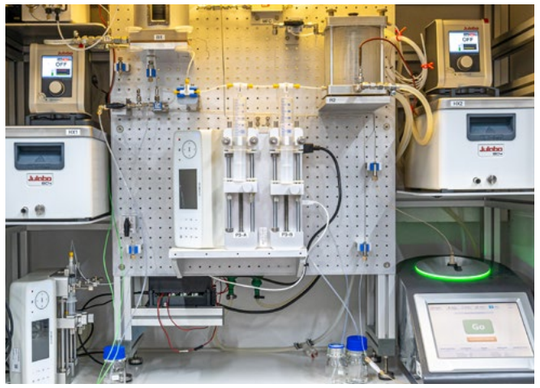
Project highlights

The subject areas presented at the beginning are backed up by a whole series of projects, at least a few of which we would like to present in more detail here. Project work is an essential part of our scientists' day-to-day work and a good example of the high degree of personal responsibility and freedom they work with here.

Photochemical assisted biocatalysis goes to flow

Fine chemicals for the pharmaceutical or agrochemical market are typically derived from chiral molecules of high purity. Currently, the synthesis of such compounds is conducted in batch mode with homogeneous catalysts, resulting in a complex and time-consuming process and purification sequence afterwards. The ILLUMINATE project addresses this limitation by introducing a new technology platform for the next level of fine chemicals production in continuous flow reactors with heterogenized and process-specific catalyst combinations. The ILLUMINATE consortium draws upon the expertise of four Fraunhofer institutes (IGB, IME, IMM, ISC) to establish photochemical assisted biocatalysis as a novel method for the stereoselective synthesis of fine chemicals and APIs under sustainable and process-intensified conditions.

Catalyst development and their heterogenization is the first integral part of the project. The use of recyclable polymer foils and supraparticles as carriers for a tailor-made combination of a photocatalyst and an enzyme as a biocatalyst is a key aspect of the project. Both concepts can be employed as highly specific materials for cascaded reaction pathways and can be implemented into novel and advanced flow reactors for the photochemical assisted biocatalysis. This chemical approach allows the introduction of new functional groups into a molecule by mild photocatalysis, whereas stereoselectivity is incorporated by the enzymatic conversion of the intermediate to the final product. Regioselective oxidations or hydroxylations are applied as well as stereoselective cyanations or ketone reductions for the purpose of benchmarking the catalysts and the flow technology. The modularization and scalability of the synthesis plant and the flow reactor concepts represent the second integral part of ILLUMINATE. The necessity for the adaptation of reactor and flow equipment as a basis for optimal conversion and selectivity in the cascade reactions arises from the use of novel catalysts and advanced process conditions. In the case of the supraparticle-based catalysts, a reliable gas-liquid-solid mixing and transportation system was developed and combined with a scalable capillary photoreactor.



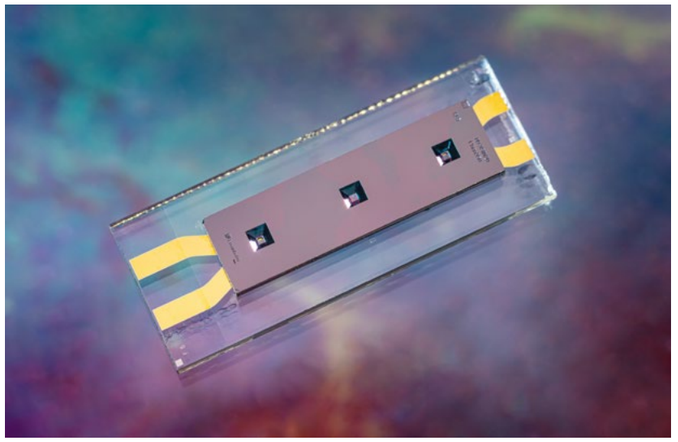
For the functionalized polymer foils, the well-known falling film microreactor was redesigned and evaluated with regard to the use of a polymeric reaction plate for mild and biocompatible photocatalysis. Computer-aided data management and plant control as well as process analytical technology via online NMR spectroscopy complement the ILLUMINATE technology platform for its future application in validation projects and feasibility studies with industrial customers.

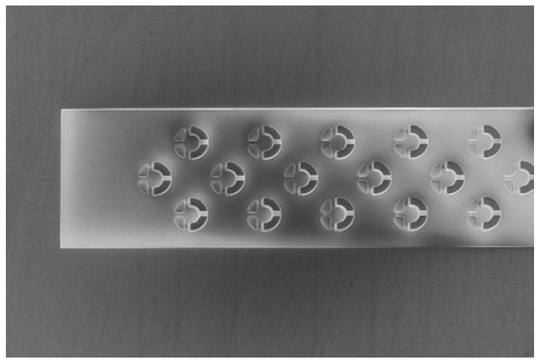
The ILLUMINATE project's various approaches serve as a blueprint for future cascade reactions in continuous flow. The key elements for achieving the maximum synergy between chemistry and technology for sustainable, scalable, and mild chemical synthesis are custom-made catalyst materials, scalable reactors, and a modular synthesis plant. The ILLUMINATE consortium is utilizing this technology platform to facilitate the secure supply of fine chemicals and APIs in the highly relevant markets of the chemical industry in Germany and Europe.

