Fraunhofer IAP

FRAUNHOFER INSTITUTE FOR APPLIED POLYMER RESEARCH IAP

BIOECONOMY
AND SUSTAINABILITY

ENERGY TRANSITION
AND MOBILITY

INDUSTRY
AND TECHNOLOGY

HEALTH
AND QUALITY OF LIFE

ANNUAL REPORT 2020

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ANNUALREPORT
20**20**

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PREFACE

Dear Readers,

This preface is where I normally have the opportunity to list the scientific, technical and staff achievements of the past year. In looking back at 2020, there is of course again much to report. However, 2020 was marked by the Corona crisis, not only at Fraunhofer IAP and throughout the Fraunhofer-Gesellschaft as a whole, but also at a personal level for everyone around the world. I sincerely hope that you and your families have made it through the past year in good health.

Last year has shown us how fragile our world and our lives within it really are. We suddenly understood what really counts and what drives us forward not only as individuals, but above all as a community. Every one of us has faced personal restrictions in order to protect the well-being of all. This has enabled us at Fraunhofer IAP to achieve what is surely the most important success of 2020: remaining healthy while enabling the institute to work to the best of its abilities.

Sadly, in late 2020 we lost our former director and Executive Board member, Professor Ulrich Buller, who passed away far too prematurely. Fraunhofer IAP owes a great deal to his work and in him we have lost a dear friend and relentless advocate of science.

Despite all the negative aspects of 2020, there are numerous developments that allow us to look to the future with confidence. These will be highlighted on the following pages. In this spirit, I wish you all the best for the future and thank you on behalf of the staff of Fraunhofer IAP for the trust you placed in us and for the successful collaboration in 2020.

Sincerely,

Prof. Dr. Alexander Böker

"I would like to thank all of our employees and their families for their great commitment in meeting the extraordinary challenges of the past year."

Prof. Dr. Alexander Böker
Director

FROM INNOVATIVE MATERIALS TO SOLUTIONS FOR THE FUTURE

Creative solutions are the key to overcoming the challenges of the present and the future – whether they be climate change, pandemics, the energy transition, structural change or new mobility concepts.

Fraunhofer IAP tackles these challenges through innovative materials, processes and technologies, targeting the entire value chain – from the idea to the customized prototype.

For decades, the Fraunhofer IAP has been recognized throughout the world for its outstanding polymer research. Beyond the pure polymer material, we have also been providing system solutions for a variety of application areas for years. In order to reflect this outwardly as well, we focus here on the following topics: *Bioeconomy and Sustainability, the Energy Transition and Mobility, Health and Quality of Life, and Industry and Technology.* This range of topics provides our customers and partners with an overall picture of the competencies that we use when developing solutions for the future. **//**

BIOECONOMY AND SUSTAINABILITY

We tap sustainable raw materials and enable a circular economy to reduce dependency on fossil energy sources.

Biopolymers made from renewable raw materials such as cellulose, starch, lignin or proteins are a focus of our materials research. They open up new approaches to the circular economy.

With our expertise in the modification and optimization of biopolymers and their industrial production, we create the basis for sustainable products.

- Bioplastics and -films
- Spin fibers: Cellulose, PLA
- Biobased carbon fibers
- Biodegradable microcapsules
- Paper: coatings, additives
- Biobased adhesives, binders
- Novel tire rubber
- Biotechnology and -catalysis

ENERGY TRANSITION AND MOBILITY

The integration of innovative materials into components and products is a key to the energy transition and the evolution of new mobility concepts.

Intelligent insulating materials and glazing reduce the energy requirements of buildings. Novel fiber composites for wind power, hydrogen storage and vehicle construction open up new options for energy generation and more efficient mobility. New catalysts and membranes for fuel cells enable hydrogen as a climate-neutral energy source.

We develop essential building blocks for the solutions of the future.

- Programmable building elements
- Functional lightweight construction
- Fiber composite components
- Hydrogen technology
- Materials for fuel cells
- Printed organic electronics
- Electroactive polymers
- Quantum dots for LEDs

HEALTH AND QUALITY OF LIFE

From arteries to wrist: For new active ingredients, products and processes for medicine, medical technology and cosmetics, we offer individual solutions from a single source.

Based on novel nanomaterials and biomolecules, we develop e.g. biosensors, diagnostic methods and therapies. We are also addressing new approaches for controlling pathogens on surfaces and in air filters.

Our interdisciplinary approach combines polymer research, biotechnology and nanotechnology for an improved quality of life.

- Biomolecules: design, production
- Nanoparticles as biomarkers
- Biofunctionalized polymers
- Encapsulation of active ingredients
- COVID-19: drug delivery
- Implants
- Aligners for tooth correction
- New plastics for medicine

INDUSTRY AND TECHNOLOGY

Your competent partner along the value chain: from innovative materials to market-relevant prototypes.

At the Pilot Plant Center PAZ, we develop and optimize the scale-up of the synthesis of polymers up to the ton scale. At sites in Brandenburg, we produce high-performance fibers and plastics optimized for them as well as biomolecules and biopolymers on a pilot plant scale.

We offer customized solutions and provide sample quantities as well as quality tests according to applicable industry standards.

- Scale-up of polymer syntheses
- Spinning pilot plant
- Prepregs for composites
- Lightweight construction: CAD, FEM
- Smart and additive manufacturing
- Pilot plant for printed electronics
- Quantum dots: Flow reactor synthesis
- Biotechnology Center

RESEARCH DIVISIONS OF FRAUNHOFER IAP

BIOPOLYMERS

In the research division *Biopolymers*, we develop sustainable materials based on renewable raw materials such as cellulose, lignin, starch or thermoplastics like polylactic acid (PLA). Using our decades of experience, we develop more effective processes as well as new and enhanced materials for new and existing applications. This is done in collaboration with our partners in the pulp and paper industry and the polymer processing industry and with end-product manufacturers.
Division director:
Prof. Dr. Johannes Ganster

FUNCTIONAL POLYMER SYSTEMS

In the research division *Functional Polymer Systems*, we develop materials with special optical and electrical properties as well as processes, technologies and conceptual designs for customer-specific applications. These materials have semiconducting, chromogenic or phototropic properties or are able to emit light, convert sunlight, or react to mechanical pressure or temperature. We use new digital printing processes, for example, for the low-cost production of OLEDs or solar cells.
Division director:
Dr. Armin Wedel

SYNTHESIS AND POLYMER TECHNOLOGY

The activities of the research division *Synthesis and Polymer Technology* span the entire value chain - from polymer synthesis to process development, analysis and characterization. We rely on a balanced mix of competencies in our departments *Polymer Synthesis, Shape Memory Polymers, Microencapsulation and Polysaccharide Chemistry*, as well as *Membranes and Functional Films.* One focus of our activities is material-oriented and technology-driven research from a laboratory to a pilot plant scale.
Division director:
Dr. Thorsten Pretsch

LIFE SCIENCE AND BIOPROCESSES

In the research division *Life Science and Bioprocesses*, we use proven mechanisms from nature to expand the functional spectrum of polymers. Our focus is on integrating new biological functions into polymer materials. We develop processes, materials and key substances for biotechnology, chemical industry, textiles, medical devices, pharmaceuticals and cosmetics, as well as for environmental technologies and nanotechnologies.
Division director:
Dr. Ruben R. Rosencrantz

PAZ

The Fraunhofer *Pilot Plant Center for Polymer Synthesis and Processing PAZ* in Schkopau is a joint initiative of the Fraunhofer Institutes IAP and IMWS.
Its main polymer synthesis activities include developing and optimizing polymer synthesis processes, upscaling and providing sample quantities.
Division director:
Prof. Dr.-Ing. Michael Bartke

PYCO

The research division *Polymeric Materials and Composites PYCO* provides key expertise in lightweight construction along the entire value chain – from monomers to high-performance components. Prototypes, including special polymers and semi-finished fiber composites developed in-house, can be designed and scaled to meet the demands of large-scale production. These synergies represent a unique selling point in the German research landscape.
Division director:
Prof. Dr.-Ing. Holger Seidlitz

CAN

Research at the *Center for Applied Nanotechnology CAN* focuses on the development of innovative, industrial-scale manufacturing processes for customized composites made of nanoparticles which can be used in displays, in lighting, in infrared sensors, as safety markings and in medical diagnostics. We also develop fuel cells with highly efficient nanocatalysts, polymers for cosmetic applications, and nanocapsules for the targeted release of active ingredients in medical applications.
Division director:
Prof. Dr. Horst Weller

SERVICES

Synthesis and modification of polymers, material development, polymer processing, scale-up up to ton scale, process optimization, technology and process development, surface analysis, structural characterization, material testing, utilization of biogenic residues, biotechnology, consulting

APPLICATION FIELDS

Plastics industry, lightweight construction, aerospace, automotive, electronics, optics, security technology, energy technology, textile industry, packaging, environmental and waste water technology, paper, construction and paint industries, medicine, pharmacy, cosmetics, biotechnology, circular economy, chemical industry, displays

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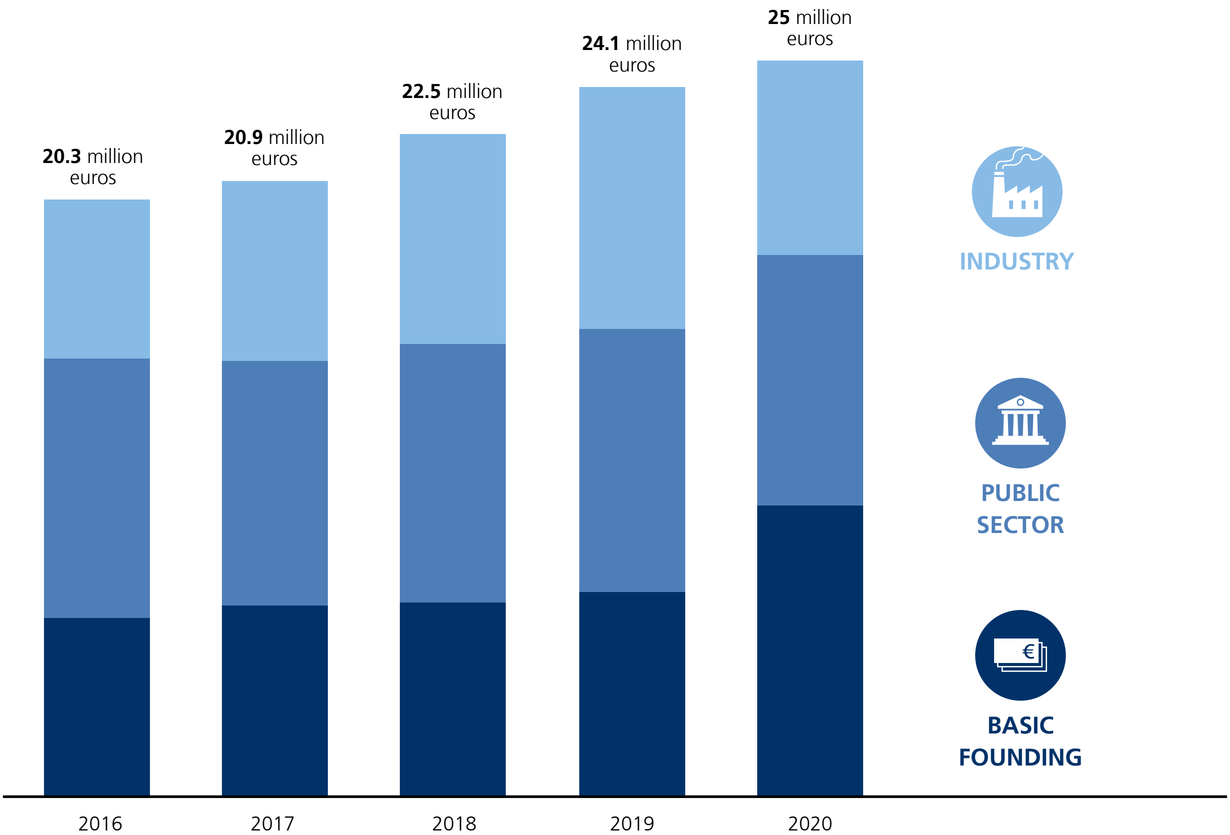
THE INSTITUTE
IN FIGURES

OPERATING BUDGET

The operating budget for 2020 amounted to 25 million euros. External revenue totaled 15.1 million euros, 43.7 percent of which was revenue from industry.

INVESTMENT BUDGET

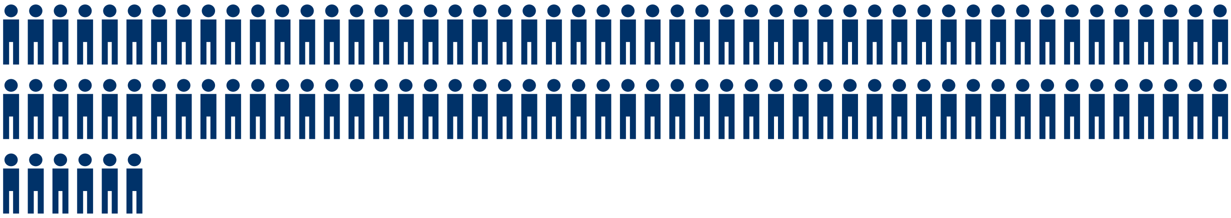
A total of 3.4 million euros were invested in 2020, including 1.6 million euros to replace equipment, for example, a vertical prepreg system and an X-ray photoelectron spectrometer.



