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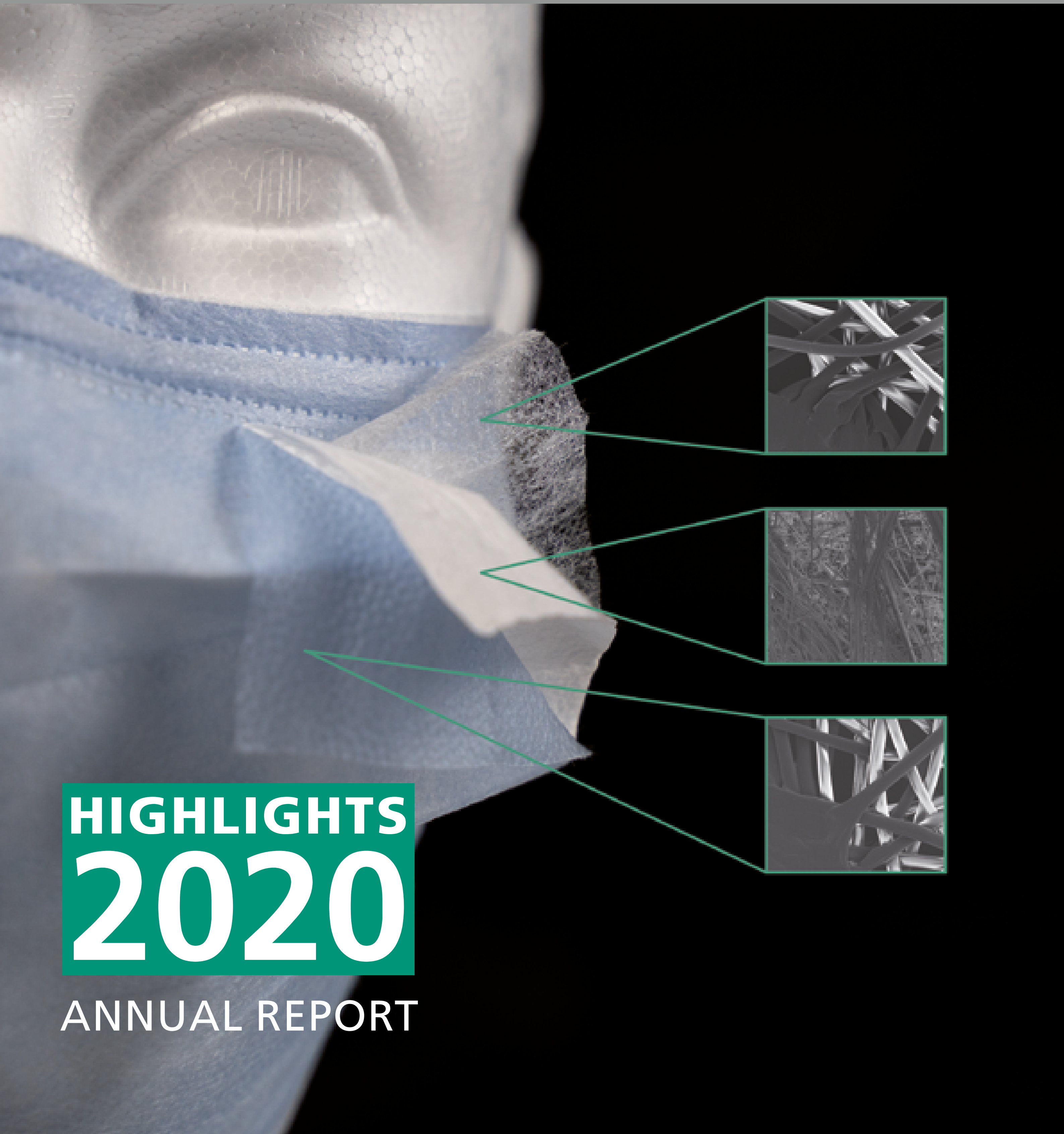
FRAUNHOFER INSTITUTE FOR
MICROSTRUCTURE OF MATERIALS AND SYSTEMS IMWS



HIGHLIGHTS 2020

ANNUAL REPORT

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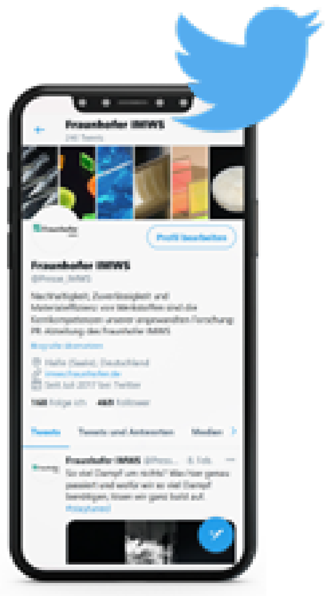

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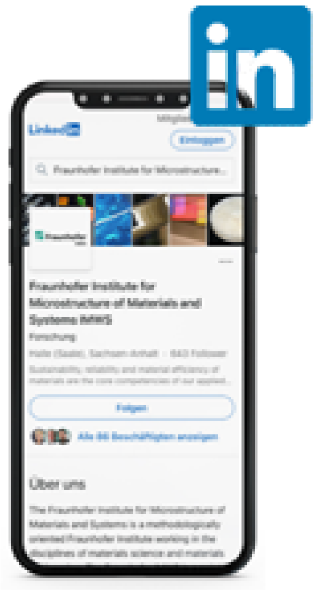

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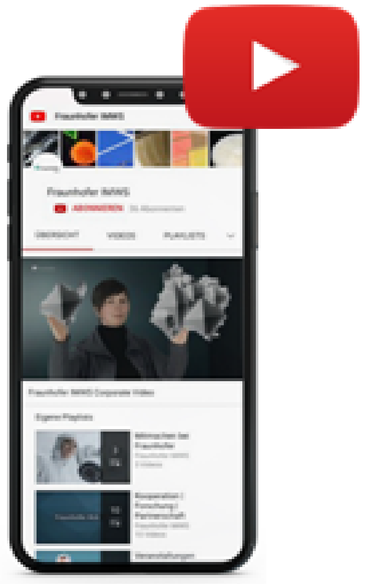

On Youtube you will find exciting videos about our work. It's worth watching!

DEAR READERS,

When we look back on 2020 one day in the more distant future — hopefully in the best of health — the coronavirus pandemic with its effects on the economy, society and our daily lives is sure to be the event that stands out from all others. It has altered our lives to an extent that hardly any of us could have imagined — including Fraunhofer IMWS. In the following pages, in addition to the technical results of our work, you will find a number of examples of the ways in which we reacted to the situation — from how we expanded the digitalization of our working environment and created new possibilities for collaborating with our customers, to the very direct contribution that we made to the pandemic response through our research in the health sector.

However, the pandemic situation cannot be allowed to divert our attention from the turbulent changes that the phaseout of coal is causing in important markets, such as the automotive, energy, health and chemical sectors. The pandemic also put the spotlight on questions relating to the resilience of companies and sectors, as well as their dependence on global supply chains. All this led to new challenges in terms of research needs, and thus also for our work. The most important thing is that even under the more difficult conditions of 2020, we succeeded in developing innovative solutions for our clients using our core competence in microstructure analysis and design. As a result, we as an institute can look back on an economically successful year with a positive financial result. To verify this performance, we only need to look to the innovator of the year award that we received from the business magazine Capital and the market research service provider Statista.

Another important step taken in 2020 was the establishment of industry advisory boards in our business units. This makes it possible for us to align our pre-competitive research with the challenges facing the industry in a future-proof, targeted way, through reciprocal discussions with the advisory boards. During this process, it became clear that questions relating to sustainability are also generally coming to the fore in industry. We are well-positioned here, thanks to our work on such areas as the future of transportation (through our research on lightweight design and electronics), recycling plastics, green hydrogen, renewable energy production and increasing the service life of high performance materials. Through our research, we aim to contribute to the recovery and reorientation of the economy in the post-crisis phase, as well as to the strengthening of our partners.

At an organizational level, this commitment is illustrated by such examples as the expansion of our research units focusing on the topic of chemical conversion processes in Leuna, Freiberg and Halle (Saale). We have also made progress in the appointment of a new head of the institute, a role that I have occupied in an acting capacity since October 1, 2019. Based on the progress made to date in the appointment procedure conducted jointly with the Martin Luther University Halle-Wittenberg, I have high hopes we will find a good candidate who will continue the successful development of the institute.