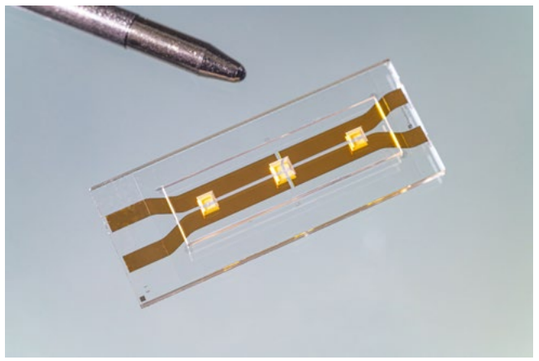
Activities partly funded by the Fraunhofer Society and the BMBF ("Zukunftstechnologien für die industrielle Bioökonomie: Schwerpunkt Biohybride Technologien" im Rahmen der Nationalen Bioökonomiestrategie); Grant No. 031B1121.

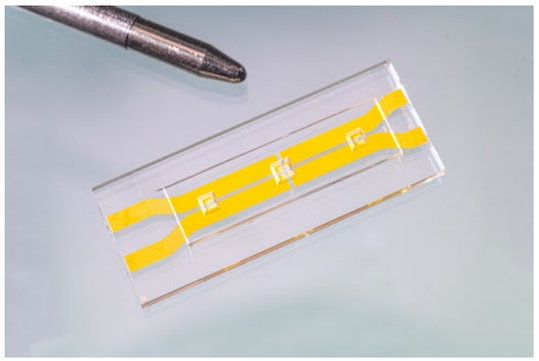
More information can be found on the project website www.kaskaden-reaktionen.de/en/

BIOPRINT – Computer simulation-aided performance enhancement of the IMM's single-cell printing lab demonstrator, including evaluation of industrial applicability









High-speed 3D printing of human tissue cells is a very active research field, revolutionizing regenerative medicine and personalized medicine. Printing entire transplantable organs is one of the technology's long-term goals. The microscopic functional substructures of these organs are so intricate, that the best way to achieve reproducible quality may be "cell-by-cell" assembly, with diverse cell-types making up the individual bricks. Single-cell dispensing also provides opportunities to personalize medical diagnosis and treatment, enabling drug-response tests directly on patient-sourced single cells, or on precisely assembled cell-clusters and organoids created from these cells. Medication can now be tailored to the patient's individual needs.
The aim of the BIOPRINT project is to further develop the productivity of IMM's lab-demonstration-bioprinter, a prototype which was developed as part of the previous ORGANOIDICS project. Productivity is divided into the following sub-tasks, which address the key identified optimization levers:

- Enhancing the experimental throughput and the repeatability of printing in general,
- Increasing the capture and printing rate of viable, functional cells, and
- Formulating bio-inks that are fluid enough for dispensing, but stiffen (gelate) upon impact

Capturing the complex interactions of the overall system using experimental methods alone is excessively time-consuming and resource intensive. In BIOPRINT, model-based simulation and optimization strategies are developed for both the cell capture and the dispensing process. These simulations can replace or accelerate the experimental-iterative processes. Our project partner, the Fraunhofer ITWM, bundles the necessary capabilities for modeling, simulation, and optimization. The synergies between model and experiment are intended to increase productivity and to consolidate and expand our joint bio-microfluidic expertise.

Fraunhofer IMM tasks

At the end of the BIPOPRINT project led by Fraunhofer IMM the following milestones will be met:

- Enhancing the throughput and capability of the bioprinting demonstrator, by greatly improving live optical monitoring capabilities, to inspect the health of the printed cells, monitor microfluidic single-cell isolation and observe the cell-ejection mechanism (a microsecond-scale process)
- Increasing the rate of silicon-based microfluidic printer-chip production
- Formulating and testing in-house and commercial of cell-inks
- A well-founded assessment of industrial usability

The BIOPRINT project is funded by the Ministry of Science and Health of the State of Rhineland-Palatinate, Grant No. 724-0032#2023/0003-1501 15402

GAMMA e-fuels project to make international shipping climate-neutral

Today, 80 to 90 percent of total global transportation over long distances is carried out by ship. However, sea freight transport requires large quantities of fuel, which today mainly originates from fossil sources. The International Maritime Organization (IMO) has set itself the goal of reducing the sector's greenhouse gas emissions to almost zero by 2050. Transportation on the oceans must therefore become much more environmentally friendly. This is also the aim of the new European project GAMMA, funded with EUR 17 million, in which companies and researchers from Europe will convert a cargo ship so that it is supplied with climate-neutral fuels.