254

people were employed at Fraunhofer IAP at the end of 2020, 228 of which were permanent staff and 26 were junior staff.

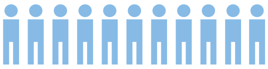
106 Scientific staff



90 Technical staff

21 Administration / scientific and technical services

11 Strategy and Marketing



22 Ph. D. students

4 Apprentices

75

bachelor's and master's students, research assistants and student research assistants, interns and guest researchers from Germany and abroad were also employed at the Fraunhofer IAP in 2020.

FIGURES 2020

18

PUBLISHED PATENTS

20

THESES

thereof 4 bachelor theses, 11 master theses and 5 dissertations

AWARDED

Also in 2020 our scientists were awarded for their work.

66

PUBLICATIONS

8 lectures, 3 posters and 55 publications

54

GRANTED PATENTS

41

LECTURING ACTIVITIES

Marcello Ambrosio, M.Sc.
Lecture and practical course: Leichtbau-seminar Brandenburgische Technische Universität Cottbus - Senftenberg

Prof. Dr.-Ing. Michael Bartke
Lecture: Polymerisationstechnik, Martin-Luther-University Halle-Wittenberg

Lecture: Polymer Reaction Engineering, Martin-Luther-University Halle-Wittenberg

Prof. Dr. Alexander Böker
Lecture: Biobased Building Blocks for Nanotechnology, University Potsdam

Lecture: Verarbeitung von polymeren Werkstoffen in Hinblick auf ihre Anwendung, University Potsdam

Seminar: Diplomanden-, Doktoranden-, Mitarbeiterseminar der Kolloid- und Polymerchemie, University Potsdam

Dipl.-Ing. Thomas Büsse
Lecture: Technologien der Kunststoff-verarbeitung, Brandenburgische Technische Universität Cottbus - Senftenberg

Practical course: Kunststoffverarbeitung, Brandenburgische Technische Universität Cottbus - Senftenberg

Prof. Dr. Christian Dreyer
Lecture: Organische Chemie, Technische Hochschule Wildau

Lecture and tutorial: Verbundwerkstoffe, Technische Hochschule Wildau

Lecture and practical course: Allgemeine und Anorganische Chemie, Technische Hochschule Wildau

Lecture: Chemische Grundlagen, Technische Hochschule Wildau

Prof. Dr. Johannes Ganster
Lecturing activities: Biobasierte Polymer-werkstoffe I, Brandenburgische Technische Universität Cottbus - Senftenberg

Lecturing activities: Biobasierte Polymer-werkstoffe II, Brandenburgische Technische Universität Cottbus - Senftenberg

lecture: Strukturcharakterisierung von biobasierten Polymerwerkstoffen, University Kassel

Compact practical course: Methoden der Strukturcharakterisierung im Fraunhofer IAP, University Kassel

Prof. Dr. Dieter Hofmann
Lecture: Physikalisch – Chemische Eigenschaften der Werkstoffe: PEW organisch, Technische Universität Berlin

Priv.-Doz. Dr. Silvia Janietz
Lecture: Polymere für die organische Elektronik, University Potsdam

Prof. Dr. André Laschewsky
Lecture: Functional Polymers (Hydrogels), University Potsdam

Lecture: Naturstoffe und Makromolekulare Stoffe, University Potsdam

Lecture: Polymerchemie (AWP 2), University Potsdam

Lecture: Protecting Group Strategies (in Organic and Polymer Synthesis), University Potsdam

Lecture: Technische Chemie, University Potsdam

Practical course: Polymerchemie, University Potsdam

Dr. Rainer Rihm
Lecture: Werkstoffkunde für Mechatroniker und Elektrotechniker I, Beuth Hochschule für Technik Berlin

Lecture: Werkstoffkunde für Mechatroniker und Elektrotechniker II, Beuth Hochschule für Technik Berlin

Tutorial: Werkstoffkunde für Mechatroniker und Elektrotechniker I, Beuth Hochschule für Technik Berlin

Tutorial: Werkstoffkunde für Mechatroniker und Elektrotechniker II, Beuth Hochschule für Technik Berlin

Practical course: Formgebende Technologien Kunststoffe, Beuth Hochschule für Technik Berlin

Dr. Ruben R. Rosencrantz
Lecture: (Bio)functionalized Polymers, Christian-Albrechts-Universität zu Kiel

Dr. Hendrik Schlicke
Tutorial: Physikalische Chemie für Fortgeschrittene, Universität Hamburg

Prof. Dr.-Ing. Holger Seidlitz
Lecture and tutorial: Einführung in den polymerbasierten Leichtbau, Brandenburgische Technische Universität Cottbus - Senftenberg

Lecture and tutorial: Mehrkomponenten-verarbeitung in der Kunststoffverarbeitung, Brandenburgische Technische Universität Cottbus - Senftenberg

Dr.-Ing. Lars Ulke-Winter
Lecture and practical course: Studierenden-konferenz für Leichtbautechnologien, Brandenburgische Technische Universität Cottbus - Senftenberg

Lecture and tutorial: Auslegung faserver-stärkter Kunststoffe, Brandenburgische Technische Universität Cottbus - Senftenberg

Prof. Dr. Horst Weller
Lecture: Nanochemie I, Universität Hamburg

Lecture: Physikalische Chemie für Fortgeschrittene, Universität Hamburg

Practical course: Vertiefungspraktikum in Physikalischer Chemie, Universität Hamburg

Lecture series: Was wie wofür studieren – Seminar zu speziellen Themen der Nanochemie, Universität Hamburg

Practical course: Nanochemie, Universität Hamburg

Dr. Ulrich Wendler
Lecture: Makromolekulare Chemie, Hochschule Merseburg

HIGH-PERFORMANCE CENTER FOR FUNCTIONAL INTEGRATION

The High-Performance Center *Integration of Biological and Physical-Chemical Material Functions* has been operating in Potsdam-Golm since 2017. In 2019 the project groups began receiving support from a transfer team to assist the scientists in the High-Performance Center who closely collaborate with colleagues at the anchor University of Potsdam and BTU Cottbus - Senftenberg. Aspects such as application potentials, marketability and utilization targets were addressed in preliminary projects.

In addition to enhance scientific work, a focus was layed in 2020 on activities that supported the innovation management of the project teams. Agile workshops were employed to define potential application fields and business areas, develop explanatory videos and storyboards, interview future users, and organize networking opportunities.

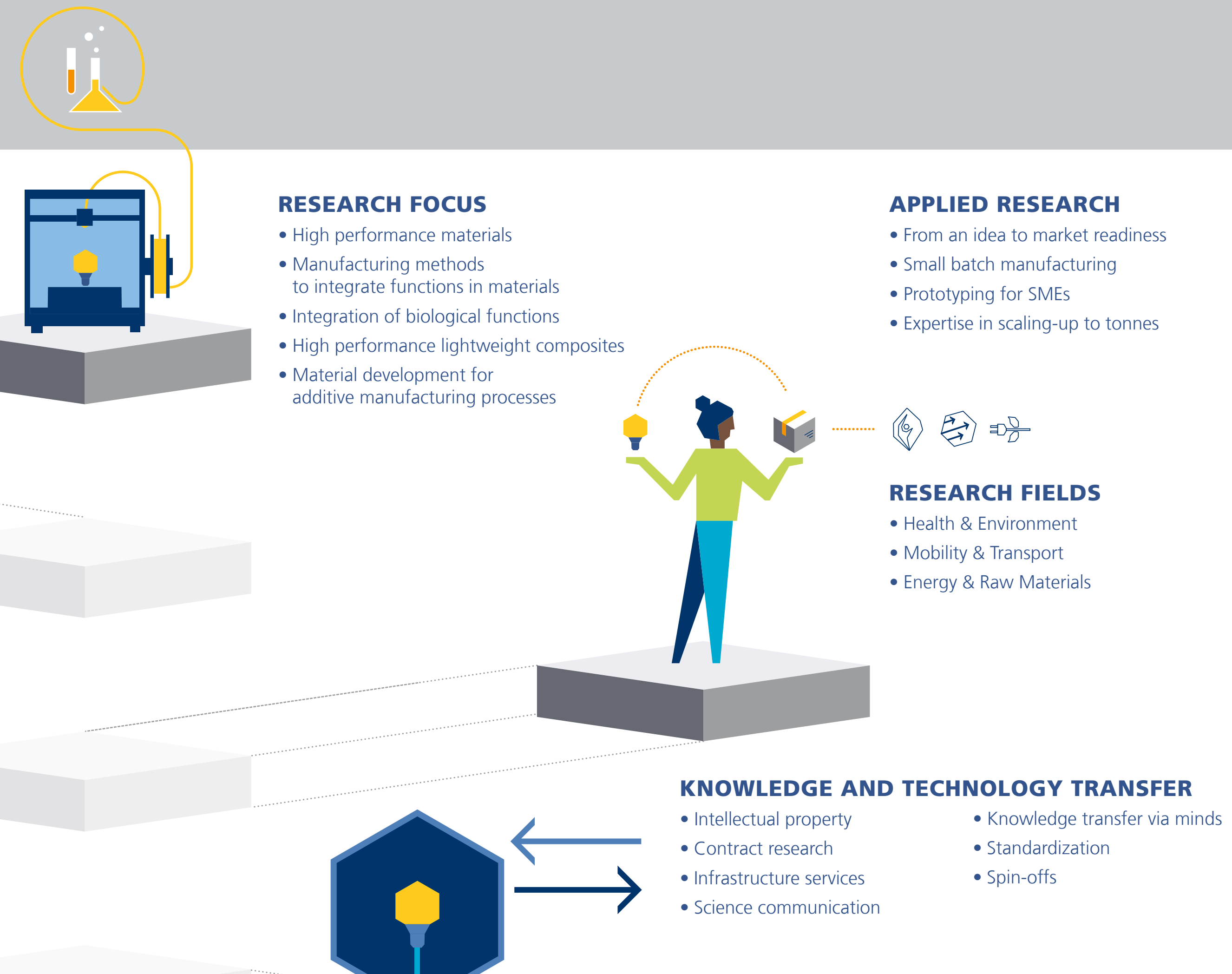
This year most networking activities took place virtually, including the annual event held jointly with the VDI Berlin-Brandenburg Association of German Engineers. Nearly 90 participants from science and industry took part in the discussion on "recycling concepts and residual power management". Active discussed were challenges faced by the plastics industry on its path to a circular economy, as well as the current developments in the High-Performance Center's research network. The discussions generated impetus for new projects and collaborations, such as the further development of Fraunhofer's self-check tool for industry to determine a product's recyclability, or the recyclable design of special materials made of fiber composites or

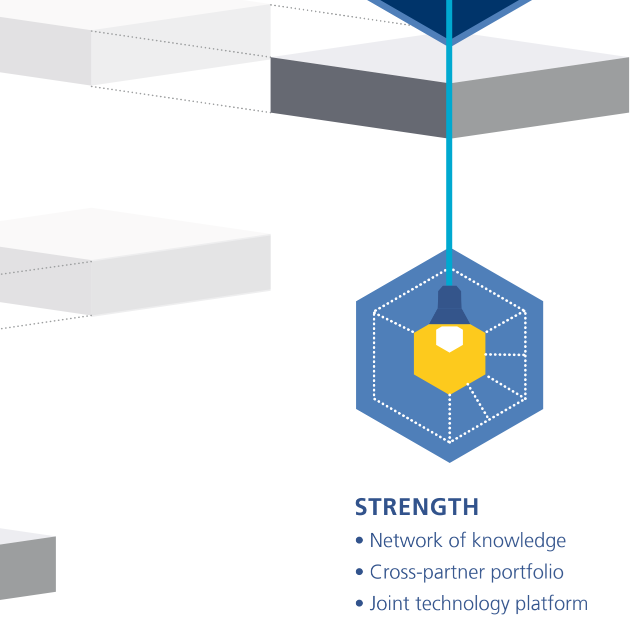
ABOUT US

- Operating instituts Fraunhofer IAP and Fraunhofer IZI-BB
- Development of intelligent plastics and materials
- Over 40 network and project partners

FUTURE FIELDS

- Climate Technologies and Resource Efficiency
- Intelligent Medicine
- Bioeconomy
- Hydrogen Technology





materials with shape memory properties. At the virtual event *International Biotech Innovation Days*, two project groups presented the progress of their projects and demonstrated the versatile application fields of industrial biotechnology. Researchers from the Fraunhofer Institutes in Potsdam used the *Potsdam Science Park Conference* as a platform to discuss innovation and patents at Fraunhofer. The High-Performance Center was also active on behalf of young scientists. In cooperation with the Economic Development Agency Brandenburg, doctoral students received insights into the industrial landscape of Brandenburg and had the opportunity to participate in a special seminar on best-practice strategies for writing successful applications. The transfer team also organized several online workshops on the topic of "how to write successful funding applications". **//**

INNOVATIVE UNIVERSITY

CHANGES IN TECHNOLOGY TRANSFER

Innovation Hub 13 – fast track to transfer of the Technical University of Applied Sciences Wildau and the Brandenburg University of Technology Cottbus - Senftenberg is an instrument of the joint federal-state initiative *Innovative Hochschule*. The interdisciplinary transfer scout team is developing a regional innovation system to sustainably strengthen knowledge and technology transfer (KTT) in the region of southern Brandenburg together with the Leibniz Institute for Research on Society and Space, Fraunhofer IMW, and the Fraunhofer IAP's research division *Polymer Materials and Composites PYCO*.