I would like to sincerely thank all our customers, funding agencies and scientific partner institutions, particularly those within the Fraunhofer-Gesellschaft, as well as all our employees, who have all played their part even under difficult overall conditions, whether it is through trust in our expertise, additional funding programs, or good ideas and firm commitment. In 2020, we were reminded of the importance of shaping the future, rather than waiting for it happen. I am looking forward to continuing to collaborate with you all on this task with creativity and confidence

Prof. Dr. Matthias Petzold

CONTENTS

COMBINED EFFORT TO COMBAT THE PANDEMIC – FROM KITCHEN TO LAB

Pulling together to combat the pandemic: The St. Elisabeth and St. Barbara hospital and Fraunhofer IMWS have joined forces. Against a background of spiraling COVID-19 infections in the city of Halle (Saale), the cooperation that took place between doctors and materials scientists produced spontaneous solutions for addressing the pandemic in the local region while also providing a number of interesting starting points for promising advances in the area of protective masks and gowns, for example. In this interview, Dr. Sven Seeger, head of the hospital's department of obstetrics, and Dr. Andreas Kiesow, head of the "Characterization of medical and cosmetic care products" group at Fraunhofer IMWS, discuss their cooperation.

Dr. Andreas Kiesow works at Fraunhofer IMWS as head of the "Characterization of medical and cosmetic care products" group and is deputy head of the "Biological and macromolecular materials" business unit.

How did the cooperation come about?

Dr. Sven Seeger:

In March 2020, as the catastrophic reports came in from Italy and the epidemic was upgraded to a pandemic, I was deeply concerned about the situation. Especially in relation to what we here in Germany and in the hospital might be facing. The main focus was on protecting staff and patients from infection. I am talking about face masks, breathing tubes and disposable gowns. I asked myself whether, if necessary, it would be possible to reuse these disposable items multiple times if they were thermally treated using steam sterilizers (a heat and steam procedure) or chemically treated using disinfectant products. As an obstetrician, I am a hands-on doctor, so one day at home, I tested what happens when you place an FFP2 mask into boiling water and then treat it with an anti-viral disinfectant. I was interested in the changes that occurred in the material's properties. As I often drive past Fraunhofer IMWS, I had the idea of having my solution investigated from a materials science perspective using Fraunhofer expertise. The very next day, we had a meeting at the institute, wearing face masks and observing the required social distancing recommendation.

Dr. Andreas Kiesow:

If I remember correctly, the institute was largely empty the day of that meeting with Mr. Seeger. Like Mr. Seeger, I also shared the same sense of urgency, a feeling that we had to do something. There was a lot of uncertainty about the situation, but for both of us, it was clear there was still a lot we could do. Given the complexity involved, Mr. Seeger had brought along a number of samples. We in the institute considered if and how the materials could be investigated.

Dr. Sven Seeger:

At that stage, the selected samples were already in scarce supply at the hospital in some cases. I had spoken with the hospital's medical director and the crisis management committee about what disposable equipment was likely to run out in, in the following days or weeks. FFP2 masks, standard surgical masks and disposable gowns was their answer. Breathing tubes for ventilators were especially critical, as it looked like we were facing the crazy situation of having ventilators, but not being able to use them because we didn't have any disposable breathing tubes. So when I went to meet Mr. Kiesow in the institute, I had about five or six samples.

Dr. Sven Seeger is head of the obstetrician department of St. Elisabeth and St. Barbara hospital in Halle (Saale).

What were the key findings?

Dr. Sven Seeger:

I am not an infectious disease expert, nor am I a microbiologist, but I did try to outline a basic test procedure. With the aim of enabling the repeated use of disposable products, I drew up a list of questions, materials examined and possible sterilization methods. The test report was divided into two sections with two points of contact. Contact A was Fraunhofer IMWS, who worked on the material properties — that is the institute's specific area of expertise, after all. The microbiology side of things was covered in section B. Here, the investigation focused on establishing whether we could pre-contaminate the samples with germs in a controlled way. We succeeded in bringing Dresden-based microbiologist Prof. Lutz Jatzwauk on board for this project, and he conducted tests to determine whether there was any reduction in the samples' microbiological load once our thermal and chemical procedures had been applied.

Dr. Andreas Kiesow:

We wanted to get a feel for how we would be able to respond in an emergency situation. It was never about carrying out an advanced scientific study backed by statistics. Our study was more exploratory in nature. It was important for all involved — and we made this very clear ourselves — to be aware of the limits of our expertise. Under scientific lab conditions, we recreated the tests that Mr. Seeger had observed himself in his home. With each method, we treated the samples up to five times. Almost all materials withstood the procedures from a macroscopic viewpoint. They were then examined under microscope. Neither the FFP2 masks nor the basic surgical masks showed any major signs of change. Some of the materials were unable to withstand the thermal procedures. The thermoplastic material used in the breathing tube had been deformed by the heat. Material degradation also occurred in the rubber-lined protective gowns. With the FFP2 masks, we were able to establish that there were minor changes in terms of aerosol permeability; however, these were still within a very acceptable range. We believe that, in the event of a more serious emergency situation, we would have felt better about telling the staff that if they sterilized their masks, they could wear them a second, third or fourth time. In any case, it would be better than not having any protection at all. Naturally, because of the limited sample size and the exploratory nature of the study, it would be important to investigate further from a scientific perspective. Normally, you would need 5 to 8 samples of each disposable item in order to produce reliable statistics at the end. Because of the high level of demand and the supply bottleneck for masks, this is not something we were able to do.

Dr. Andreas Kiesow

Studies of microsystems engineering,
Fraunhofer IMWS employee since 1999,
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and cosmetic care products" group since 2009

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ADVISORY BOARD

RECOGNIZING INDUSTRY NEEDS EARLIER AND SERVING THEM EVEN MORE EFFECTIVELY

What are the needs of our clients? What are the trends shaping the industry? What issues should our in-house research focus on to put us in the best position possible for meeting our customers' future requirements? These are the questions at the crux of our ongoing strategy process at Fraunhofer IMWS, which I supervise in my capacity as consultant to the institute management team.

I can personally look back on more than 30 years of experience in the field of research and development with Schott AG in Mainz, where among other roles, I was the head of the central research division. This experience allowed me to develop diverse contacts in industry and academia, and demonstrated time and again how closely the content of my work was related to many of the topics researched at Fraunhofer IMWS.

I have worked with the institute since 2004 as a member of the advisory board, and served as chair of this board from 2016 to 2019. My role afforded me the opportunity to support the institute strategically and to watch it grow over the course of many years. Assessing market and technology trends was already an important aspect of my work at that time. Today, this activity plays a vital role in the strategy update process for the individual business units. We have established our industry advisory boards to support us in these assessments. Tailor-made to suit the topics and markets covered by each business unit, the boards give core clients and other experts the opportunity to advise on strategic courses of development, in areas including the refinement of portfolios and investment in equipment.

The emphasis here lies on the Fraunhofer mission, which has proven to be a unique model for success worldwide: providing R&D services to industry. We wish to bolster this core business activity and, by involving important stakeholders in the industry advisory boards, ensure that the institute's expertise and creativity is even more closely aligned with current and, above all, future demands in the research market. Our experiences so far have shown how valuable this close contact is on both sides, and accordingly, I would like to take this opportunity to thank the established industry advisory boards for their work and to extend this invitation to collaborate to any other institute partners who may be interested.

Digitization in all its forms constitutes an important element of strategic development, and I also act as a consultant to Fraunhofer IMWS in this area. This extends to the internal processes of the institute, which we continually review, asking ourselves: Are we where we want to be? Are we heading towards our targets? Digital tools also help us with another future-oriented topic that I have devoted myself to in my work: new solutions for evaluating technology.

All these measures are aimed at making our services even more attractive to industry and making collaboration with Fraunhofer IMWS as efficient and flexible as possible for our partners; in this way, we can work together to turn our good ideas into genuine value creation, in order to increase our customers' competitiveness and benefit society as a whole.