Electricity from hydrogen and green fuels

A freighter from the fleet of project partner ANT Topic will serve as a demonstration platform on which an innovative power supply system will be installed. Ammonia and green methanol will be stored on the ship and then converted into hydrogen using cracker and reformer technologies. The hydrogen will be purified and then converted into electricity using fuel cells, which will supply the ship with up to 1 MW electrical energy, replacing the auxiliary generators powered by fossil fuels.

Fraunhofer IMM tasks

Fraunhofer IMM is responsible for the fuel conversion technology into hydrogen, i. e. the ammonia cracker and the methanol reformer.

- Scale-up, fabrication and testing of both fuel conversion lines (methanol and ammonia) to hydrogen
- Process simulations and system design
- Detailed reactor and component design and flow simulations
- Development of control hardware and software for the conversion systems
- Methanol and ammonia conversion systems assembly and separate testing

The GAMMA project is funded by the European Commission, Grant No. 101138620.

Hybrid nanocarriers: Targeted and compatible – a topic that deserves an award!

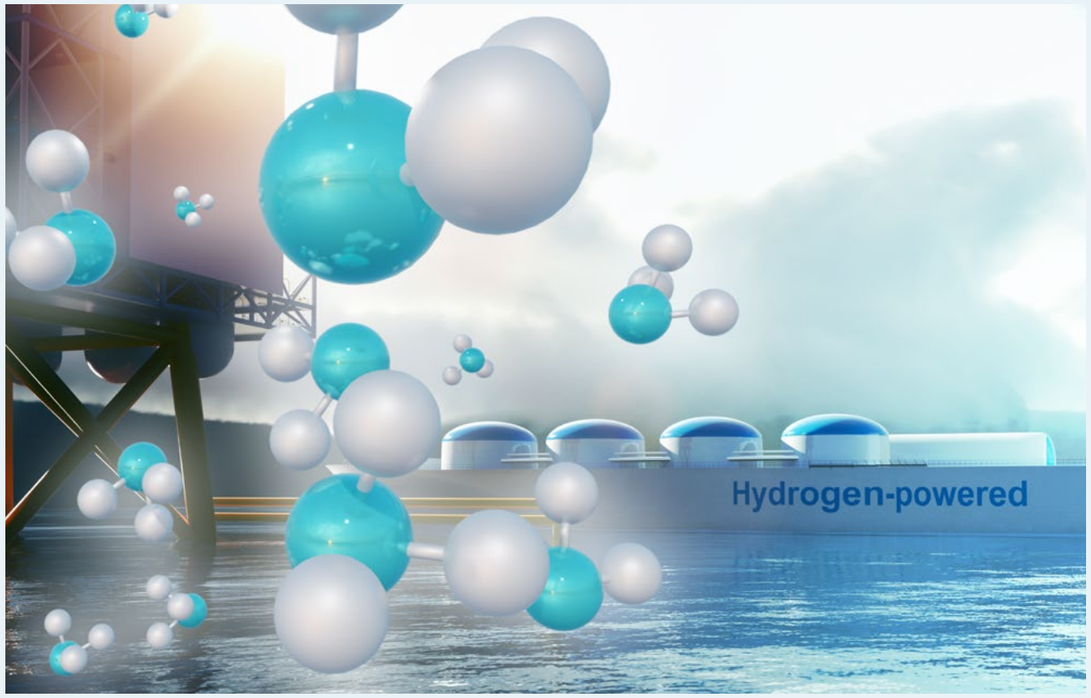
Eilien Heinrich rocked the Fraunhofer Ideas Competition 2024 and won 1st place for herself, her topic and the Fraunhofer IMM!

Nanocarriers as drug transporters have long been a central topic in research and development. They are regarded as a solution for targeted drug transport, prevention of resistance formation and as a more efficient alternative to conventional therapeutics. In the future, active targeting should ensure even more precise drug delivery. However, this requires complex production, quality assurance and complicated approval procedures.

The hybrid nanocarrier project aims to develop a platform for a hybrid carrier system that combines synthetic and biogenic nanocarriers. The aim is to connect the automatable and scalable production of synthetic nanocarriers with the natural targeting properties of biogenic nanocarriers. Biogenic nanocarriers, which are formed by human cells as communication tools, contain natural targeting components. Using intelligent processes, these components can be easily combined with synthetic carrier systems to create economically interesting and innovative applications.