Examined topics include *Life Sciences*, *Digital Integration* and *Lightweight Construction*. Companies receive support in analyzing technology trends and future markets and advice on the development of business models. *Lightweight construction with polymers* is being addressed as part of the Innovation Hub 13 project in the research division *PYCO* and is supervised by transfer scouts Dr. Mathias Köhler and Marcello Ambrosio. The joint appointments of Prof. Holger Seidlitz from BTU (polymer-based lightweight construction) and Prof. Christian Dreyer from TH Wildau (fiber composite material technologies) enable the universities' expertise to be used effectively.

In 2020, new cooperation projects in the areas of lightweight construction, resource efficiency and recycling were launched with companies from Berlin-Brandenburg and Saxony. Because of a lack of in-person events like trade fairs and conferences as a result of the Corona crisis, a new digital format for networking events called *InnoMix* was developed to enable the initiation of collaborations with industry partners. Further platforms included the virtual working group meetings of the VDI Association, in particular the working group on *Plastics and Lightweight Technologies*, which brought together many regional stakeholders at the BTU in Cottbus. This enabled the network to be expanded and additional transfer projects to be initiated in order to increase innovation capabilities. A concept was also developed for the early transfer of research results to society in the fields of composite materials, hybrid multilayer composites and additive manufacturing processes. This will initially be aimed at mechanical and electrical engineering students at BTU and will be rolled out in various lectures and workshops in 2021. **//**

Innovative Hochschule

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

Gemeinsame Wissenschaftskonferenz GWK

INNOVATIVE UNIVERSITY POTSDAM – INNO-UP

The project *Innovative University Potsdam (Inno-UP)* is part of the joint federal-state initiative *Innovative Hochschule*. In January 2018, Fraunhofer IAP joined the project of the funding initiative of the German Federal Ministry of Education and Research and the Joint Science Conference as a direct partner of the University of Potsdam. The project comprises three sub-projects: Education Campus, Society Campus and Technology Campus. Fraunhofer IAP is active in the Technology Campus sub-project, which involves the establishment and testing of so-called *Joint Labs* (JLs).

In 2020, focus was on the format of the JLs themselves. A workshop was held in February with nearly 100 participants from all over Germany. Together they discussed the Joint Lab idea and various aspects of how to successfully implement it. Prominent speakers were recruited to speak on the topics of *Open Innovation in Science* (Prof. Dr. Marion Poetz, Copenhagen Business School), *Shaping Collaborative Innovation* (Florian Schütz, Fraunhofer CeRRi) and *Living Labs* (Dr. Kai Hielscher, BMWi). Their lectures laid the groundwork for subsequent workshops. The results were published in a report.

Through the Joint Lab *Biofunctional Surfaces* (BioF), Fraunhofer IAP is taking a leading role in the technical design of the JLs, which is to become an important transfer module for the High-Performance Center *Functional Integration*. The JL *BioF* will also explore the potentials, challenges and limits of new open cooperation formats. A key aspect of this work is managing and harnessing cross-organizational knowledge flows to make research more relevant and useful to end users. Concepts from the field of open innovation are to be used in a scientific context, e.g. to generate new research questions together with the partners and to take greater account of the specific needs of society and industry. In addition to networking with stakeholders in the Potsdam Science Park, the JL *BioF* will also increasingly encourage industry partners to jointly develop and implement new ideas. **//**

Innovative Hochschule

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Gemeinsame Wissenschaftskonferenz GWK

FRAUNHOFER CLUSTER OF EXCELLENCE

The Fraunhofer Clusters of Excellence are established by the Fraunhofer-Gesellschaft to concentrate applied research by relevant Fraunhofer Instituts on topics which have a disruption potential with respect to societal problems. Complementary expertise is brought together synergistically on a specific topic to generate a structure with international visibility for industry, science and society.

CIRCULAR PLASTICS ECONOMY CCPE

Circular concepts are playing an increasingly important role in the economy in order to achieve the Sustainable Development Goals (SDGs) set out in the UN's 2030 Agenda. This is particularly evident in the plastics industry. Plastic production is growing and represents an important economic factor in many countries. The plastics used in industry and consumer goods have a broad and optimized range of properties and in many cases cannot be easily substituted. Their light weight, ease of manufacture and handling make them indispensable for resource-efficient products. However, far too much plastic waste ends up in the environment at the end of its life cycle. The desired move away from today's - still largely linear - global system towards an efficient circular economy requires systemic, technical and social innovations.

The CCPE research cluster will contribute significantly to this. The aim is to establish a virtual, cross-institute, synergetic structure with new competencies, methods and products for the circular plastics economy. Fraunhofer IAP is responsible for the cluster's research department *Circular Polymers* and works closely with the Fraunhofer Institutes LBF, ICT and UMSICHT. Work at Fraunhofer IAP focuses on biobased and biodegradable plastics. One of its objectives is to conserve fossil resources while reducing the carbon footprint. It also aims to ensure rapid degradability of plastics when their release into the environment is unavoidable, for example, microplastics released as a result of weathering and abrasion. More specifically, Fraunhofer IAP is developing branched polybutylene succinates with the aim of expanding their range of applications, similar to the approaches established for polyethylene. Another focus is on new thermoplastic elastomers based on biobased furandicarboxylic acid. In the area of polymer processing, effective methods are being developed for spinning higher temperature-resistant fibers from polylactide (PLA) based on stereocomplex crystal structures (scPLA). These are tested as reinforcement fibers in composite applications in collaboration with Fraunhofer ICT. Work on additives to control degradability is performed with the Fraunhofer Institutes LBF and UMSICHT. An interim evaluation of the cluster was successfully completed in March 2021 and funding will be provided until 2023. **//**

Participating Institutes: Fraunhofer IAP, Fraunhofer ICT, Fraunhofer IML, Fraunhofer IVV, Fraunhofer LBF, Fraunhofer UMSICHT

PROGRAMMABLE MATERIALS CPM

The Fraunhofer Cluster of Excellence *Programmable Materials CPM* is laying the scientific and technological foundations for the development of materials whose internal structure allows them to fulfill the function of entire systems. This enables miniaturization and reduces system complexity. The aim is to combine various elements of programmable materials with a desired functionality with customer-specific systems.

Important advancements were also made in 2020 on the key topic of programmable transport properties. For example, autonomously switching membranes that react specifically to a chemical signal were successfully developed for water treatment. This activates protective mechanisms that retain chemical compounds such as specific sugars. Proof-of-principle was also provided for capsule structures with application-optimized release kinetics. The technology is promising, especially for preventing fouling. Another advantage is that the production of the capsules can be easily scaled up. Shape memory polymers produced via reactive foaming open up new possibilities for thermally switchable air slots in buildings and represent one of the *CPM's* basic technologies for switchable heat transfer. In the field of programmable mechanical material properties, light irradiation can instantaneously adjust the viscosity of newly synthesized, silicone oil-based lubricants. In the future this will help limit the loss of energy and materials in applications with lubricated components and offer the possibility of developing more disruptive lubricants. Another material innovation in the area of shape memory polymers has brought about new actuators with a controllable switching behavior. The pre-programmed shape changes can be reliably used in thermally switchable grippers and unit cells and bring about new system behaviors.

Based on the scientific and technological understanding of programmable materials, further steps were taken to develop a common library of functions and processes to provide a sustainable basis. It is meant to link the material mechanisms and systemic functions with the process steps needed for manufacturing. ***//***

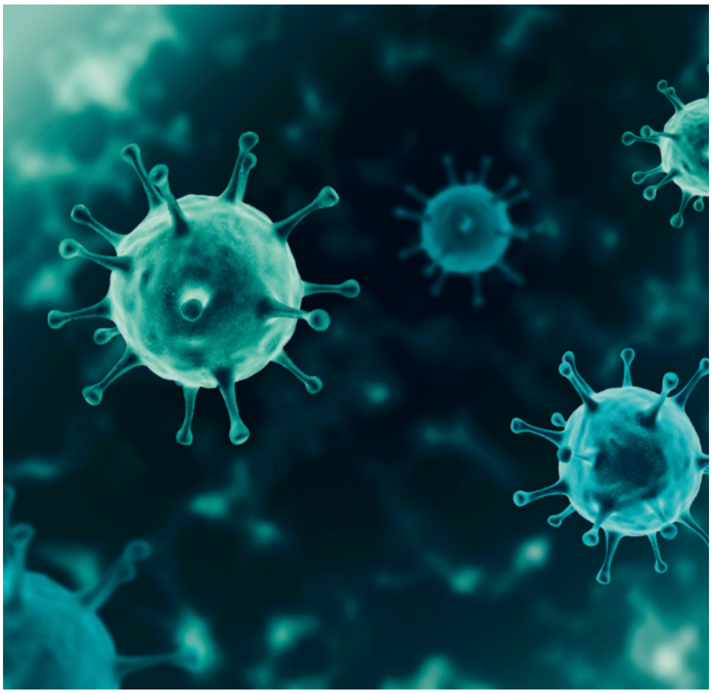
Core institutes of Fraunhofer CPM: Fraunhofer IAP, Fraunhofer IBP, Fraunhofer ICT, Fraunhofer ITWM, Fraunhofer IWM, Fraunhofer IWU

ANTI-CORONA RESEARCH AT FRAUNHOFER IAP

The SARS-CoV-2 pandemic was an overarching issue in 2020 which not only changed society and impacted people's health, but also shifted the focus of research to new topics.

Fraunhofer IAP is working with other Fraunhofer Institutes and partners on new ways to treat COVID-19 as well as new diagnostic methods, membranes and filters, protective textiles, and antiviral surfaces.

The BEAT-COVID consortium is an alliance made up of five Fraunhofer Institutes and various universities with expertise in preclinical and clinical drug development. It is pursuing three goals: preventing the virus from entering the cell, combating the virus directly, and finally regulating the exuberant immune response triggered by the virus. RNA interference, whereby siRNA (small interfering RNA) turn off the virus docking sites on the cell, is aimed at preventing the virus from entering the cell. Respiratory administration allows the siRNA to quickly reach the area most affected by SARS-CoV-2: the lungs. The Fraunhofer IAP's role within the consortium is to encapsulate the siRNA in order to improve their stability and uptake in the target cell. By formulating the active ingredient with tailored-made glycopolymers and cleverly encapsulating it, the drug is able to penetrate the lung mucosa, thus ensuring targeted delivery and effective treatment of COVID-19.



Another research topic is the development of new methods of diagnostic testing. Fluorescent markers are often used which selectively bind to pathogens. The binding causes excitation and they emit light (fluorescence). However, even these methods can be insufficient when the pathogen is only present at extremely low concentrations, as in the case of the RNA on a SARS-CoV-2 swab. In such cases, reliable detection requires complex methods such as PCR (polymerase chain reaction). Fraunhofer IAP is looking to solve this problem through an innovative approach that uses magnetofluorescent nanoconstructs. This will create a new technology platform for fluorescence diagnosis.

Ten Fraunhofer Institutes are participating in the Fraunhofer Anti-Corona Project Next Generation Protective Textiles. Fraunhofer IAP is collaborating with Fraunhofer IZI-BB as part of a sub-project to develop a coating for polypropylene nonwovens that can be used in protective masks or

filter elements. The aim is to create antiviral, switchable bio-repellent polymer coatings for protective textiles. Fraunhofer IAP is developing the immobilization concepts for this. The coating concept can also be transferred to other textiles, for example textiles in public buildings or on modes of transport, such as buses, trains and airplanes, where immediate cleaning and disinfection is difficult.