Dr. Roland Langfeld
Doctorate at the Institute for Nuclear Physics at Goethe University Frankfurt in 1985, joined central research division of Schott AG in 1988, served as chair of the advisory board at Fraunhofer IMWS from 2016–2019, consultant to institute management team since 2020
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Tasks of the advisory board

The advisory board of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS includes personalities from politics, business and science who are close to the institute in terms of their technical area of interest. The advisory board meets once a year.

Together with the Fraunhofer Board, the members of the advisory board advise the institute with their expertise in strategic issues, setting the course at the institute and developing future perspectives. They are appointed by the Fraunhofer Board in consultation with the institute's management and work on a voluntary basis.

Members

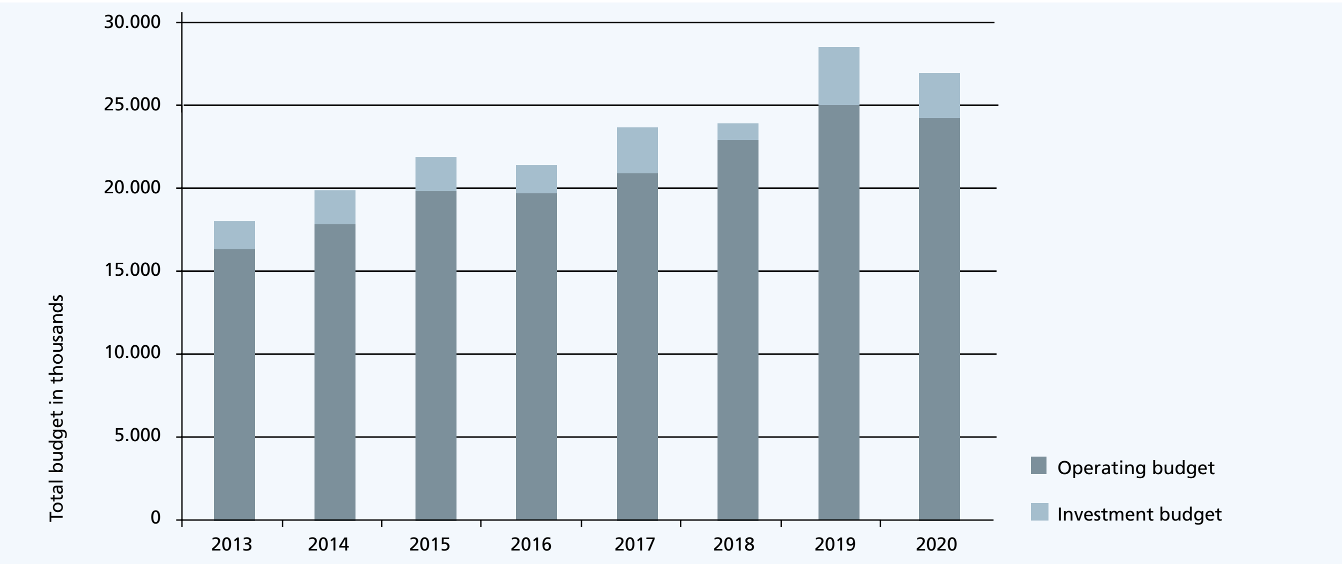
- Prof. Dr. Jörg Bagdahn, Anhalt University of Applied Sciences
- Dr. Steffen Bornemann, Folienwerk Wolfen GmbH
- Dr. Torsten Brammer, Wavelabs Solar Metrology Systems GmbH
- Thomas Gerke, Ministry of Economy, Science and Digitalization of the State of Saxony-Anhalt
- Uwe Girgsdies, Audi AG (deputy chair of the advisory board)
- Prof. Dr. Frank Gonser, Sanofi-Aventis Deutschland GmbH
- Dr. Andreas Grassmann, Infineon Technologies AG
- Prof. Dr. Peter Gumbsch, Fraunhofer Institute for Mechanics of Materials IWM
- Dr. Sandra Hofmann, Trinseo Deutschland GmbH
- Dr. Florian Holzapfel, Pedanios GmbH
- Prof. Dr. Ingrid Mertig, Institute of Physics, Martin Luther University Halle-Wittenberg
- Dr. Christoph Mühlhaus, chemistry plastics cluster Central Germany
- Matthias Müller, Schott AG
- Prof. Dr. Stuart S. P. Parkin, Max Planck Institute of Microstructure Physics
- Engineer Tino Petsch, 3D-Micromac AG
- Dr. Wolfgang Pohlmann, Hella GmbH & Co. KGaA.
- Jef Poortmans, imec vzw
- Dr. Thomas Rhönisch, Rehau AG + Co.
- Dr. Carsten Schellenberg, Lanxess – IAB Ionenaustauscher GmbH
- Dr. Frank Stietz, Heraeus Deutschland GmbH & Co. KG (Chair of the advisory board)
- Hans-Jürgen Straub, X-FAB Semiconductor Foundries AG
- Marco Tullner, Minister of Education of the State of Saxony-Anhalt
- Dr. Jürgen Ude, State Secretary in the Ministry of Economy, Science and Digitalization of the State of Saxony-Anhalt
- Dr. Bert Wölfli, Polifilm Extrusion GmbH

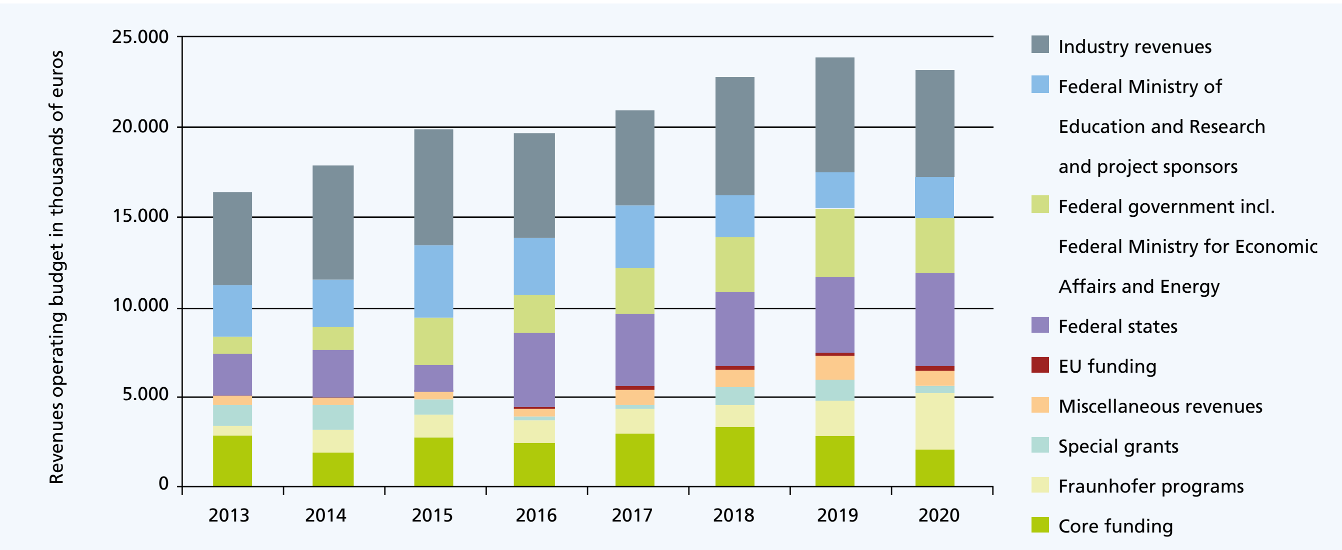
THE INSTITUTE IN FIGURES

Budget

The budget of the Fraunhofer IMWS is composed of an operating budget and an investment budget. The operating budget of the Fraunhofer IMWS amounted to 23.3 million euros in 2020. The operating budget includes all personnel and material expenses.