What´s next

Our scientists have no shortage of new ideas, so there are always several projects in the pipeline waiting to become reality, expand our project portfolio and increase our knowledge base.



Project AmmonVektor

The AmmonVektor consortium is developing technologies and acquiring expertise with high utilization potential in the field of decentralized production, transport and energy use of ammonia. These are addressed in the sense of sector coupling to create a carbon-free value chain for electricity, heat and hydrogen with optimum efficiency at minimum cost. They include new ways of synthesizing ammonia, for example using plasma. The reliability and safety of ammonia processing in the new energy technology applications are to be improved. Innovative concepts for the use of ammonia to generate heat, primarily for commercial and industrial applications, electricity in both fuel cells and gas turbines, hydrogen via catalytic cracking and for driving combustion engines through homogeneous combustion are being researched.

This work was supported as a Fraunhofer FLAGSHIP PROJECT.

Project Kom-e-BIO

Electron-mediated biocatalyzed synthesis of fine chemicals in flow – within the KOM-e-BIO project, bioelectrocatalysis will be evaluated as one state-of-the-art and sustainable method of biotechnology. As part of the project, bioelectrocatalysis will be combined with flow chemistry and micro process engineering to produce chiral fine chemicals as the basis for active pharmaceutical ingredients. KOM-e-BIO thus represents the use of white (industrial) biotechnology as an application in red (medical) biotechnology.

Activities funded by the Ministry of Science and Health of the State of Rhineland-Palatinate, Grant No. 724-0032#2023/0005-1501 15402

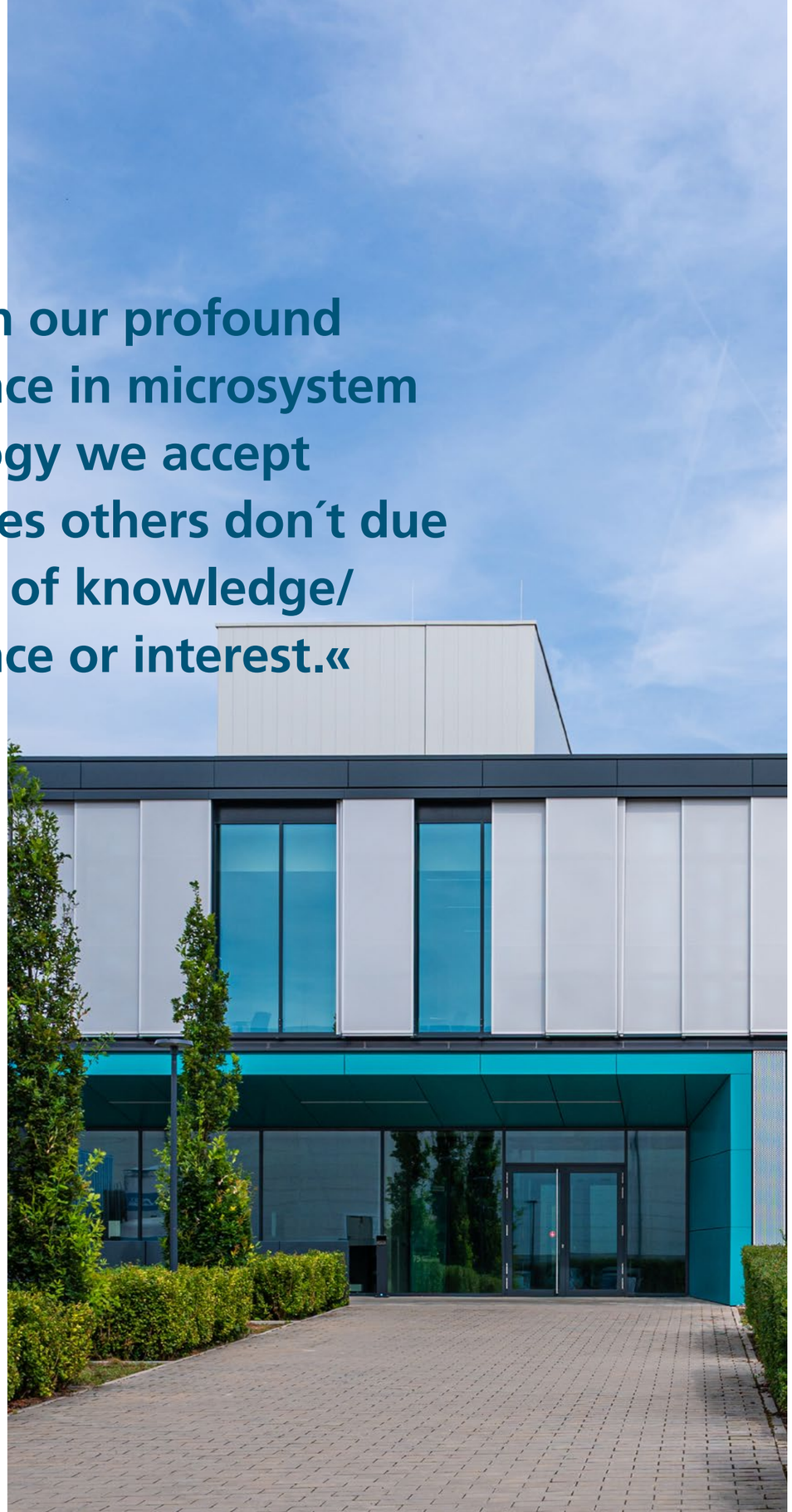
Fraunhofer center for single-cell technologies