As part of the Fraunhofer project AVATOR – *Anti-Virus Aerosol: Testing, Operation, Reduction,* Fraunhofer IAP, together with Fraunhofer LBF, is processing special nonwovens that can destroy viruses by means of an integrated electret (electrically insulating material). The nonwovens are used in room and ventilation technology, for example in open-plan offices or airplanes. Membranes have also been developed at Fraunhofer IAP that use size separation to filter out SARS-CoV-2 viruses, for example. The membranes are chemically and mechanically stable and can be cleaned and reused. It is believed that there will be a range of applications for these membranes even in a post-Corona era. ***//***

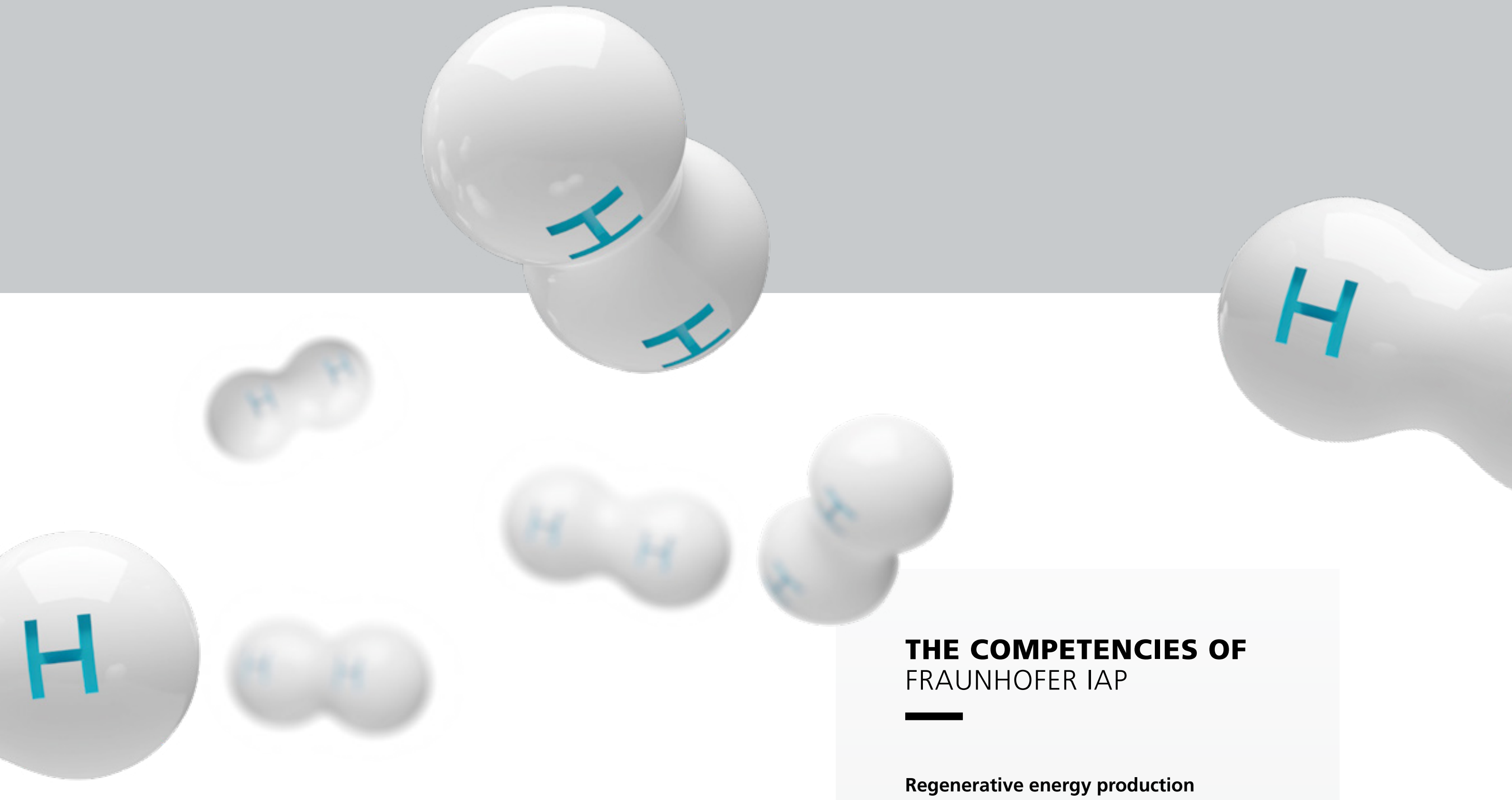
HYDROGEN – ENERGY CARRIER OF THE FUTURE

Hydrogen is an energy carrier of the future, with green hydrogen being a climate-neutral source of energy. Hydrogen is also tremendously important for the mobility sector (e.g. as a fuel for trucks, trains and inland waterway vessels), in industry (as a basic chemical), and in the heating sector.

Hydrogen is essential for tackling the energy transition and meeting the related climate targets. The "National Hydrogen Strategy", adopted in 2020 by the German Federal Ministry of Education and Research, calls hydrogen the "petroleum of the future". The establishment of the entire value chain – from generation, to storage, distribution and application – is to be supported via investment and research programs. The competencies of Fraunhofer IAP put it in an excellent position to address future research tasks and to help shape the respective value chains.

Hydrogen is produced from water by electrolysis. The reaction does not occur spontaneously and requires external energy. Green hydrogen is produced using only electricity from renewable energy. The electrolysis takes place in the electrolyzer which is a key component in hydrogen production. Currently, the investment and operating costs of membrane electrolyzers are not competitive. This is due to expensive materials (e.g. precious metal catalysts), a complex set-up, and production technology that has yet to be optimized. Therefore, new, cost-effective and more efficient components must be developed. A key element of the electrolyzer is the ion-conducting membrane which significantly influences efficiency and reliability. Fraunhofer IAP has the synthesis expertise needed to create new, inexpensive, high-performance, ion-conducting polymers. Efficient - in other words power-saving – electrode materials also play a crucial role in the reaction that takes place during electrolysis. Nanoscale catalysts that save on precious metals during hydrogen production are ideally suited for this purpose. These tailor-made nanoparticles are successfully produced and used in our *CAN* research division.

In addition to electrolysis, regenerative energy production and hydrogen storage are also crucial. In our *PYCO* research division, a small-scale, energy-generating wind turbine is currently being developed together with industrial partners and having blades made of fiber-reinforced plastic composites. Any excess energy generated is converted into hydrogen in an adjoining electrolysis unit. This is then stored in fiber-reinforced high-pressure vessels



(power-to-X). The vessels are fitted with sensors to detect any leaks. Development work is taking place within the framework of the *Regional Investment Concept (RIK) Lausitz* of the German Federal Ministry of Economics and Technology.

As a member of the Saxony Innovation Cluster for Fuel Cell and Hydrogen Technology – *HZwo e. V.*, the *Hydrogen Initiative Group* of the German-Russian Chamber of Commerce, the Brandenburg-Saxon Hydrogen Network *DurcH2atmen*, and the *Fraunhofer Hydrogen Network*, Fraunhofer IAP is well-connected at national and international level, which allows it to advance its research activities. **//**

THE COMPETENCIES OF
FRAUNHOFER IAP

Regenerative energy production

Electricity for hydrogen generation

- Lightweight materials and systems
- Glass fiber reinforced plastic
- Carbon fiber reinforced plastic

Hydrogen generation and usage

Polymer electrolyte electrolyzers and fuel cells

- Development of new ionomer materials, in particular fluorine-free materials for membranes and binders for catalysts
- Production of membranes, composite membranes including surface engineering and morphology adaption
- Materials for catalysts (nanoscale electrode materials that save on precious metals) for fuel cells and electrolysis
- System-level testing of fuel cell components

Hydrogen storage

- Materials and production technologies for highly integrated lightweight components
- Design and production of pressure vessels
- Development of structural health monitoring systems
- Holistic design and optimization of multilayer fiber composite structures
- Testing of pressure vessels

RESEARCH TOPICS 2020

BIOECONOMY AND SUSTAINABILITY

Prof. Dr. Johannes Ganster

Material Development and Structure Characterization

GREEN CARBON FIBERS

Fraunhofer IAP is part of a cooperation that will contribute to a sustainable structural transformation of the coal area Lusatia in the coming years. A memorandum of understanding relating to this was signed on September 16, 2020. With the support of the Saxon State Ministry for Regional Development and the scientific expertise of the Cluster of Excellence *Merge Technologies for Multifunctional Lightweight Structures - MERGE* at the Chemnitz University of Technology as well as the Fraunhofer IWU and Fraunhofer IAP, new opportunities will be created for the Boxberg power plant site as well as the Brandenburg Technical University location in Cottbus in the area of carbon fiber research and utilization.

In the cross-state initiative, Fraunhofer IAP provides its expertise in sustainable precursor materials for carbon fibers as well as its know-how in converting these materials into carbon fibers. In addition to the existing laboratory line used to produce precursor fibers (laboratory white line) and the continuous conversion line (mini-black line) in Potsdam, a fully equipped pilot plant white line and a laboratory-scale black line will be set up in Lusatia to scale up the process. **//**

Laboratory carbonization oven at Fraunhofer IAP.

The spooled viscose filament yarn was made from recycled cotton.

A NEW T-SHIRT FROM OLD JEANS

Processing recycled cotton into viscose fibers made of pure cellulose has finally been achieved by a team of researchers from Fraunhofer IAP and the Swedish company re:newcell. Cotton clothing has not been recyclable up to now since items like trousers and shirts are usually made of a blended fabric and it has not been technically possible to separate the interwoven fibers. Adjusting the parameters of the solution and spinning processes enabled the foreign fibers contained in the cellulose to be extracted. This resulted in a filament yarn - in other words a continuous fiber several kilometers long - that was made of 100 percent cellulose and comparable in quality to wood-based regenerated cellulose fibers. The textile fiber can also be mass produced. This will allow cotton clothing to be recycled multiple times in the future, thus contributing to greater sustainability in fashion. **//**

Dr. André Lehmann
Fiber Technology

Partner: *re:newcell*

Dr. Evgueni Tarkhanov
Fiber Technology

The project is being conducted as part of the Fraunhofer Cluster of Excellence Circular Plastics Economy CCPE®.

SELF-REINFORCED PLA-BASED COMPOSITES

The areas of application for biobased and biodegradable polyester polylactic acid (PLA) have so far been largely limited by its low melting temperature and associated low thermal resistance. The Fraunhofer CCPE Cluster is exploring ways to increase the melting range, also with the aim of developing innovative self-reinforced PLA-based composites in the future. A significant improvement of the thermal and mechanical properties of PLA-based materials could decisively expand their areas of application and generate clear advantages over the current fiber-reinforced system when it comes to recycling. **//**

A test system can be used to determine the oxygen demand during biodegradation in fresh water, seawater or even in soil for a wide variety of samples.

DATABASE ON THE BIODEGRADABILITY OF MICROCAPSULES

Do biobased polymers remain biodegradable even after they have been chemically modified? So far, the scientific literature contains very little data on the biodegradability of microcapsules or particles ranging in size from around one micrometer to a few millimeters. A team of researchers at Fraunhofer IAP is therefore investigating various modified natural materials and creating a database with information on biodegradability. This data is not only important for microcapsules, but also for a variety of other applications in which bioplastics end up in the soil. A manometric respiration test is carried out in order to determine the biodegradability.

Another test method is also available at the Fraunhofer IAP's Processing Pilot Plant for Biopolymers Schwarzheide. The two measuring systems enable the samples to be examined in different testing media. This allows biodegradability to be simulated in fresh water, seawater and soil, providing a wide range of information for the database. **//**

The measuring system was purchased using funds from the project 'Improvement of the biodegradability of modified biobased polymers through the use of microencapsulated enzymes – Enzymics'.
FKZ: *22014118*

Kathrin Geßner
Microencapsulation and Polysaccharide Chemistry

Gefördert durch:

Bundesministerium für Ernährung und Landwirtschaft

aufgrund eines Beschlusses des Deutschen Bundestages

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

Light microscopy analysis of the foam structure of a medium-density foamed bioplastic.

Dipl.-Ing. Thomas Büsse
Processing Pilot Plant for Biopolymers Schwarzheide

Project: *Foamed biobased plastics for use in packaging, vehicle construction (automotive) and building materials*
FKZ: *AZ19.1.18*

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

FOAMED BIOBASED PLASTICS

Foamed plastics are a versatile class of materials that are significant in terms of cost and energy efficiency. Lightweight and load-bearing construction elements, effective insulating materials or functional packaging materials are made of it. There is an increasing demand for more sustainable alternatives to traditional plastics. However, due to insufficient suitability of bioplastics or processing methods that are not specifically tailored, their availability is limited. This is where the project X-Bio-P comes in, which was started at the Fraunhofer IAP's Processing Pilot Plant for Biopolymers Schwarzheide. Since the start of the project in August 2020, biobased plastics have been shown to be generally suitable for foam applications and the existing process technology has been expanded to include components for controlling and optimizing foam densities. The economic region of Lusatia has been supporting this project as part of the model project Unternehmen Revier and has utilized the competencies of Fraunhofer IAP to initiate a collaborative project between regional companies. ***//***

Dr. Antje Lieske
Polymer Synthesis

Joint project: *Development of PLA film grades based on thermoplastic lactide-glycol block copolymer elastomers and an innovative process for their production*

FKZ: *22005717*

Partner: *TechnoCompound GmbH*

PLA GRADES FOR FLEXIBLE FILM APPLICATIONS

Polylactic acid (PLA) is not suitable for producing soft film materials due to its low elongation at break and melt strength. Currently, flexible PLA materials are mainly achieved by compounding them with high amounts of non-biobased materials (Ecoflex). Polyethers, such as polyethylene glycol (PEG), are effective plasticizers for PLA. However, they tend to diffuse out of the PLA matrix, resulting in a sticky surface and a deterioration of the mechanical properties over time. By synthesizing block copolymers from PLA and polyethers, the project has found a way to prevent these undesirable effects. At the same time, a new polymerization process for these materials has been developed in collaboration with the company TechnoCompound GmbH. The new materials could be processed on a blown film line on a pilot plant scale, resulting in PLA films with very high elongations at break. **//**

Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages
FNR
Fachagentur Nachwachsende Rohstoffe e.V.

The processing of the new PLA grades on a blown film line at the Processing Pilot Plant for Biopolymers Schwarzheide.