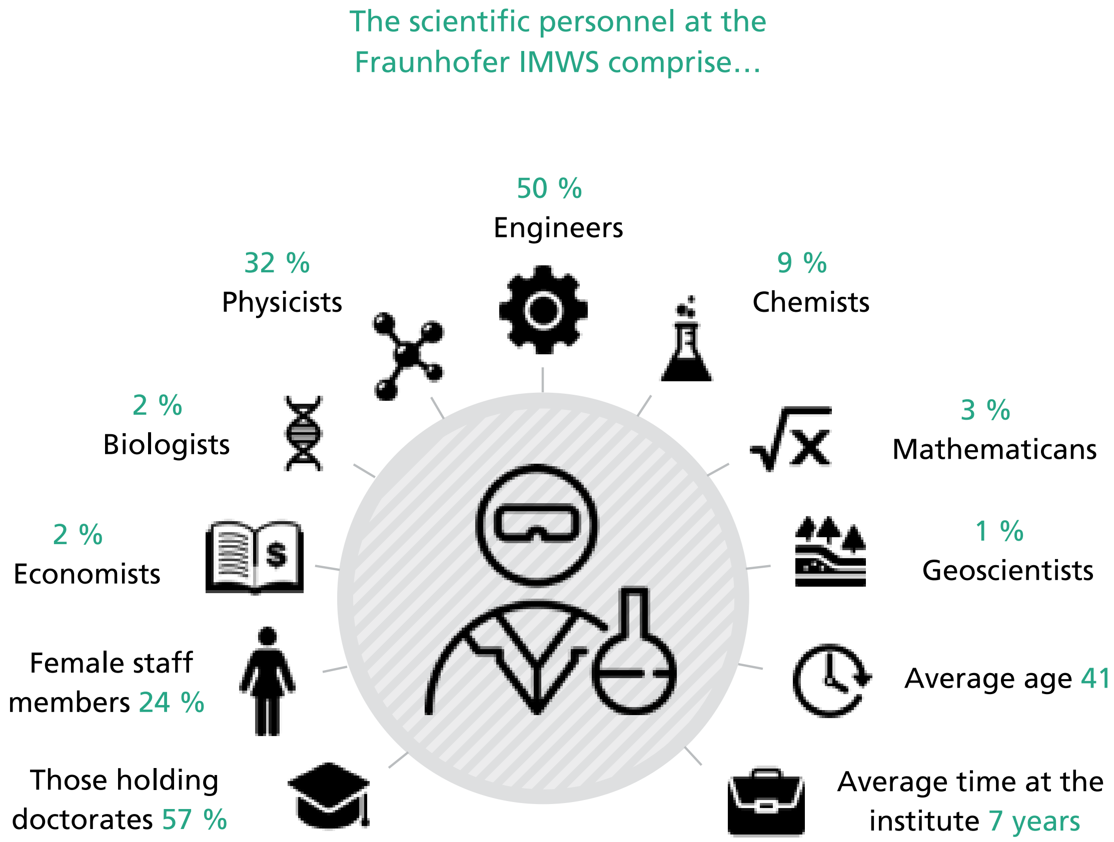
It is financed by external revenues from industry and the public sector and by institutional funding (base funding). The share of industry revenues in the 2020 operating budget is 26 percent. The 2020 investment budget amounts to 2.7 million euros.





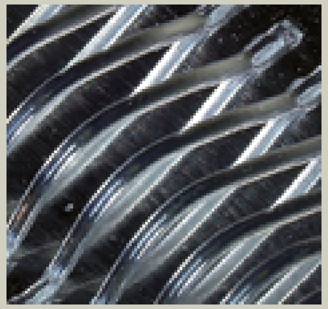
Personnel development

At the end of 2020, the Fraunhofer IMWS will have a total of 251 employees as permanent staff. This includes 110 scientists. Including trainees, scientific assistants, and interns, the institute's workforce comprises 333 people.



A SELECTION OF RESEARCH SUCCESS STORIES

BUSINESS UNIT ELECTRONIC MATERIALS AND COMPONENTS Head of business unit Frank Altmann +49 345 5589-139	
Assessment of electronic system integration Sandy Klengel +49 345 5589-125	Diagnostics of semiconductor technologies Frank Altmann +49 345 5589-139



12 | Heavy-wire bond technology is increasingly used to connect power semiconductors. Fraunhofer IMWS has produced new findings in relation to shear tests, which are used to determine the stability of bond contacts.

14 | How long is the service life of the inverters used for photovoltaics and battery storage applications? Fraunhofer IMWS aims to develop new prediction methods to answer this question.

"OUR KNOW-HOW COVERS ALL ASPECTS OF THE ELECTRONICS SUPPLY CHAIN"

Interview with head of business unit Frank Altmann

The coronavirus pandemic shaped the year 2020. How did that impact your business unit?
The most direct repercussion was the implementation of new health and safety measures at the institute. We worked in shifts to some extent so that we could make good use of our laboratories and equipment while still adhering to social distancing. This allowed us to maintain our partnership with clients largely without restrictions, even during the crisis. Luckily, the economic effects have been limited for us so far. After the initial shock caused by the pandemic in spring, we saw a rapid recovery in the microelectronics markets and the semiconductor industry. In the automotive industry, recovery appears more restrained. But even in that sector, megatrends such as electromobility and autonomous vehicles have resulted in a great demand for R&D support, with a view towards process quality, reliability and the service lifetime of electronic components.

What added value can companies in these markets achieve by collaborating with Fraunhofer IMWS?
We can offer innovative solutions to improve reliability and quality assurance for electronic components. Our core competence is a comprehensive and high level suite of failure diagnostics services, which covers all aspects of the electronics supply chain, from semiconductors to assembly. From a detailed analysis of a material's microstructure, we can draw conclusions about the properties of the components and their impact on electronic functionality and reliability. This helps us to better understand the degradation mechanisms and to predict the lifetime of devices. In this way, we can flag failure risks and assess the potential of new materials, component designs and manufacturing technologies, for example. We also use our know-how to develop more efficient failure diagnostic techniques.

What were the highlights of 2020 for your business unit?
In 2020, we launched multiple important research projects focusing on the reliability of power electronics, such as the ECSEL project IREL40. In addition, we have been cooperating with the leading component manufacturers in the EURIPIDES-PENTA project FA4.0 and developing AI-driven solutions for advanced failure analysis techniques and workflows. As the topic of physics of failures is becoming ever more important, we will be working on it even more intensively from next year on.

What are your hopes and goals for 2021?
The previous year has shown us all that good health should be number one on all our wish lists. My goal for this business unit is to support our clients as best we can in their response to the crisis and into the recovery phase, which should hopefully begin soon. With our expertise and technological capabilities, alongside our newly established funding projects, we are in a very good position to make a significant contribution in that respect.

Frank Altmann
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NEW EVALUATION CRITERIA FOR HEAVY WIRE BOND CONTACTS

New materials are also used in the smallest of dimensions such as in wire bond contacts, which are found in chips, electronic components, as well as electric interfaces and those which connect circuits. Heavy wire bond technology for connecting power semiconductors is used in the constantly growing power electronic application fields such as that of alternative energy production and electrification of vehicles.

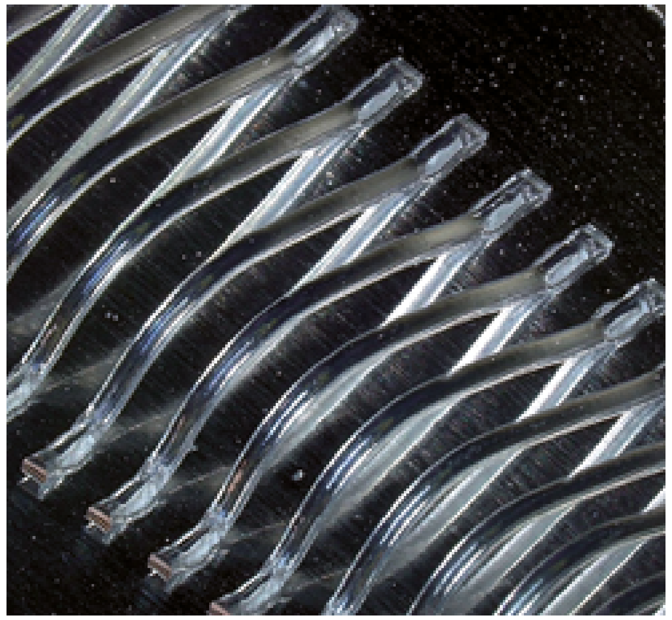
Here, aluminium (Al) heavy wire is used almost exclusively for bonding. Apart from the usual ultra-pure and pure types of aluminium, innovative aluminium wire materials as well as aluminium coated heavy copper wires are increasingly being used. These have the advantages that they are corrosion resistant, have higher strength and are thermally stable. This results in these materials having a service life up to ten times longer.