The isolation, analysis and further processing of biological single cells is the fundamental starting point in many highly relevant fields of application, from diagnostics and personalized therapy to food production, and addresses rapidly growing future markets. The Center for Single-Cell Technologies is intended to further develop the research focus on single-cell technologies anchored in the Rhine-Main/Rhine-Neckar region through networking activities and interdisciplinary cooperation between competent key players from basic research, clinics and industry, to transfer it even more specifically into applications through jointly promoted transfer ventures and thus to address the need for innovative technologies for a strong competitiveness of commercial enterprises. More information will follow in a press release at the beginning of 2025.

Profile

After the freestyle comes the duty – here in the shape of background information and a couple of figures.

Based on our profound experience in microsystem technology we accept challenges others don´t due to a lack of knowledge/ experience or interest.«



Fraunhofer Institute for Microengineering and Microsystems

Based on existing societal challenges and driven by sustainable development goals Fraunhofer IMM focusses the majority of the workforce as R&D service provider, across the divisions ENERGY, CHEMISTRY and DIAGNOSTICS, on the topics of CLEAN ENERGY, SUSTAINABILITY and HEALTH. Thereby we rely on our fundamental core competencies in MATERIALS, TECHNOLOGIES, PROCESSES and ENGINEERING. Following our roots, we apply fundamental processes based on microstructure technology wherever they are target-oriented.

The **MATERIALS** competence comprises our very profound knowledge about chemical and biological compounds, their utilization and synthesis, their properties and their potential application fields. It includes our knowledge about materials, their properties and processing as well as their suitability for various applications.

The **TECHNOLOGIES** competence comprises our very profound knowledge about machining, processing, detection and analytical methods. It includes decades of experience in optimized operation parameters as well as suitable application scenarios for each of these technologies.

The **PROCESSES** competence comprises our ability to perform the translation of concepts into devices or entire systems essentially required for fulfilling any single kind of operation. It is about our application related knowledge of processes in various disciplines as well as our ability to perform the physical construction work.

The **ENGINEERING** competence comprises our higher-level engineering abilities used to initiate, design, develop, fabricate and realize a process or system reaching the required level of integration, functionality and complexity.

Very similar to the organic bases of the DNA the unique combination of these core competencies makes us what we are and allows us to provide our customers and partners with system and technology oriented innovations, solutions that contribute to their competitiveness and provide value for their businesses.

The **CLEAN ENERGY** topic translates into solutions for hydrogen-based energy supply, power-to-chemicals, ammonia utilization and radiation monitoring.

The **SUSTAINABILITY** topic translates into solutions for flow chemistry-based process intensification, decentralized production concepts for chemicals, environmental monitoring and process monitoring.

The **HEALTH** topic translates into solutions for infection diagnostics, liquid biopsy and single cell analysis, biological media analysis and nanoparticle systems for therapeutic and diagnostic as well as industrial applications.

Our goal always is **TO MAKE A DIFFERENCE.**

Quality policy

Preamble

The Fraunhofer IMM management level stipulates our 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. Our quality goals are set to continuously increase customer satisfaction and to improve our process performance.

Who we are and what we expect from ourselves

We are the leading contract research organization providing research and development services to our customers and partners from industry, other research organizations and universities. We provide solutions for partially complex problems. Thus, usually our services cannot be low cost but they are always worth their price. And we do our best at all times to meet or exceed the expectations and demands placed on us relying on a reproducibly high quality of our work. Our employees are the backbone of our institute. Maintaining adequate communication structures, training and qualification opportunities as well as a positive and productive working environment is our continuous effort.

How we work

We are developing solutions with and for industry on direct order. But we are as well working together with our customers and partners in projects being co-financed by the federal government, the federal state of Rhineland-Palatinate or the European Commission in order to tackle important societal challenges.

We are a reliable and loyal partner cultivating fair relationships to customers and suppliers, communicating openly and honestly with all stakeholders to establish constructive long-term collaborations. We strive for a project-oriented continued development of our capabilities. 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 for the satisfaction of our customers. 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.