PURIFYING
IRON-RICH WATER

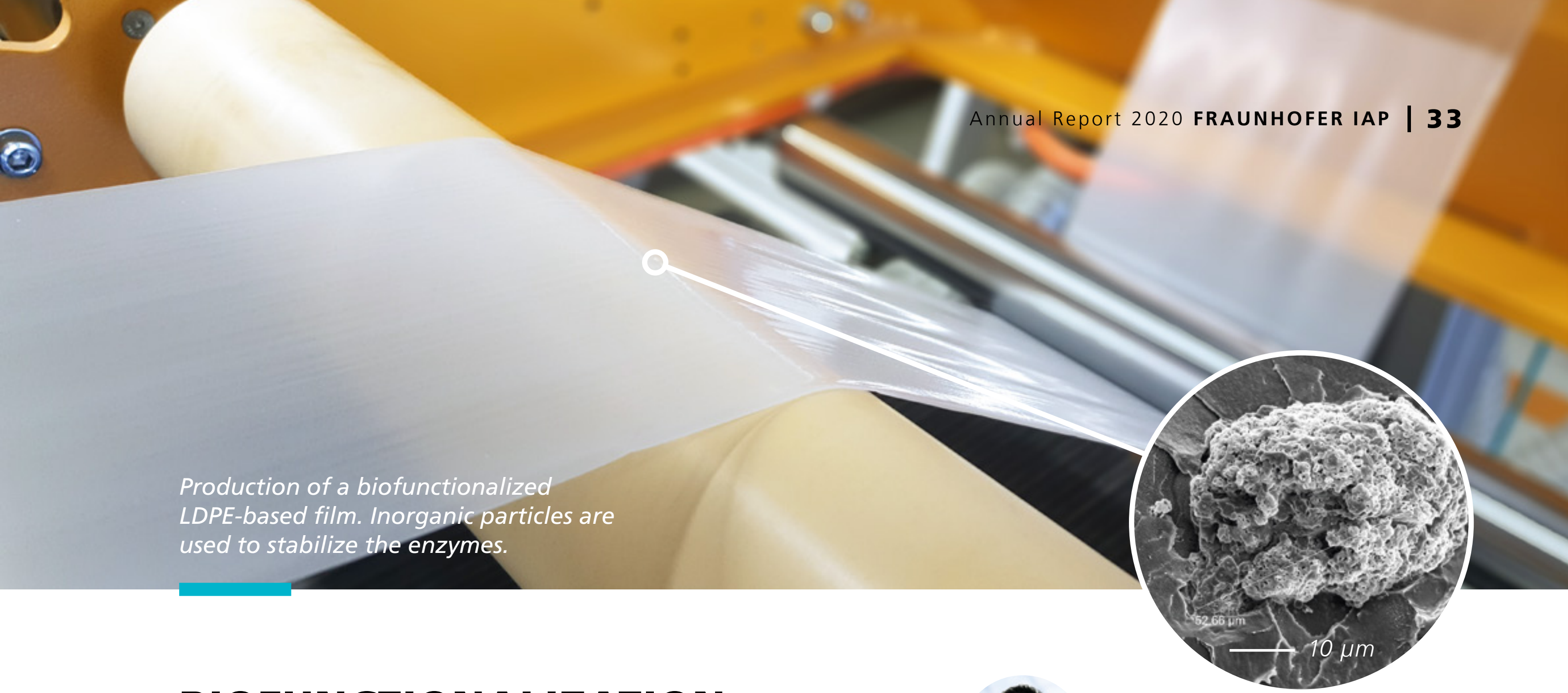
In order to meet the growing demand for drinking water in the future, the ecosystem of our inland waters and the quality of our groundwater will need to be preserved. Lignite mining in Lusatia in the past has had a particularly profound and lasting impact on the water balance. An elimination of iron compounds in these waters is essential in combating the unwanted effects. Currently, synthetic flocculants are used to treat water that contains iron. Research into more environmentally friendly and degradable flocculants is being carried out as part of the *BioFloc* project. A variety of manufactured starch derivatives were investigated and compared with commercial products in collaboration with the Brandenburg University of Technology Cottbus - Senftenberg. The flocculation results were comparable to those of synthetic products when slightly higher doses of anionic carboxymethyl starches and newly developed carboxy starches were added to the iron-rich Lusatian well water. Building on these results, further field trials with starch-based flocculants could follow, e.g. at the Spremberg dam. ***//***

Dr. Jens Buller
Starch Modification/
Molecular Structures

Project: *Development of biobased flocculants for the purification of iron-rich water (BioFloc)*

EUROPÄISCHE UNION
Europäischer Fonds für
Regionale Entwicklung

Modified starch in flocculation trials with iron-rich model water.



Production of a biofunctionalized LDPE-based film. Inorganic particles are used to stabilize the enzymes.

BIOFUNCTIONALIZATION OF POLYMERS

The aim of the BioPol project group is to sustainably give polymers new functions. Fraunhofer IAP and the Brandenburg University of Technology Cottbus - Senftenberg are conducting joint research on the biofunctionalization of polymers. This includes using active biomolecules in the functionalization of bulk polymers, surfaces and dissolved polymers. During the five-year project, three classes of biomolecules will be investigated: glycans, peptides and proteins/enzymes. In 2020, the project focused on using enzymes in the functionalization of thermoplastics. These could be used, for example, in self-cleaning components. The challenge was to develop processes, stabilization techniques and analytical methods that would keep the enzymes stable and active and, for example, enable them to be compounded into thermoplastics and then be processed into films at the Processing Pilot Plant for Biopolymers Schwarzheide. ***//***

Dr. Ruben R. Rosencrantz
Biofunctionalized Materials and (Glyco)Biotechnology

Project: *Biofunctionalization/ biologization and polymer materials (BioPol)*

FKZ: *F241-03-FhG/004/001*

LAND BRANDENBURG
Ministerium für Wissenschaft, Forschung und Kultur

EVOBIO: SOLUTIONS FOR A SUSTAINABLE ECONOMY

Prof. Dr. Johannes Ganster
Biopolymers

The initiative project *Evolutionary Bioeconomic Processes EVOBIO* was approved as part of the Fraunhofer-Gesellschaft's Innopush program. Nineteen Fraunhofer Institutes were involved in developing future ideas for a sustainable economy up until the project ended in late 2020. New process concepts were developed that use material flows in bioeconomic process cycles to produce optimized materials for innovative products. The project was managed by the Fraunhofer Institutes IGB, IAP and IVV. Various organizational units at Fraunhofer IAP participated in the project. ***//***

RESEARCH TOPICS 2020

ENERGY TRANSITION
AND MOBILITY

Dr. Thorsten Pretsch
Synthesis and Polymer Technology

PROGRAMMABLE INSULATION MATERIALS

Innovative insulation materials made of shape memory polymers are being developed and investigated at Fraunhofer IAP. The institute is collaborating with the Fraunhofer Institutes ICT and IBP as part of the Fraunhofer Cluster of Excellence Programmable Materials CPM. These high-tech foams can be used as functional materials, for example in construction. New applications are also being sought for the unique functionalities of the foams made from shape memory polymers. Self-sufficient insulation systems with switchable air permeability are being developed. The insulating material changes shape, e.g. the diameter of the flow channels, depending on the temperature, thus controlling the heat transfer. At low temperatures, for example, the flow channels close, creating an insulating effect. When heated, the channels open and air flows through them. This is particularly relevant for applications in which outside temperatures vary greatly. Fraunhofer IAP synthesizes the programmable high-tech foams and develops technologies for programming their property profiles. **//**

Special reactive foaming equipment is used to produce shape memory polymer foams.

MOBILE IR-THERMOGRAPHY PROCESS

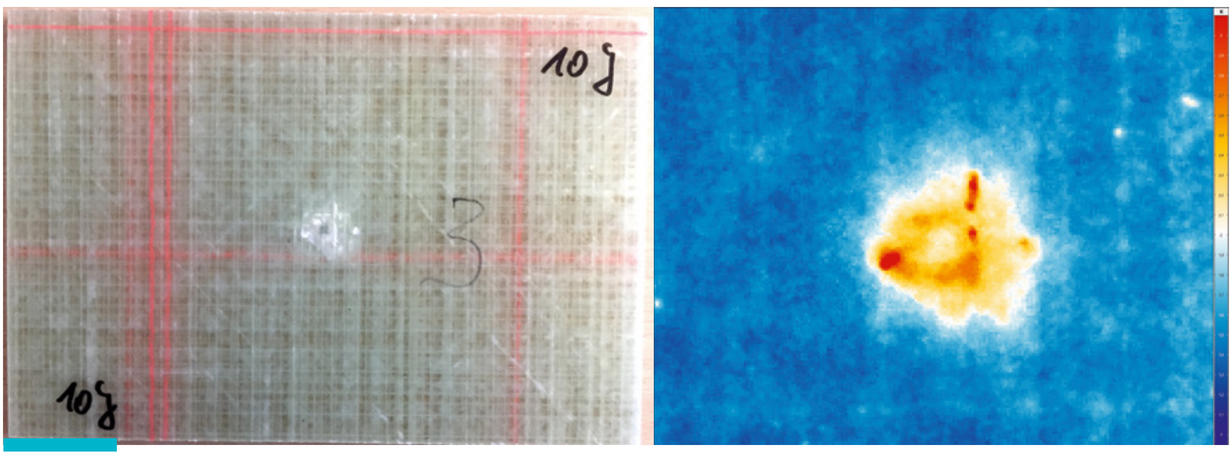
Christoph Uhlig
Structural Testing and Analytics

Project: *Mobile thermography method for automated damage analysis and repair of large fiber-reinforced components in rail vehicles and wind turbines for use in the field (ThermRep)*

FKZ: *03WIR2504A*

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

The initiative *Designing Structural Change through Innovations in the Digitalization of Maintenance, Servicing and Repair* is being funded in the region of Lusatia as part of the German Federal Ministry of Education and Research program *WIR! - Transformation through innovation* in the region. *ThermRep* is a sub-project of this. Fiber-reinforced plastics (FRP) are used in Lusatia in wind energy and rail vehicle construction. Both industries require automated, cost-effective ways to detect damage and derive repair concepts that can replace conventional subjective analysis which uses visual inspection and tapping. Infrared thermography is ideal for this application since analysis can take place from a distance with a large field of vision. In the project, the basics for the outdoor use of IR thermography on FRP components are being developed together with the project partners BTU Cottbus - Senftenberg (the departments of *Polymer-based Lightweight Construction and Electronic Circuit Technology*), the Berlin-based company Nanotest und Design GmbH, and project partners from the region's wind energy industry (maintenance and repair). The department of *Electronic Circuit Technology*, under the leadership of Prof. Schacht, and Nanotest und Design GmbH contribute their expertise in the thermography of microelectronic assemblies, while the research division *PYCO* and the department of *Polymer-based Lightweight Construction*, led by Prof. Seidlitz, contribute their know-how in FRP manufacturing technologies. As part of the project, the research division *PYCO* produces FRP model materials, introduces defined damage using the instrumented drop weight tower, and analyzes this by means of a micrograph. ***//***



Impact damage in glass fiber reinforced plastic (GFRP)
Left: light-optical image; right: thermographic image

Marcello Ambrosio, M.Sc.
Simulation and Design

Project: *Production of lightweight wire-wound high strength pressure vessels for hydrogen storage with integrated condition monitoring (HoDH2)*
FKZ: *20.1.4.1*

Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

PRESSURE VESSEL
FOR HYDROGEN STORAGE

Safely transporting and storing hydrogen, an energy source of the future, is essential for the energy transition. The research division *PYCO* is working together with the company EAB Gebäudetechnik Luckau GmbH to develop a robust, lightweight fiber-reinforced high-pressure vessel for hydrogen storage that has an integrated sensor system for monitoring the operating status. The high-pressure vessel can be used for stationary and mobile applications. For example, it can be used to store self-generated electricity in private households and as a transport container for hydrogen on commercial vehicles.

The stationary unit will be the first of its kind to be equipped with integrated sensor technology, thus guaranteeing operational reliability at all times. In a second step, the stationary unit will be developed further for mobile applications. ***//***

QUANTUM MATERIALS FOR
DISPLAYS AND LIGHTING

Indium phosphide (InP) quantum materials for new innovative applications in the display and lighting industry were developed from 2017 to 2020 by Fraunhofer IAP as a non-university partner in a German Federal Ministry of Education and Research project. Quantum materials (QD) were used as replacement for the commonly used phosphorescent metal complexes as emitting material in the light emitting diodes (LED), resulting in new devices called QD-LED. New concepts were applied to improve the interaction between the quantum materials and the charge transport materials. These materials were also used to develop inks that can be processed utilizing ink-jet printing technology. During the development of devices structures for the QD-LEDs, high efficiency was achieved in these devices as well as a very high maximum luminance (> 20,000 cd/m2), a value that is among the highest parameters ever achieved for InP-based quantum materials. ***//***

Dr. Armin Wedel
Functional Materials and Devices

Project: *Research into quantum materials – new ways of achieving innovative optoelectronic components*
FKZ: *13N14421*

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RESEARCH TOPICS 2020

HEALTH AND QUALITY OF LIFE

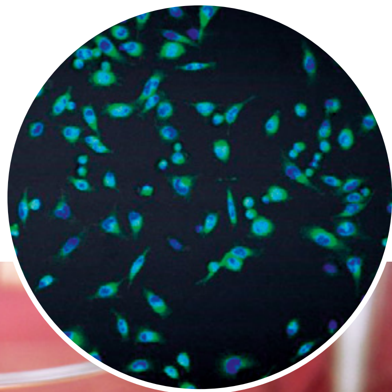
REAL-TIME BREAST CANCER DIAGNOSIS

Dr. Neus Feliu Torres
Nanocellular Interactions

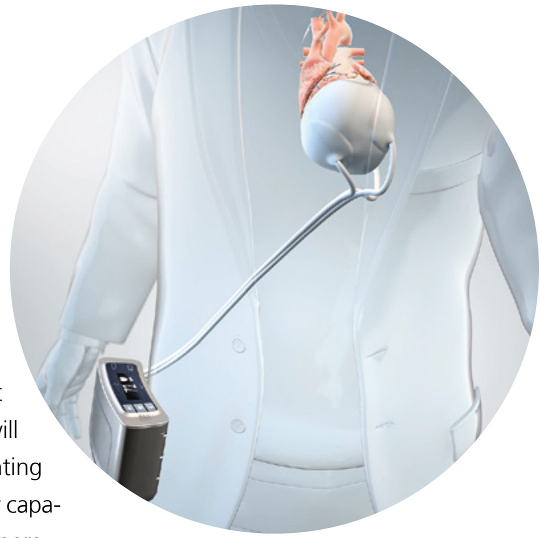
Project: *LIBIMEDOTS*

Gentle and effective blood-based tests for detecting breast cancer are being developed by a research team led by Dr. Neus Feliu Torres at our Hamburg site. Liquid biopsy methods are a non-invasive alternative that will enable the status and progress of breast cancer patients to be monitored in real time. The circulating tumor cells (CTCs) in the blood are enriched and characterized for specific tumor markers (cell typing). This will enable the disease to be monitored on a continuous basis and, for example, provide information on whether a therapy is successful or needs to be adjusted. The method could also be used in the future in early cancer screening. ***//***

Magnetic nanoparticles are modified so that they are readily taken up by tumor cells. Using magnetic separation, the tumor cells are isolated from other components in the blood and enriched. This increases detection sensitivity.