To examine bonding quality, standard mechanical tests, such as so-called pull and shear tests, are carried out during process optimisation as well as during manufacturing. For the latter method, the contact is pushed with a chisel to a specific height in the bonding point and is thus separated. After that, specific quality features such as shearing force and fracture patterns, found as a result of the test (a so-called shearing code), are evaluated. New and further development of wire materials and the changes in mechanical properties connected with this, however, affect the results of the shear tests: The interpretation of the test results and the evaluation criteria for good/bad classification of bonding quality used to date must be modified.

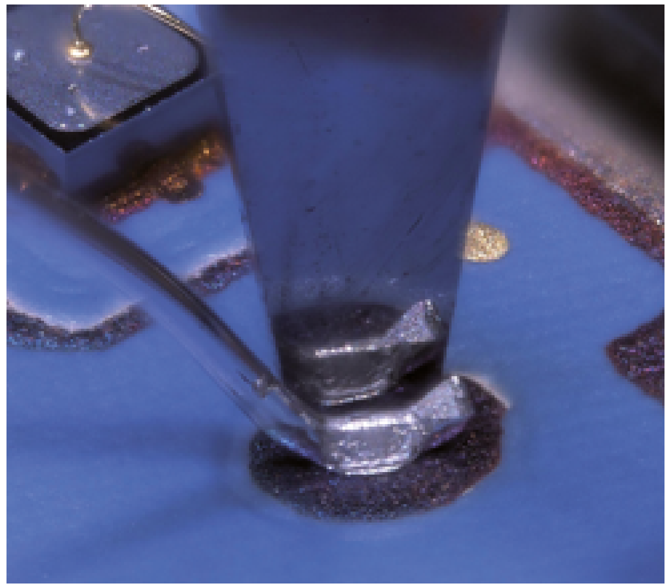
In the course of the current AiF research project 'Correlation of shear test results and reliability of fine crystalline aluminium-based heavy wire bond contacts' the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in cooperation with the Fraunhofer Institute for Reliability and Microintegration IZM is developing a fundamental knowledge base on the microstructural property relationships of bond contacts.

This forms the conditions upon which universal assessment and evaluation guidelines for shear test results may be defined. The minimum of required shear power values are achieved without problem for the new, reliability optimised wire materials. However, shear codes are a challenge, as they are significantly altered compared to conventional wires. Based on current evaluation criteria these may represent inadmissible material reactions so that insufficient connectivity and therefore poor bonding quality is assumed. Hence, no universal assessment and evaluation guidelines for the new wire qualities exist as far as shear test results are concerned. An elementary part of quality management thus remains outstanding.

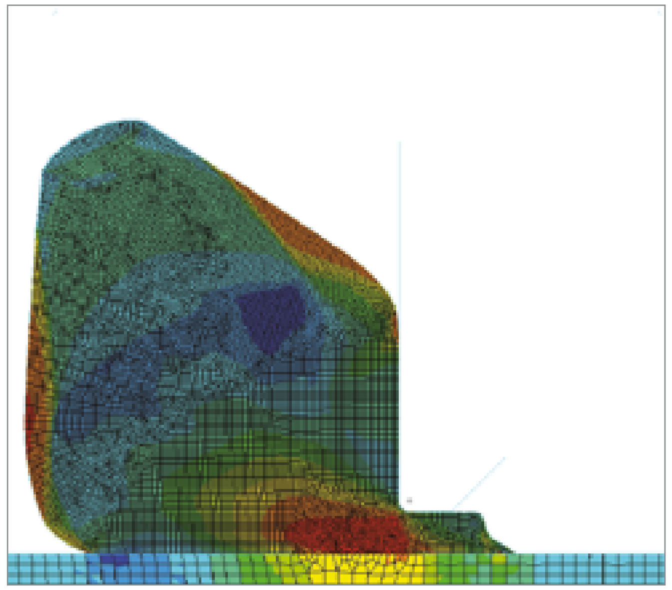
Since output quality always affects durability, a new definition of admissible criteria with regards to shearing force and shear code for heavy wire materials is urgently required. A central question remains of how shearing results and, with this,



A series of aluminium heavy wire contacts as test samples for examining microstructure-property-relationships.



A shearing chisel positioned behind an aluminium heavy wire contact; the shear test is the standard method applied to test the bond quality of heavy wire contacts.



A shear test FEM simulation to determine the deformation and tension processes in the aluminium material of a heavy wire bond contact.

bonding quality can be reliably assessed in future, considering the large range of available raw materials. The research project is developing various test patterns for this, whereby raw materials are examined and contacts undergo the shear test in various stages of maturation. The microstructure of the contact zone is also analysed at every stage in order to relate it to the shear test results.

The scientists are examining the microstructural and mechanical processes of bond connections with the shear test. The aim is to establish the interrelation of shear test result, structure and bonding quality as well as their impact on durability, which has to be predicted. These results will later be included in leaflets and/or standard guidelines.

The project is funded by the Federal Ministry for Education and Research BMBF. The AiF Consortium for Industrial Research is lead partner. The project was submitted via the research alliance DVS – Deutscher Verband für Schweißen und verwandte Verfahren e.V. (The German Association for Welding and Related Processes).

Robert Klengel
Studies of electrical engineering with specialization in packaging and interconnection technology,
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ACCURATELY PREDICTING THE RELIABILITY AND WORKING LIVE OF PHOTOVOLTAIC AND BATTERY INVERTERS

In the project entitled Reliability Design, the Fraunhofer Institute for Microstructure of Materials and Systems IMWS together with other partners plans to develop an efficient and trustworthy method for predicting the reliability and working life of inverters for use in photovoltaic and battery storage systems. The method could make a significant contribution to reducing the costs of generating electricity.

In the extremely competitive market of renewable energy technologies, the costs incurred per kilowatt-hour generated are of decisive importance. This means that it is all the more frustrating when problems arise during the operation of such plants: the operator of the plant suffers a drop in yield and the manufacturer has to meet costs in relation to guarantee claims or the need to dispatch a technician to carry out repair work. If such incidents occur more frequently than expected, cost-effectiveness – no matter whether a private solar system mounted on the roof of a house or a large ground-mounted solar plant is involved – can be severely affected.

So it will undoubtedly be useful to develop new methods capable of predicting the service life of solar components in a demonstrably accurate manner, reducing the amount of testing required and arriving at a purposeful definition of service life so as to reduce equipment costs. In the research project entitled Reliability Design, SMA Solar Technology AG, ELECTRONICON Kondensatoren GmbH, MERZ Schaltgeräte GmbH, the Institute of Machine Components of the University of Stuttgart and the Fraunhofer IMWS plan to achieve this goal for photovoltaic and battery inverters.

In their joint project, sponsored by the Federal Ministry of Education and Research as part of the program entitled Innovations for Energy Transition, they intend to analyze field data on inverter failures, clarify the mechanisms involved in degradation at component level and evaluate and optimize testing and measuring procedures in relation to accelerated ageing. All of this provides the basis for the development of a method for predicting the service life of solar components. The main contribution made by

New methods for predicting the working life of components could render the generation of electricity using photovoltaic panels (here a ground-mounted plant connected to batteries in Templin) cheaper.

the Fraunhofer IMWS to this project is its expertise in material diagnostics and damage analysis, in-depth physical and chemical analysis and modelling of the causes of defects and factors affecting reliability.

In photovoltaic systems, inverters convert the direct current of the solar modules connected into alternating current, which can then be fed into the network. They also play a central role in the provision of reactive power or an operating reserve and in energy management, e.g. in combination with a battery storage facility. Special demands are made of power electronic inverters with nominal power outputs of a few hundred watts up to the megawatt range: they must have an extremely robust design to protect them against environmental factors during virtually continuous operation over large periods exceeding 20 years. Specifically, the interaction between voltage, temperature and humidity can accelerate ageing and failure processes.

Given that the solar power industry is still relatively young – the first modules mass produced for the market are only now reaching the end of their working lives – there are still gaps in our understanding of how the materials and components used to manufacture them actually behave. In order to ensure the required levels of performance, power electronic components currently undergo intensive testing and in part are manufactured so that in case of doubt, they are capable of exceeding the demands made of them. This means that they are designed to cope with high demands for long service lives, which they are never actually required to satisfy in actual use. At the same time, inverters are characterized by rapid innovation cycles, which means that any experience acquired cannot be readily transferred to new models and future generations of products.