The value we create

- We transfer requirements into workable and customer-friendly solutions.
- We secure a competitive edge and a head start in innovation.
- "We boldly go where no one has gone before": We accept challenges others don't due to lack of interest or lack of knowledge/experience.

The Fraunhofer IMM in numbers (2023)

Revenues
from external funding sources research

78.7 %
publicly financed R&D projects

21.3 %
industrially financed R&D projects

116
projects

<51,7 % public
>48,3 % industrial

11.5
million euro
contract research

91,5 % operational spending

8,5 % capital 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.

COOPERATIONS AND STAFF EXCHANGE

University of Mainz // Max Planck Institute for Polymer Research Mainz // RheinMain University of Applied Sciences

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 // Darmstadt University of Applied Sciences // University of Stuttgart // University of Duisburg-Essen // Karlsruhe Institute of Technology // University of Ulm

RESEARCH NETWORKS

AMA Verband für Sensorik und Messtechnik e.V. // BMBF Project Partners // TU Eindhoven // Hasselt University // European Technology Platforms // EU Project Partners // BAM Bundesanstalt für Materialforschung und -Prüfung // Dechema // Process-Net // DWV // DGO // Microtec Südwest // N.ERGHY

NETWORKS

IVAM // Dual Career Network Rheinmain // Mainz Research Alliance e.V. // Cluster for Individualized Immune Intervention (CI3) e.V. // INNOMAG // Kompetenznetz Verfahrenstechnik Pro3 e.V. //Transferinitiative Rheinland-Pfalz // Cluster Nanotechnology – Netzwerk NanoAnalytik und -Messtechnik in der Produktion

Associations and alliances

within Fraunhofer

Fraunhofer **Energy Alliance**

Fraunhofer **Chemistry Alliance**

Fraunhofer **Syswasser Alliance**

Fraunhofer **Aviation & Space**

Fraunhofer **Nanotechnology FNT**

Fraunhofer **Group Materials**

Fraunhofer **Hydrogen Network**

Initiative Nano **in Germany for Fraunhofer Institutes**

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, based in Germany, is one of the world's leading applied research organizations. It plays a crucial role in the innovation process by prioritizing research in key future technologies and transferring its research findings to industry in order to strengthen Germany as an economic hub as well as for the benefit of society.

As an important customer group, small- and medium-sized companies in particular tap into Fraunhofer's expertise and resources to develop new technologies and maintain their competitiveness. For years, Fraunhofer has been one of the most active patent applicants in Germany and Europe. The research organization is therefore developing an extensive, international patent portfolio in various technology sectors, primarily as a basis for transferring technology through research projects, spin-offs and licensing. In this way, Fraunhofer experts support industry partners from ideation to market launch, and Fraunhofer's interdisciplinary and international collaboration in specific market environments addresses social objectives in important technology areas. Fraunhofer also promotes research into key technologies that are vital for society as a whole by applying specific, interdisciplinary and international collaboration geared to the needs of the market. Examples include technologies for the energy transition, cybersecurity and underlying models for generative artificial intelligence. Fraunhofer is an attractive and established party for public-private partnerships and also makes a significant contribution to strengthening Germany as a hub for innovation and ensuring its viability in the future. Its activities create jobs in Germany, boost investment effects in the private sector and increase the social acceptance of new technology. International collaboration projects with excellent research partners and companies across the globe ensure that the Fraunhofer-Gesellschaft remains in direct contact with the most prominent scientific communities and economic areas.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Its nearly 32,000 employees, predominantly scientists and engineers, work with an annual business volume of 3.4 billion euros; 3.0 billion euros of this stems from contract research, which is divided into three funding pillars. Fraunhofer generates a share of this from industry and license-fee revenue to a sum of 836 million euros. This high proportion of industrial revenue is Fraunhofer's unique selling point in the German research landscape. The importance of direct collaboration with industry and the private sector that this requires ensures a constant push for innovation in the economy, while at the same time strengthening German and European competitiveness.

Another share of contract research revenue comes from publicly funded research projects. The final share is base funding that is supplied by the German federal and state governments and enables our institutes to develop solutions now that will become relevant to the private sector and society in a few years.

Highly motivated employees are the most important factor in Fraunhofer's success. The research organization therefore creates opportunities for independent, creative and goal-driven work. Fraunhofer fosters professional and personal development in order to provide career opportunities for its employees in the private sector and society at large.

The Fraunhofer-Gesellschaft is a recognized nonprofit named after the Munich scholar Joseph von Fraunhofer (1787–1826), who enjoyed equal success as a scientist, inventor and entrepreneur.