ARTIFICIAL PERICARDIAL
TISSUE FROM A 3D PRINTER



New forms of polymers will one day enable artificial, elastic replacement tissue to be individually manufactured for the pericardium (pericardial sac), heart valves and blood vessels. In the *PolyKARD* project, biomimetic polymers are being developed that can mimic the mechanical properties of pericardial tissue. They will enable customized implants to be produced by means of 3D printing and electrospinning. Another goal is to develop the first 3D printer capable of producing Class III medical devices. The PolyKARD partners – AdjuCor GmbH, Fraunhofer IAP, the Natural and Medical Sciences Institute NMI, Young Optics Europe GmbH and pro3dure medical GmbH – are advancing the production of the implants up to the first clinical trials, which are expected in 2022. ***//***

Dr. Wolfdietrich Meyer
Polymers and Electronics

Project: *Synthesis of a biomimetic pericardial polymer for cardiac applications (PolyKARD)*
FKZ: *13XP5087E*

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PHOTON NANOANTENNAS
FOR OPTOGENETICS

Dr. Christoph Gimmler
Nanoscale Energy and Structure Materials

Project: *Photon nanoantennas for optogenetic applications (joint project BioPACE)*
FKZ: *13N15035*

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Light stimulation is an attractive and less invasive alternative to the electrical stimulation of cardiovascular tissue. In the future, it could replace conventional pacemakers. The technique (optogenetics) has already been successfully demonstrated in *in vitro* and *in vivo* experiments on neuronal cells and has recently been used on cardiovascular cells. The cells are stimulated via channelrhodopsin-2, a non-selective cation channel in the cell wall which can be excited with blue light. Within a collaborative project, a team of researchers from Fraunhofer IAP has optimized and tested upconverting nanoparticles (UCNP) for this specific application which are especially suited for this application due to their unique optical properties. The work was successfully completed at the end of 2020. ***//***

Dr. Thorsten Pretsch
Shape Memory Polymers

Project: *Shape memory polymer actuators as functional components of microbioreactors for cell cultures (FormCell).*

EUROPÄISCHE UNION
Europäischer Fonds für Regionale Entwicklung

SHAPE MEMORY POLYMERS FOR MICROBIOREACTORS

Cell clusters that have the primary characteristics of human organs are greatly needed for tissue engineering as well as to evaluate active ingredients and their toxicity. The formation of functional tissue requires mechanical stabilization, which is achieved through so-called scaffolds. Cells also need to be supplied with suitable stimuli, such as growth factors at a high spatial-temporal resolution. Current reactor systems are unable to provide the complex cultivation conditions required for such cell models. The Formcell project combines the expertise of the Fraunhofer Institutes IAP and IZI-BB in the synthesis and processing of novel thermoplastic polymers, microbioreactor construction and cell cultures. The development of new shape memory polymers has facilitated innovative concepts for releasing active ingredients in microbioreactors. In the future, this could lead to more efficient testing procedures as part of drug approval processes. ***//***

Thermally induced release in a water bath of a dye-containing liquid from a tube made of a shape memory polymer.

From a 100-milliliter Schlenk line to a 10-liter stainless steel reactor.

SUPERELASTIC MULTI-GRAFT COPOLYMERS

Superelastic multi-graft copolymers have a high market potential on the medical technology market due to their outstanding mechanical properties and their ability to be used in various processing techniques. They can act as a substitute for commonly used materials. Potential uses include hoses, pump membranes and balloon catheters. Extensive advanced testing is needed due to the complex requirements of the materials. These include being heat resistant during common cleaning processes, being biocompatible and being resistant to disinfectants and sterilization. The materials investigated by the *ProMed* project are polymers produced in a multistep synthesis process using anionic solution polymerization followed by coupling with chlorosilanes. The mechanical parameters of these potential materials include a high elongation at break combined with high strength. Fraunhofer PAZ has been testing, developing and simplifying the synthesis pathway - also with regard to the reproducibility of the process steps and cost. Successful trials were carried out in a 10-liter steel reactor using the knowledge gained at a small scale of about 10 to 100 grams. In addition to the ideal molecular structure, other requirements need to be kept in mind, such as improved processability during injection molding or extrusion, and the bonding ability of the material in the area of application. **//**

Dr. Hendrik Budde
Synthesis and Product Development

Project: *Superelastic multi-graft copolymers for medical device applications (ProMed).*

Project partner: *Joint project involving Fraunhofer IWMS and a medium-sized medical technology company*

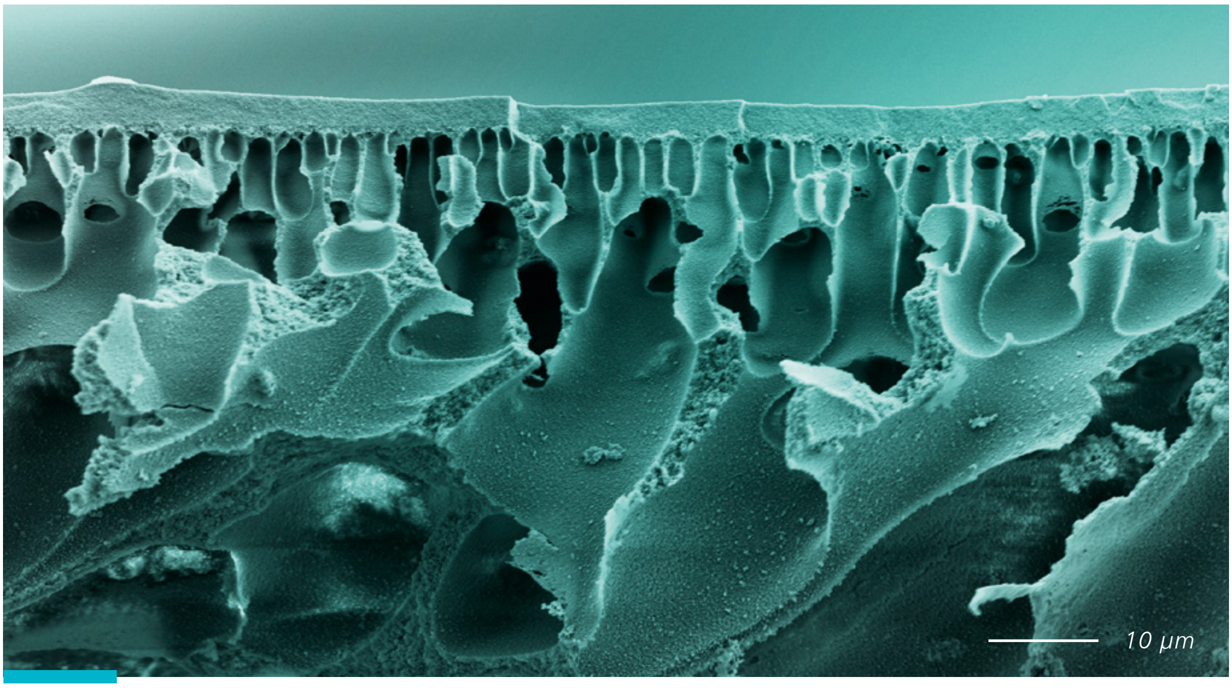
EUROPÄISCHE UNION
Europäischer Fonds für Regionale Entwicklung

POLYMER MEMBRANES FACILITATE OXYGEN EXCHANGE IN THE BODY

Dr.-Ing. Murat Tutuş
Membranes and Functional Films

Partner: *CCORE Technology*

A novel membrane structure has been developed by a team of researchers at Fraunhofer IAP. It enables a faster exchange of gas in critically ill lung patients who are on ventilation, thereby making blood oxygenation gentler on the patient. During extracorporeal membrane oxygenation (ECMO), an alternative to traditional mechanical ventilation, blood is drawn from the body via a cannula, oxygenated outside the body using a membrane oxygenator, depleted of carbon dioxide and re-injected into the bloodstream via a second cannula. Fraunhofer IAP has been commissioned by the Austrian company CCORE Technology to develop a membrane morphology that will intensify respiratory support. Commercial membranes have a symmetrical structure and are designed for a slow exchange of oxygen. The research team is therefore developing asymmetric structures whose properties enable gas to be exchanged at a much faster rate than conventional membranes. The unique selling point of the research team is to adapt specific membrane structures produced from different polymers. ***//***



Membrane morphology with an adapted structure and very efficient material transport. The open caverns enable convective transport up to the boundary layer.

RESEARCH TOPICS 2020

INDUSTRY AND TECHNOLOGY

DIELECTRIC ELASTOMER
ACTUATORS (DEA)

Dr. Michael Wegener
Sensors and Actuators

Dielectric elastomer actuators (DEA) are electromechanical transducers whose actuator deflection can be controlled by applying an electric field. Large deflections, silent actuator movements and energy efficiency make these DEA attractive for a wide range of applications, e.g. in automation technology or soft robotics. DEA are also used in linear actuators or in loudspeakers in the field of communication technology.

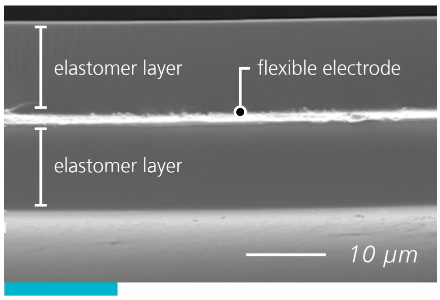
Current application-oriented development goals include the creation of specific actuator shapes from laminates, stack actuators, media-resistant encapsulation for direct use in fluids, and the optimization of actuator properties by adapting elastomers and electrodes while simultaneously reducing layer thicknesses.

The research work is being carried out at Fraunhofer IAP as part of several joint projects within the *Smart3* project consortium. Focus is on the optimization of the material properties of elastomers, processing them as thin layers or films, the development and processing of thin flexible electrodes, the processing of laminates and actuators, and their complete electrical, mechanical and electromechanical characterization.

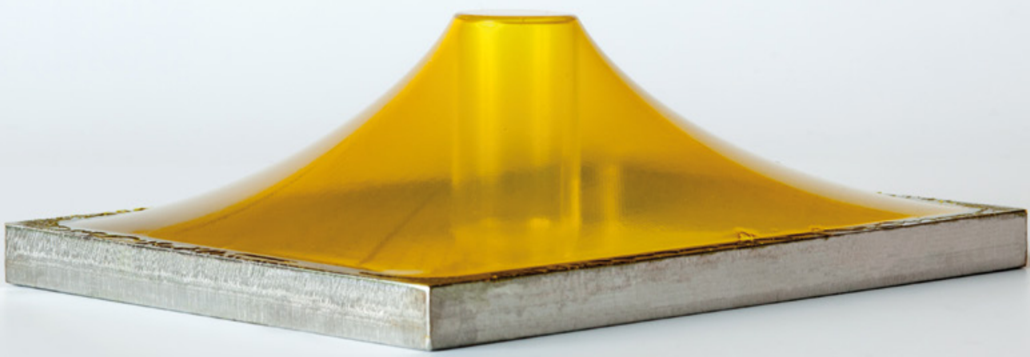
This research and development is expanded by contributions towards the digitization of materials and converters with the aim of facilitating in the future a more targeted and faster transfer of research into applications through the use of data and parameters on elastomers, electrodes and actuators. This work is being funded as part of the *SmaDi* joint research project in the BMBF's *MaterialDigital* initiative. ***//***

*The research work is being carried out within several collaborative projects as part of the **Smart3** project consortium in the Unternehmen Region – **Zwanzig20** program of the German Federal Ministry of Education and Research*

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung



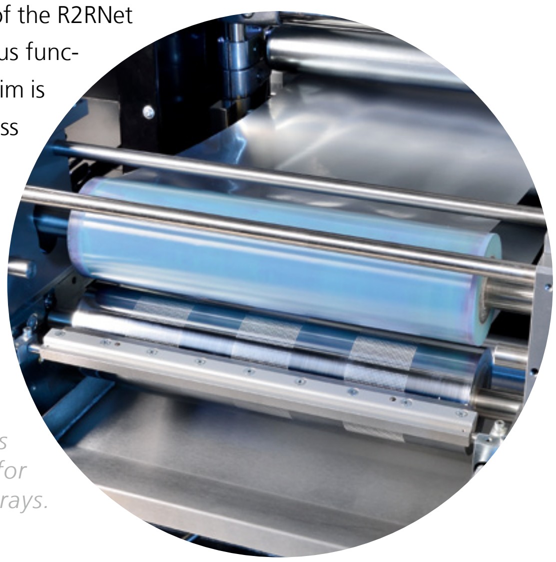
Composite layer of two thin dielectric elastomer layers, optimized for use in a DEA with a flexible electrode sandwiched in between.