The project focuses on the reliability of inverters. They convert the direct current of the solar modules into alternating current.

As opposed to what occurs, say, in microelectronics, there are components and ageing processes that are still critical and as yet insufficiently researched. This is why the project participants want to help arrive at a deeper understanding and at the same time develop new methods. This will lead to a feasible method for a development process for new power electronic components and systems. This will open up the prospect of cost savings for manufacturers while at the same time ensuring reliability for users over long working lives. Specifically, it should be possible to arrive at verifiable predictions of the lifecycles of inverters, enabling a reduction in the volume of testing required. It will also be possible to design equipment in a more targeted fashion for its required working life, further reducing costs. The project focuses in particular on film capacitors and electromechanical switches.

> *Equipment can be targeted more specifically to the required service life to reduce costs.*

Here, the work of the Fraunhofer IMWS centers on the clarification of failure and ageing mechanisms, including the interaction of these mechanisms with one another and exhaustive failure analysis of damaged power electronic components and inverters and the investigation and modelling of the temperature and humidity conditions in solar equipment. The experts in Halle will also turn their attention to the evaluation and optimization of test procedures for components and equipment with regard to reliability, robustness, ageing and accelerated ageing.

Together with the project partners, the Fraunhofer IMWS scientists want to establish a new development methodology, which could have a significant impact on the reduction of costs. This will make quality assurance less expensive for manufacturers as well as reduce the costs of generating renewable energy overall. Renewable energies will become more competitive compared to conventional electricity generation – while at the same improving their reliability.

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A SELECTION OF RESEARCH SUCCESS STORIES

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"THE IMPORTANCE OF PHOTOVOLTAICS IS INCREASING EXPONENTIALLY"

Interview with head of business unit Prof. Dr. Ralph Gottschalg

The coronavirus crisis has had an impact on all aspects of 2020, including Fraunhofer CSP. What have been the repercussions from your perspective?
We had to rapidly re-organize several of our internal processes and proved our ability to do so. From an early stage, we were able to support other business units on projects aimed at combating the crisis. For example, we purchased new equipment to help us develop a deeper knowledge of the distribution of aerosols, which is also significant for other areas of research.

Which markets do you want to focus on, and what are the benefits for companies that collaborate with Fraunhofer?
We primarily support the photovoltaics industry with regard to quality control and optimizing the performance, durability and reliability of products. That ranges from selecting suitable materials, improving manufacturing methods and advising on installation, right through to solutions for managing existing power plants. We use our expertise to help suppliers, manufacturers, operators and power plant owners understand and avert risks. To this end, we draw on our excellent technical infrastructure for solar cell diagnostics and metrology, failure diagnostics and elucidating the cause of defects and degradation. We also provide polymer and chemical analytics services alongside the assessment and automation of processes. In this respect, Industry 4.0 approaches are becoming more and more relevant.

Can you foresee a return to the manufacture of photovoltaic modules in Germany?
Photovoltaics is a growing sector, however, its success is overshadowed by problems upstream (production of wafers, cells and modules). This growth will accelerate due to structural change, cross-industry collaboration, electromobility and the commitment to green hydrogen, for example. For us at Fraunhofer CSP, however, having an overview of the entire value chain and successful integration into the energy system is essential. I see a strong need for research into the issue of how the value of existing power plants can be assessed, preserved and enhanced, either through the use of artificial intelligence or the implementation of quality assurance processes over the complete life cycle. Likewise, we can achieve considerable improvements in the planning, operation and maintenance of power plants and systems. This would significantly reduce energy production costs in Germany and therefore represent a valuable contribution to protecting the environment.

What activities do you have planned for 2021?
I hope that soon we will all be able to live and work in a way that is free from pandemic restrictions and allows us to cultivate our relationships with our colleagues and customers once again. With regard to photovoltaics, I hope that it can continue to make a significant contribution to the transition to renewable energies.

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HOW SOLAR MODULE SOILING IMPACTS YIELD – AND HOW TO COUNTER IT

Every year, the soiling of solar modules and the resulting reduction in power production causes revenue losses amounting to at least three billion euros in the solar industry. Researchers are constantly intensifying their efforts to find out how this soiling occurs and what can be done to prevent it.

Photovoltaics constitutes a growth market, with installed capacity predicted to exceed 3 TW by 2040. A significant portion of this growth will take place in countries such as China and India. Many new solar parks are also being built in desert regions, thus bringing an issue with major consequences for the efficiency of photovoltaic systems to the fore: the accumulation of contaminants on solar modules. Known as soiling, this phenomenon can drastically reduce power production.

Together with its partners, the Fraunhofer Center for Silicon Photovoltaics CSP has developed a process that can be used to simulate soiling in a laboratory. This is an important requirement for optimizing the materials used and so also the power yield, as soiling processes are physically complex and have yet to be fully analyzed and understood. The results of this process indicate that at present, soiling is reducing worldwide solar power production by at least three to four percent, which corresponds to annual revenue losses of at least three to five billion euros.

For certain regions, the focus on the development of successful countermeasures offers far more potential than exclusively concentrating on further optimizing the efficiency of crystalline solar cells — especially when you consider that the enhancements achieved in that area over the last 20 years are close to the physical optimum.

Due to the many influencing factors involved, such as unique weather, location and system specifications and surface nanoproperties, and the way these factors vary over time (e.g. weather changes over the course of a day or year), the physics behind dust deposition and adhesion is highly complex. This problem is being systematically investigated at Fraunhofer CSP by means of open-area and laboratory tests and simulations, right down to microstructural material characterization.

So far, results have shown that dust concentration in the air is the most important influencing factor for soiling, together with rainfall frequency, as rain can clean soiled modules very effectively. Other important parameters include wind speed (which affects particle deposition mechanisms) and the photovoltaic module's angle of inclination (soiling rates are higher on flatter surfaces). Relative humidity and dew play a particularly prominent role, as both increase dust adhesion on surfaces due to capillary forces and cementation processes. Another factor affecting deserts is that the photovoltaic modules' glass surfaces cool down overnight and become even colder than the ambient air due to radiative cooling through the night sky. This regularly leads to the formation of dew on the module surfaces. The combination of soiling and humidity can permanently reduce the photovoltaic capacity.

Even today, there are multiple solutions for countering soiling. Soiled modules are primarily cleaned by mechanical means, for example, through manual, semi-automated or fully automated wiping or sweeping. However, this can result in scratching or abrasion that can damage the anti-reflective coating (ARC) typically used on solar modules, which negatively impacts their efficiency. Other possible consequences include corrosion or thermal shocks, because when cold water meets the hot modules, it can cause the solar cells or their glass covers to break. It can also result in the widening of microcracks.

Consequently, optimized module surfaces that do not allow dust and sand to adhere strongly to them in the first place would be a better solution. Developing these anti-soiling coatings (ASC) is another key research area at Fraunhofer CSP. In ideal circumstances, the coatings would be highly transparent, anti-reflective, long-lasting, non-toxic, suitable for application at industrial scale, cost-effective and of course, self-cleaning. In some studies, the coating reduced the soiling effect by more than 80 percent. When viewed over a longer time period, the average values currently amount to a reduction in soiling rates of between 20 to 50 percent.

If grime is deposited on photovoltaic modules, less light reaches the solar cells and the power yield is reduced. This problem is particularly relevant for the growing use of photovoltaics in desert areas and regions with high levels of air pollution. © Fraunhofer CSP

Solar park operators have other options for reducing the negative effects of soiling apart from protective coatings, such as changing the modules' angle of inclination for example. In addition, it has been shown that soiling is particularly severe at night. That means solar trackers, i.e. motorized modules that automatically align themselves with the sun, could be positioned vertically or flipped over at night in order to reduce soiling.

Another solution involves heating surfaces to prevent dew from forming. Dew formation is especially common in the period before dawn, when the relative humidity is high and the temperature of the photovoltaic modules is lower than the ambient air temperature. If the modules are heated during this period, by means of a controlled power supply to the solar cells for example, it can reduce condensation. And last, but not least, the design of and the materials used in the photovoltaic modules can also be optimized. Examples include using half-cells, which reduce the effects of partial shading on the overall performance of the module, or frameless modules, which helps to prevent the accumulation of grime at the edges.