Figures as of: April 2024

The Fraunhofer-Gesellschaft in numbers (2023)

3.0
billion euro research budget

76
institutes and research units in germany

> 30,800
staff

2.6
billion euro contract budget

Appendix

And, finally, we would like to give you a brief overview of our trade fair and conference participations, as well as our public relations work.

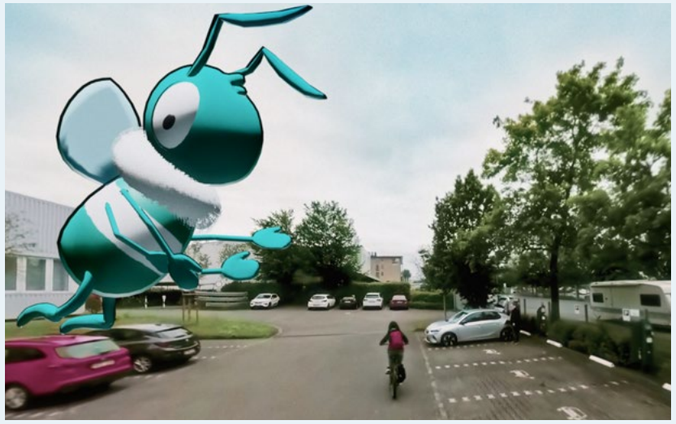
Trade fairs & events

Fair/Event/Conference	Date	Type of Event
21. Mainzer Wissenschaftsmarkt	09.–10.09.2023	Science market
ECCE 2023	17.–21.09.2023	Conference trade fair, Berlin
Hydrogen Technology Expo Europe 2023	27.–28.09.2023	Trade fair, Bremen
Webinar “How can optical sensor technology make a difference in microfluidics?”	11.10.2023	Virtual presentation
Medica 2023	13.–16.11.2023	Trade fair, Düsseldorf
Compamed 2023	13.–16.11.2023	Trade fair, Düsseldorf
meet@uni-mainz 2023	03.12.2023	Career fair
Bio360 Expo 2024	24.–25.01.2024	Trade fair, Nantes
analytica 2024	09.–12.04.2024	Trade fair, Munich
Hannover Messe 2024	22.–26.04.2024	Trade fair, Hannover
IFAT 2024	13.–17.05.2024	Trade fair, Munich
Hydrogen Online Workshop 2024	05.06.2024	Online conference
ACHEMA 2024	10.–14.06.2024	Trade fair, Frankfurt/M.

Communication highlights

This year, we would like to continue to give you a small glimpse behind the scenes of communication. As a small institute, we were able to achieve a good communication reach in 2023 with a fair contribution to the Fraunhofer strategic research fields.
Our internal newsletter is now an integral part of our institute culture and we put a lot of heart and soul into every issue.

A major project in the first half of 2024 was the shooting of our new image film. Unlike our last image film, which was shot in the traditional way with a film camera, this time the footage was shot with a drone. And of course, our mascot, the MicroBee, was not to be missed. Take a look at the final result, you can find the film on our homepage!



Of course, a cheerful get-together among colleagues was also a must this year.

Internal
newsletter

Press reach
2023

30 contributions published

21.2 Mio
contacts reached

of which
19 are in **Fraunhofer strategic fields**

- Bioeconomy
- Hydrogen Technologies
- Artificial Intelligence (AI)
- Resource Efficiency and Climate Technologies

Advisory board

Dr. Peter Dziezok
Chairman of the Supervisory Board of Fraunhofer IMM
Director R&D Open Innovation
Procter & Gamble Service GmbH

Dr. Andreas Gerhardt
Head of Division Supraregional Research Funding
Ministry for Science and Health of Rhineland-Palatinate

Stefanie Nauel
Policy Issues for Innovation and Cluster Policy
Innovation Funding
Ministry for Economy, Transport Agriculture and Viniculture of the State of Rhineland-Palatinate

Prof. Dr. Georg Krausch
President
Johannes Gutenberg University Mainz

Dr. Ulrich Küsthardt
Managing Partner
Creanova GmbH
formerly Evonik Senior Fellow / former Chief Innovation Officer
EVONIK Industries AG

Prof. Dr. Kurt Wagemann
Executive Director DECHEMA Frankfurt
DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.