ESTABLISHMENT OF AN R2RNET NETWORK

Dr. Andreas Holländer
Functional Materials and Devices

Roll-to-roll (R2R) processes play an important role in many industrial processes. They can be used to functionalize films, textiles, flat membranes, metal foils or even ultra-thin glass. Twenty-one European partners from industry, research organizations and universities came together on June 10, 2020 to discuss the establishment of the R2RNet network as a way to pool their expertise in the continuous functionalization of surfaces using roll-to-roll processes. The aim is to promote the exchange of experience and facilitate access to the required technologies and equipment. The network was initiated by the Fraunhofer Institutes for Applied Polymer Research IAP and for Interfacial Engineering and Biotechnology IGB. **//**



Structured surface functionalization of films using R2R technology, e.g. for the production of microarrays.

NEW POLYMER LUBRICANTS

Dr. Dmitry Grigoriev
Multifunctional Colloids and Coatings

Project: *Water-based multifunctional polymer lubricants for highly efficient and environmentally friendly metal forming*
FKZ: *02P19K130*

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

The cold forming of metals is an extensive process due to the intensive pre-treatment and post-treatment that it requires. Current lubricants often do not meet the needs of the end processors, e.g. due to adhesive residues. As part of the KMU-innovativ project *Polyschmierung*, a new class of polymer lubricants is being developed for the cold forming of wires and tubes and for cold bulk metal forming. The lubricants are to be made of environmentally friendly, water-soluble polymers. Even though the lubricant layers on the metal will be thinner, they need to efficiently reduce friction-related energy dissipation and thus significantly minimize the wear and tear on tools. First, polymers made from highly pure precursors are synthesized on a laboratory scale and their properties are analyzed. The aim is to gradually increase polymer production to a pilot plant scale using technical precursors. The lubricants produced from this will then be used in more extensive coating and forming trials on a technical scale in collaboration with industry partners. **//**

Dr. Marlen Malke
Synthesis and Product Development

Project: *Piloting of an innovative subwavelength nanostructure technology for optical and injection molding applications*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 760915

SUB-WAVELENGTH NANOSTRUCTURE TECHNOLOGY

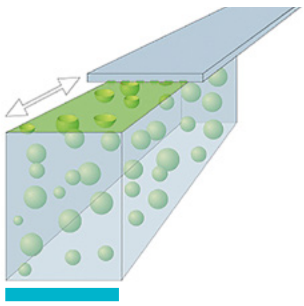
The goal of the EU project *SUN-PILOT* is to develop a novel and cost-effective platform for up-scaling the fabrication of sub-wavelength nanostructures that can be applied to large and non-planar surfaces. Using state-of-the-art block copolymer chemistry and highly scalable etching and injection molding methods, a cost-effective method is to be developed for creating nanopatterned surfaces that can be used in the optical and automotive industries. Patterned surfaces at the sub-wavelength level represent an alternative way of achieving anti-reflection that has superior performance characteristics and a longer service life (e.g., solar panels and smartphone and laptop displays). In addition to providing the anti-reflection that gives vehicle interiors a high-quality appearance, their haptic qualities will also be improved. **//**

SELF-LUBRICATING COMPOSITES

Self-lubricating composites have been developed by the SKZ Plastics Center in collaboration with Fraunhofer IAP. Friction reduction, protection against wear and tear, and reduced energy consumption were essential aspects for extending the service life of tribologically stressed plastic components. Most of the currently available friction-reducing additives are dry lubricants. The investigations therefore aimed at enabling the use of liquid or paste-like lubricants, which offer a wider range of material options and thus can be better adapted to the respective plastic matrix. In microencapsulated form, such lubricants can be easily integrated into the polymer matrix by extrusion. When subjected to mechanical stress, the capsules break open and release the lubricant as required, minimizing friction at the stress point.. **//**

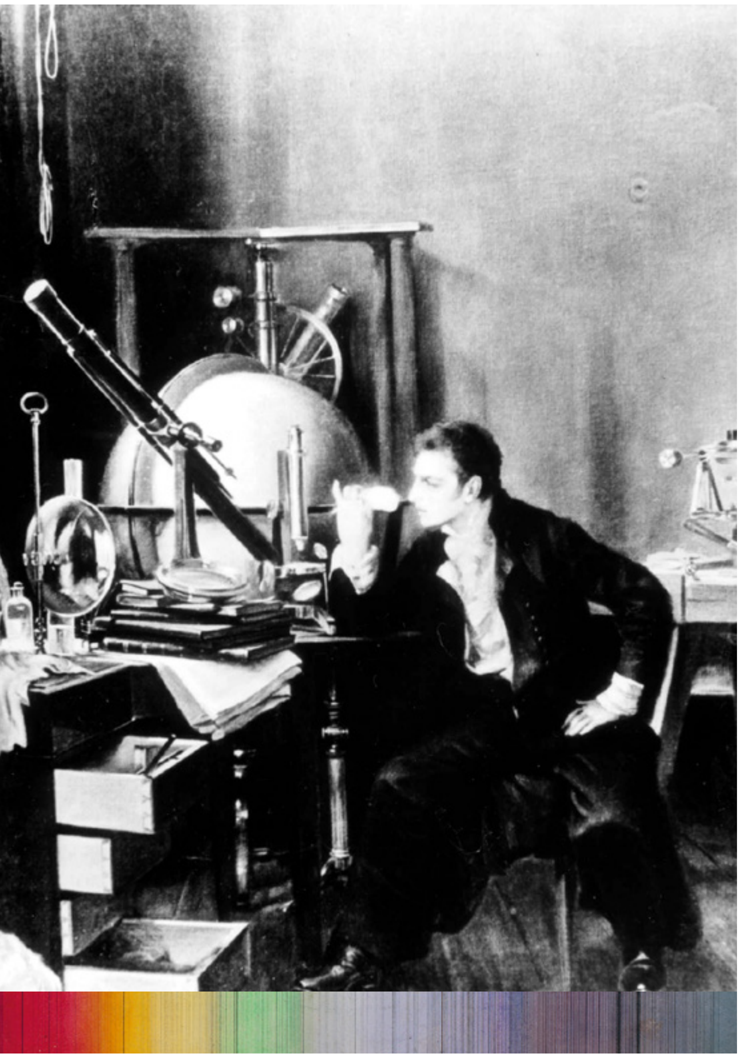
Dr. Alexandra Latnikova
Microencapsulation and Polysaccharide Chemistry

Partner: *SKZ – Das Kunststoff-Zentrum*



When subjected to mechanical stress, the microcapsules filled with the liquid lubricant break open and release the lubricant as required.

THE FRAUNHOFER-GESELLSCHAFT



Joseph von Fraunhofer

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 com-mitment 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 75 institutes and research institutions. The majority of our 29,000 staff are qualified scientists and engineers who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros are generated through

The headquarters of the Fraunhofer-Gesellschaft in Munich.

https://www.fraunhofer.de/en.html

contract research. Around two thirds of Fraunhofer's contract research revenue is derived from contracts with industry and publicly funded research projects. The remaining third 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 that 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. ***//***

Last updated: January 2021

BOARD OF TRUSTEES 2020

The board of trustees advises and supports the Fraunhofer-Gesellschaft as well as the institute´s directory. The following persons were members of the board of trustees of Fraunhofer IAP in 2020.

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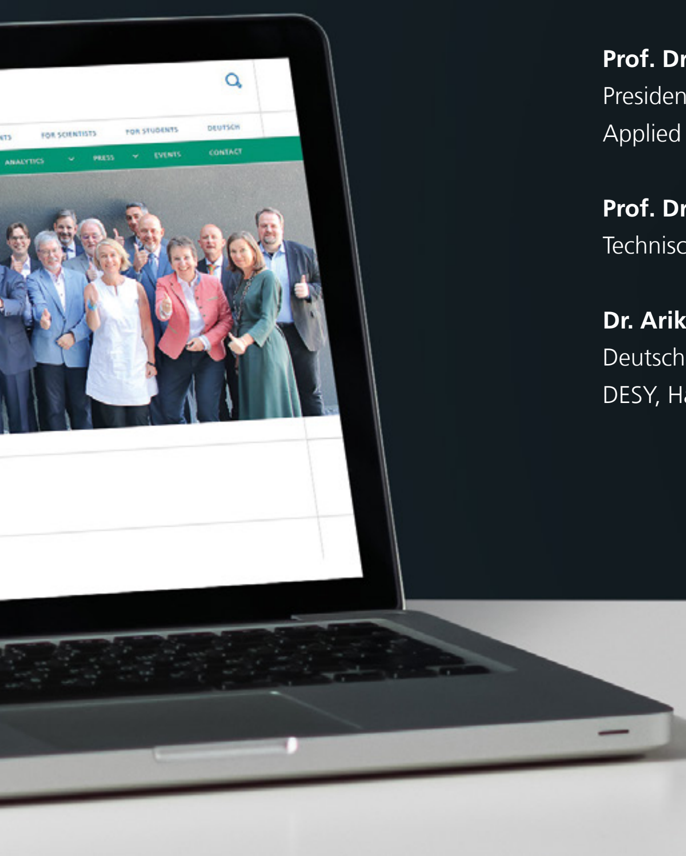


FRAUNHOFER GROUP FOR MATERIALS AND COMPONENTS – MATERIALS

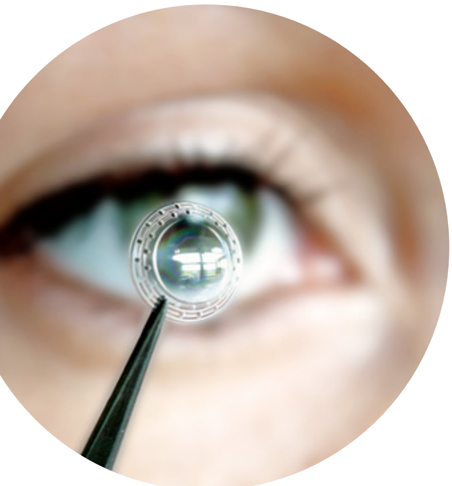
Fraunhofer IAP is a member of the Fraunhofer Group for Materials and Components – MATERIALS. This group combines the competencies of the Fraunhofer-Gesellschaft's materials science institutes and is active across the entire value chain – from the development of new and the improvement of existing materials, to suitable manufacturing processes on a quasi-industrial scale, the characterization of properties, and the evaluation of in-service behavior. This same applies to the components and products made from the materials and their behavior in the respective systems.

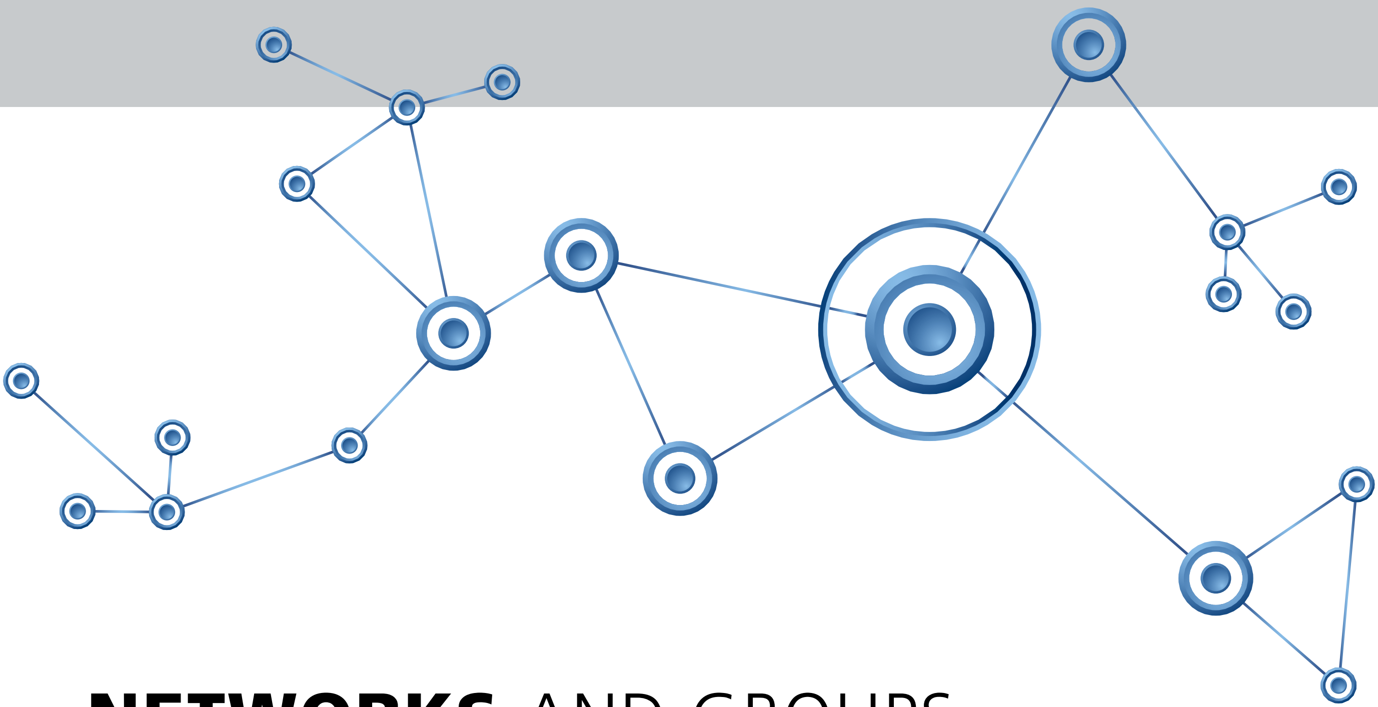
Numerical simulation and modeling techniques are equally utilized alongside experimental investigations in laboratories, technology centers and pilot plants at all scales - from the molecule through to the component, complex system, and process simulation. In terms of materials, the Fraunhofer MATERIALS Group covers the full spectrum of metals, inorganic non-metals, polymers, materials made from renewable raw materials, and semiconductor materials. Hybrid materials and composites have risen in importance in recent years.