The selection of the location also plays a decisive role. The combination of precise knowledge of meteorological data and site-specific soiling risks enables the development of optimized cleaning solutions, taking into account soiling types and deposition rates, water availability, location and system configuration.

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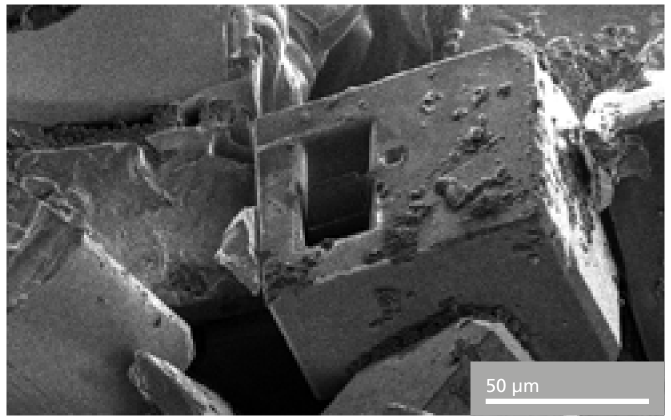
THE FRAUNHOFER LIGHTHOUSE PROJECT "MANITU" DEVELOPS MATERIALS FOR SUSTAINABLE TANDEM SOLAR CELLS

High-efficiency solar cells generate electricity cheaply while also taking up less space and consuming fewer resources. They also help promote the use of new products, such as electric vehicles, which can be charged from solar cells. Due to their physical limits, the efficiency of silicon solar cells cannot be increased much further. However, the use of tandem solar cells made of several light-absorbing layers enables efficiencies to be increased to over 35%, which is why so much attention is being devoted to them in current solar cell research. In the **"MaNiTU" project**, six Fraunhofer institutes are developing sustainable, highly efficient and cheap tandem solar cells based on new absorber materials.



Preparation of a TEM lamella from a $CsPbBr_3$ single crystal through focused ion beam technique.

For Germany, the development of innovative and disruptive technologies such as tandem solar cells represents a further opportunity, alongside research, solar plant construction and the supply of materials, to carve out a leading role internationally in the manufacture of solar cells. This means that "MaNiTU" also opens up an alternative perspective for a successful European PV industry.

Perovskite solar cell technology, which over the last ten years has managed to increase the efficiency of solar cells from 3.8 to 24.2%, has simplified the manufacture of cells and has the potential to substantially reduce production costs, lies at the heart of the lighthouse project "MaNiTU" – materials for tandem solar cells with ultrahigh conversion efficiency. Perovskite materials are deemed to include any materials whose crystalline structure corresponds to that of the mineral calcium titanate. Such materials are especially good at absorbing light and enable high electron mobility – ideal for use in photovoltaic systems. Given their physical properties, these types of materials are also suited for use in tandem structures based on silicon solar cells.

However, the use of lead means that this material is not without its drawbacks. Given that over the next five to ten years the power output of photovoltaic installations will increase to over 1 TWp, the use of critical materials in the construction of solar modules must be avoided wherever possible. Starting out with familiar perovskite absorber materials, "MaNiTU" employs ultramodern techniques from materials science to develop new lead-free absorber layers and contact and passivation layers suitable for use with the former, enabling critical and toxic materials to be excluded from the outset. The innovative approach consisting of handling absorber and contact layers together enables the targeted use of interface effects for the desired functionalities. Perovskite technology is then combined with conventional silicon technology. This is achieved by depositing perovskite cells directly on silicon solar cells. Given that the individual solar cells are particularly efficient at using different sections of the solar spectrum, efficiency overall is increased and more electricity can be generated using the same area of solar cells. At the end of the project stability and high rates of efficiency are demonstrated at module level.

This Fraunhofer lighthouse project is scheduled to last four years. The aim of this research program is to fully exploit the potential for synergies by pooling competencies at several Fraunhofer institutes to deliver solutions for the challenges faced by German industry.

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USING ARTIFICIAL INTELLIGENCE TO ANALYZE AND PREDICT PHOTOVOLTAIC SYSTEM STATES

Photovoltaic systems contribute significantly to sustainable power supply in Germany. However, it would be impossible for every single module and component in every system to work perfectly at all times. Possible vulnerabilities and defects can lead to a reduction in yield. If they are not detected in good time, this can result in significant financial losses for the operator. However, these days, it is not always possible to search for defects in a way that is tailored to every module and that takes into account the unique features of the materials selected, the manufacturing process, the installation and the location. There is an urgent need for monitoring solutions enabling to detect damage early and correct it without significant financial loss.

This is where "Mon-KI" comes in — a joint project by Fraunhofer CSP and GETEC green energy GmbH in Magdeburg, a company that develops renewable energy supply solutions. This two-year project aims to use AI methods to enable better prediction of yields and maintenance work on photovoltaic modules.

Photovoltaic park with a variety of solar modules used for experimental purposes at the Fraunhofer Center for Silicon Photovoltaics CSP.

To achieve this, Fraunhofer CSP scientists are conducting computer-assisted actual-value vs. planned-value data analysis. Field data, historical data and laboratory testing are used to generate defect models from the monitoring data. These will be used in training machine-learning models. This allows the researchers to automatically record defects that can lead to degradation and loss of yield in photovoltaic modules. The research team took the following into account as defects: potential-induced degradation (PID), light- and elevated-temperature-induced degradation (LID and LeTiD), bypass diode failure, AC fuse failure, cell breakage, and shading and partial shading, which can be caused by soiling, vegetation, close and distant shadows, and snow.

Defining the target state makes it possible to generate a depiction of the ideal photovoltaic system in terms of the individual components, such as modules, cables, inverters, electrical wiring, topography and weather conditions. This can then be used to predict the capacity or energy yield. In this process, new systems, which are expected to be defect-free when they commence operations, are differentiated from existing systems that have already been put into operation and may possibly be impacted by defects. The actual data is collected by the monitoring box prototype developed during the project, which records parameters from the surroundings using various sensors, thus making it possible to compare, identify and quantify different photovoltaic systems.

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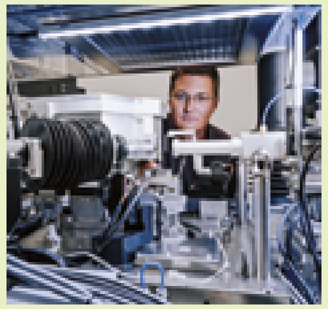

24 | Researchers at Fraunhofer IMWS explored the feasibility of synthesizing metal nanoparticles for new transition-metal glassmatrix composites. Various methods, including X-ray microscopy, were used to investigate the nanostructure.

"WE WANT TO CONTRIBUTE TO THE GROWTH OF THE ECONOMY"

Interview with head of business unit Prof. Dr. Thomas Höche

What will you remember most about your business unit in 2020?
The institute management decided to support the work and direction of the business units at Fraunhofer IMWS by establishing market-specific industry advisory boards. At the inaugural meeting of our high-profile advisory board, we were able to achieve reassurance on our future direction. We feel that our existing infrastructure, which was further improved in 2020, puts us in a strong position to meet the challenges of the future. What I will remember most is the really personal commitment of the individual advisory board members and the way they identified with our situation. Our industry advisory board will support us in further developing innovative solutions already explored in previous projects so that we can meet specific industry needs.

What markets are you targeting? How can companies benefit from cooperation with your business unit?
We support customers from the optical industry, the pigment industry and the specialized mechanical engineering industry with our know-how. This is especially the case with the application of microstructure diagnostics techniques for glass, glass ceramics and effect pigments as well as optical coatings for lithography, laser technology, and ophthalmics. Our understanding of the microstructure of materials helps us accelerate the development of new materials and optimize methods for laser-based material processing.

As a member of the institute management team you are on the committee for appointing the future head of Fraunhofer IMWS. How did you find that experience?
Once the call for applicants was published, we embarked on a very tightly scheduled, constructive process together with Martin Luther University Halle-Wittenberg. The very different ways applicants interpreted the future leadership and direction of the institute were very impressive, as were the outstanding solutions they presented. This makes me very confident that the appointment of someone from outside Fraunhofer IMWS to the role of institute director can help strengthen the institute's position within the German research landscape.