Dr. Wolfgang Reich
Managing Director
C2INNO GmbH
formerly Director Innovation Management BASF SE

Hans-Mario Dechent
formerly Director Research and Development Center
Eckes-Granini Group GmbH

Edgar Mähringer-Kunz
Managing Director
IMSTec GmbH

Dr.-Ing. Douglas Khoo
formerly Head of ISEE Region Germany/Europe
Boehringer Ingelheim Pharma GmbH & Co. KG

Dr. Tobias Brosze
Managing Partner
Palladio Kommunal GmbH
formerly Managing Board Mainzer Stadtwerke AG

Dipl.-Ing. Albert Thomas Haugg
Managing Partner
Haugg Holding GmbH
formerly Head of New Developments AKG Thermotechnik International GmbH & Co.KG

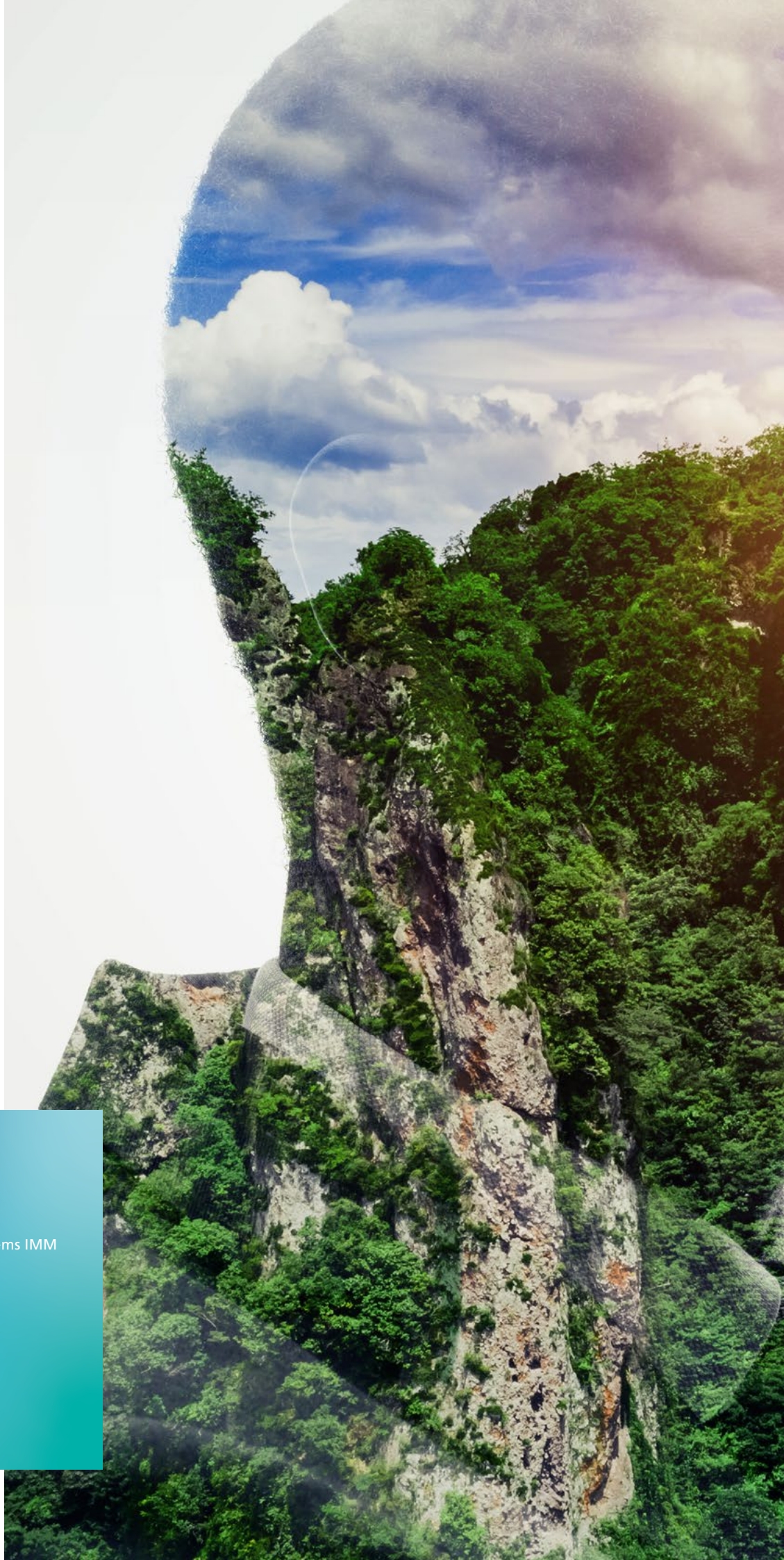
New appointments on May 3, 2024

We would like to thank Prof. Dr. Kurt Wagemann and Mr. Hans-Mario Dechent, who left our Advisory Board on june 30, for their valuable support during their time on the Board and at the same time warmly welcome our three new members, Dr. Lydia Simon, Dr. Sarah Schmitz and Mr. Tilman Bechthold.

Tilman Bechthold
Vice President Research and Development
RWE Power AG

Dr. Lydia Simon
Managing Director
tec4future consult GmbH

Dr. Sarah Schmitz
Managing Director
DELTA Engineering & Chemistry GmbH



Contact

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