The scientists working in the Group's institutes apply their know-how and expertise on behalf of customers in the areas of mobility, health, machine and plant engineering, construction and housing, microsystems technology, safety, and energy and the environment. They are well-connected at a national and international level and contribute to a wide range of material-related innovations and innovation processes. **//**

Key figures:
– largest group within the Fraunhofer-Gesellschaft
– 18 member institutes
– 6 guest institutes
– more than 5,000 staff members
– approx. 2,639 researchers
– a budget in excess of 500 million euros

More information
https://www.materials.fraunhofer.de/en.html





NETWORKS AND GROUPS

Networking and knowledge exchange are important elements of successful research. Fraunhofer IAP cooperates with Fraunhofer Institutes from different fields as part of Fraunhofer groups and networks. Our scientists also sit on many reputable committees and are involved in various associations and networks.

Fraunhofer POLO® combines the expertise of five Fraunhofer Institutes in developing innovative concepts, technologies and materials for the functionalization of polymer surfaces.

Fraunhofer IAP focuses on nanomaterials as part of its research activities within the **Fraunhofer Nanotechnology FNT** group. Here, a total of 15 Fraunhofer institutes work together.

Fraunhofer Institutes have joined forces as part of the **Research Area Technical Textiles**. By bundling their individual competencies, they are able to cover the entire textile value chain.

Fraunhofer IAP is also an active member of the **Fraunhofer Electrochemistry Network**, one of 18 institutes in the **Fraunhofer Sustainability Network**, and a member of the **Cultural Heritage Research Alliance**, an alliance of the Fraunhofer-Gesellschaft, the Leibniz Association, and the Prussian Cultural Heritage Foundation. ***//***

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https://www.textil.fraunhofer.de/en.html
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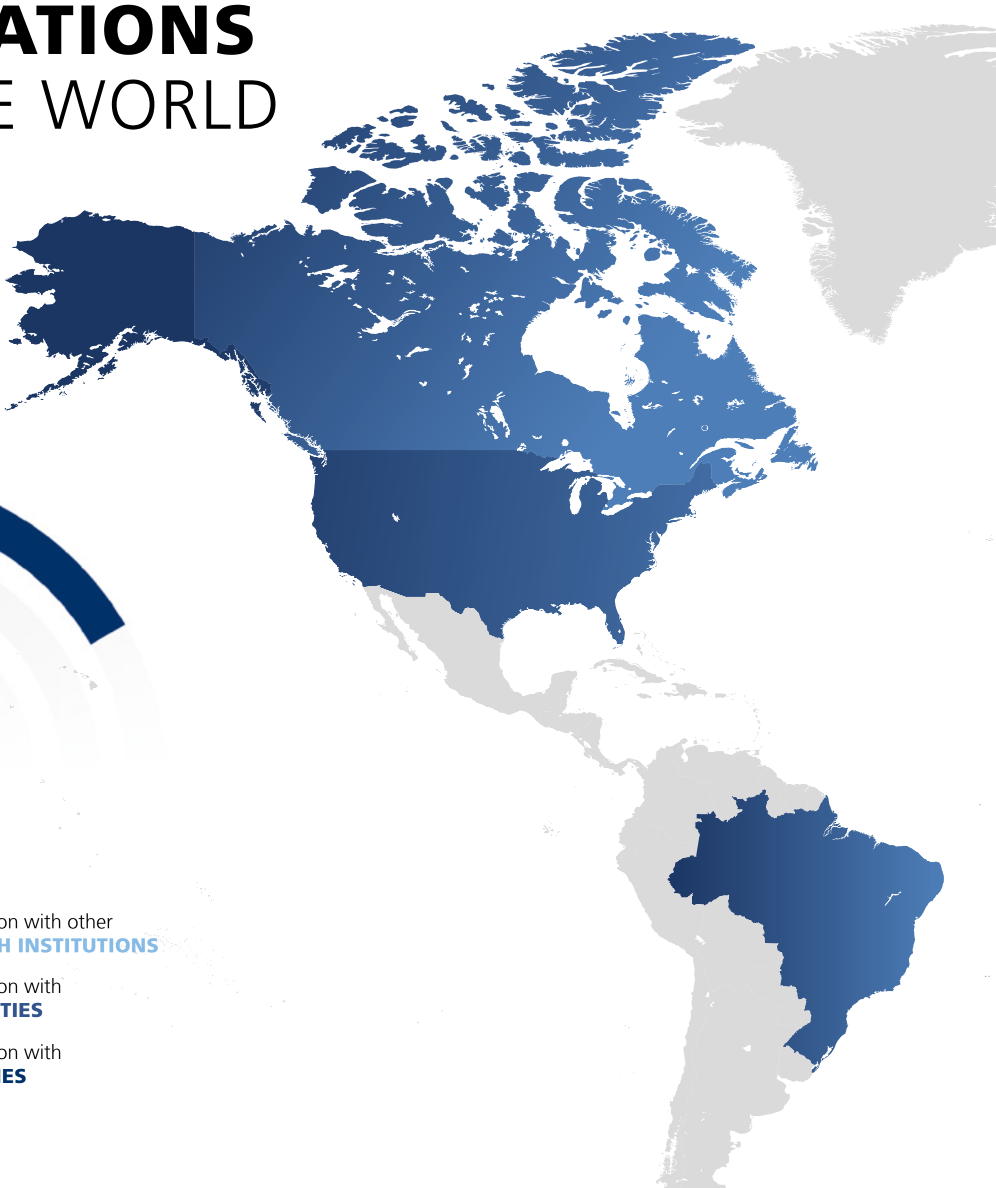
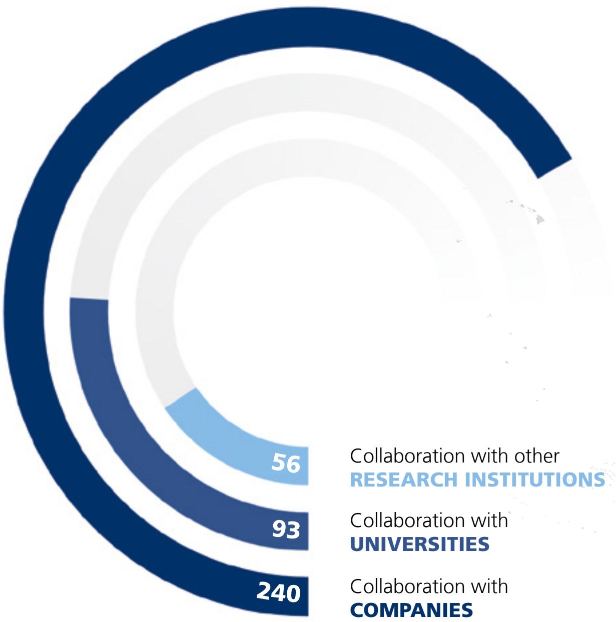
COLLABORATIONS
AROUND THE WORLD



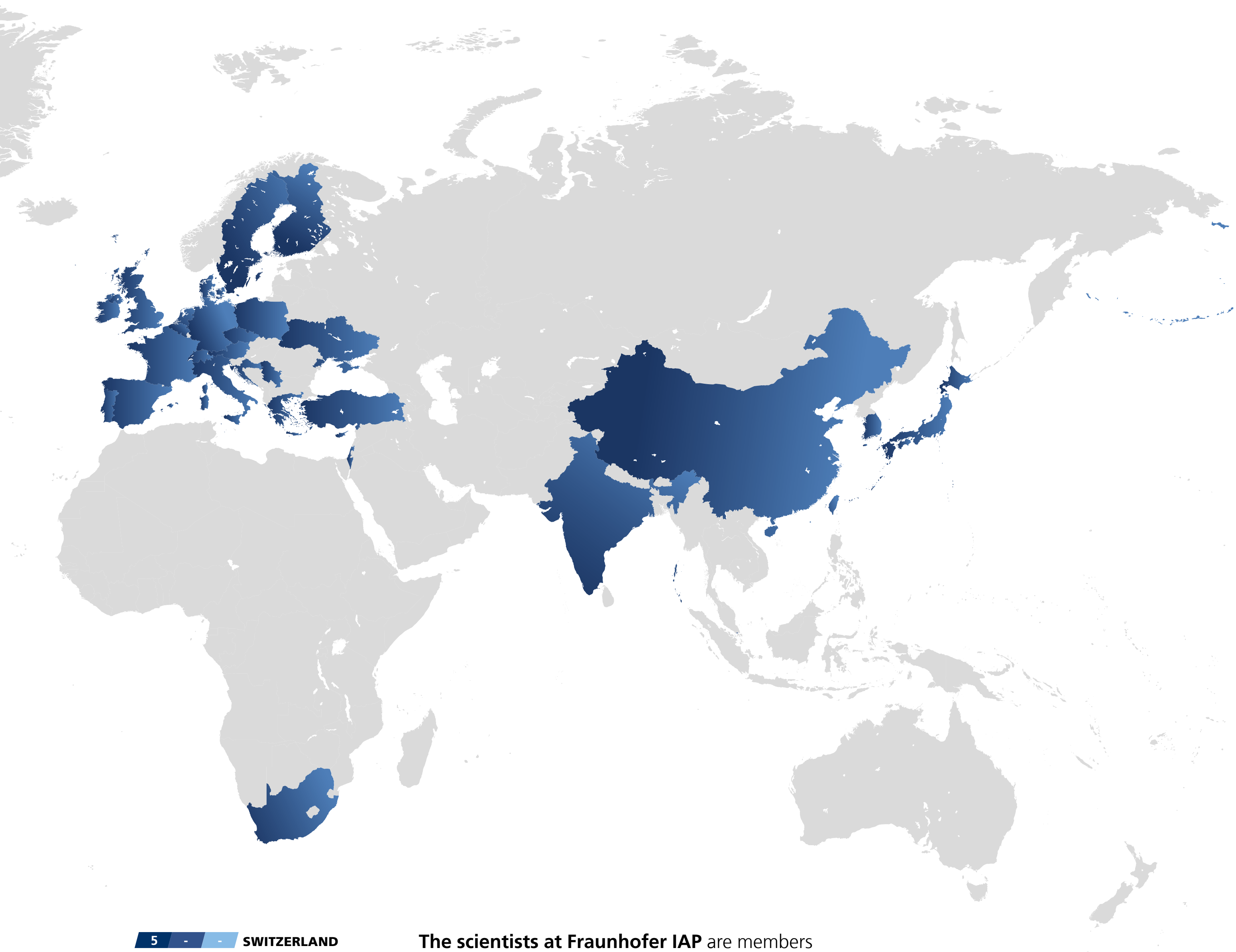


Collaboration with other **RESEARCH INSTITUTIONS**

Collaboration with **UNIVERSITIES**

Collaboration with **COMPANIES**

6	3	3	AUSTRIA
2	-	3	BELGIUM
1	2	1	BRAZIL
2	1	-	CANADA
2	2	1	CHINA
-	-	1	CROATIA
-	1	-	CYPRUS
-	1	-	CZECH REPUBLIC
-	2	-	DENMARK
-	2	1	FINLAND
1	2	1	FRANCE
182	51	37	GERMANY
1	1	-	GREECE
2	5	3	GREAT BRITAIN
1	-	-	INDIA
-	2	-	IRELAND
3	2	1	ISRAEL
3	-	1	ITALY
1	-	-	JAPAN
4	2	-	NETHERLANDS
6	4	2	POLAND
1	-	-	PORTUGAL
-	2	1	REPUBLIK KOREA
-	2	-	SERBIA
1	-	-	SINGAPORE
1	-	-	SOUTH AFRICA
1	1	1	SPAIN
3	-	1	SWEDEN



5	-	-	**SWITZERLAND**
-	1	-	**TAIWAN**
1	-	-	**TURKEY**
-	-	1	**UKRAINE**
6	5	2	**USA**

The scientists at Fraunhofer IAP are members of international networks and cooperate with research institutes, universities and companies in Germany, Europe and around the world. Many research topics are also tackled jointly within the Fraunhofer-Gesellschaft. ***//***

FRAUNHOFER IAP
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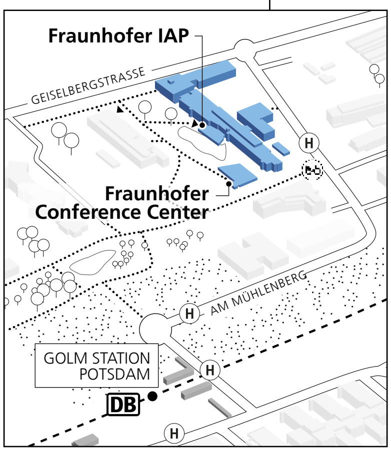

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EDITORIAL
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Portrait photos on the pages 10, 11, 27 – 47

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