What does 2021 have in store for you?
I am looking forward to work with our highly effective business unit team on further exciting challenges facing our customers, and thus contribute to the growth of the economy, which is the basis of prosperity in Germany. Our aim is to justify the given trust by public funding.

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SYNTHESIS OF TRANSITION METAL NANOPARTICLES IN GLASS MATRICES

Scientists believe that promising optical and magnetic properties can be attributed to new kinds of transition-metal glass matrix composites (Ni/Co) when the corresponding parameters are successfully controlled through targeted adjustment of the nanoparticle size distribution. As part of the project "Precipitation kinetics of super-paramagnetic nickel and cobalt crystals in silicate glasses controlled by redox potential" funded by the German research foundation (DFG) and in collaboration with Clausthal University of Technology, we explored the feasibility of synthesizing metal nanoparticles and the influencing variables of precipitation reactions controlled by redox potential. The project was an optimal combination of Clausthal University of Technology's expertise in various synthesis procedures and the nanostructural analysis techniques offered by Fraunhofer IMWS.

While numerous studies have been carried out on noble metal nanoparticles in glass, it is still very rare for the literature on this subject to describe the synthesis and properties of the transition metal nanoparticles that are precipitated in glass matrices.This means that the work conducted here was ranging far into new scientific territory.

In addition to a comprehensive series of tests on metallic reducing agents, reduction in hydrogen atmospheres was investigated as an alternative. After the construction of a hydrogen flow oven at Clausthal University of Technology, nanoscale precipitates of both metallic nickel and metallic cobalt were found to be present in the glass flakes at a sampling depth of up to 10 µm.

One surprising experimental finding was the confirmation of the synthesis of cobalt particles in a silica matrix, which are present in the ε-phase (figure 1). Because this cobalt phase is metastable, it was possible to thoroughly investigate its properties by "freezing" this phase in glass. Among other things, this enabled us to successfully ascertain the previously unknown thermal expansion coefficient of ε-Co for the first time.

As part of the project, we also comprehensively investigated the influence of basic glass composition on the precipitation kinetics of metallic nickel nanoparticles in the glass matrix. Among other things, this investigation revealed that the electron transfer reaction is the step that determines the rate of the precipitation process.

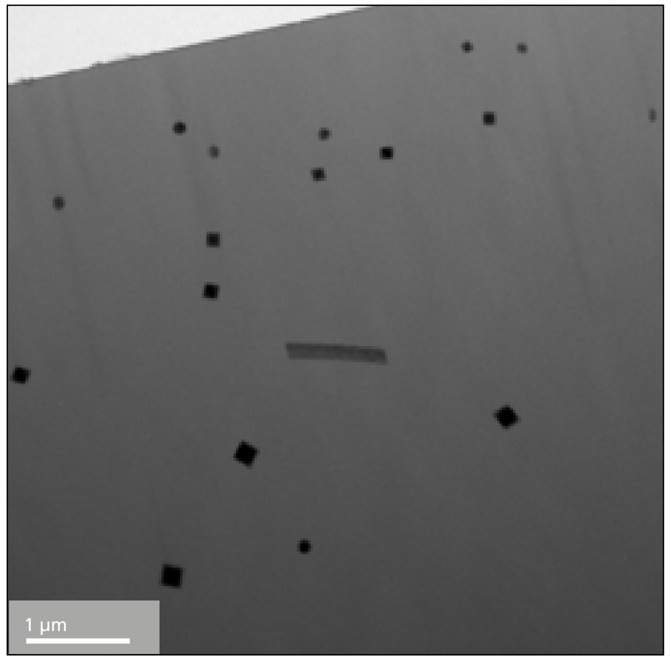

Figure 1: TEM image showing elongated and cubic cobalt particles (ε-phase), embedded in the surrounding glass matrix.

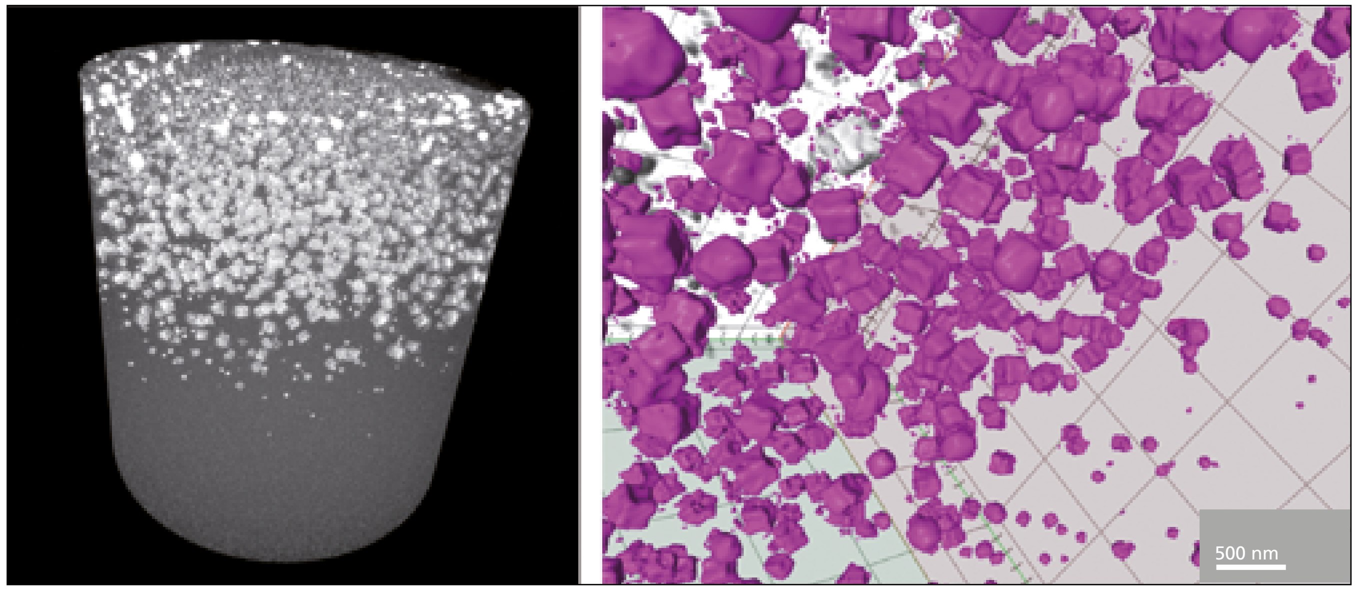

Figure 2: Reconstruction of the scanned sample volume (height and diameter 16 µm respectively) of a glass sample containing precipitated nickel nanocrystals; left, X-ray microscopy image; right, 3D-representation after segmentation.

Thanks to an X-ray microscope, one of the few devices with sufficiently high resolution available in all of Europe, that Fraunhofer IMWS uses in cooperation with Martin Luther University Halle-Wittenberg, it was possible to conduct a nondestructive investigation of the three dimensional structure of the samples and a detailed analysis of the distribution of the precipitated nanoparticles in the sample volume (Figure 2).

The results achieved in this project were both highly promising and scientifically fruitful. First of all, they clearly prove that nanoscale nickel or cobalt functional phases can be synthesized in silica matrices; new hybrid materials were successfully developed through manipulating the redox potential. Secondly, they emphasize the potential long-term benefits of establishing these new nanoparticle synthesis pathways (for example, as an alternative to precipitation reactions or hydrothermal synthesis), as they appear to make it possible to influence the distribution and size of the precipitated nanoparticles. However, these types of syntheses can only be used to carry out reductions at the edges of the volume material for now. Consequently, in follow-up projects, we will carry out reduction of glass powders with basic glass compounds, which, based on the results that have already been achieved, are suitable for precipitation of metallic nanoparticles in the desired density and size distribution. The aim is to achieve a homogeneous distribution of nanocrystals throughout a full sample by means of subsequent compaction, in order to open up further potential applications.

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28 | The Hydrogen Lab Leuna offers unique opportunities for testing hydrogen technologies on an industrial scale.

30 | The "InnoSynFuels" project aims to bring synthetic CO_2-neutral fuels to market-ready status.

31 | Working together in a strategic partnership. RECENSO GmbH and Fraunhofer IMWS intend to develop new technology for chemical recycling.

"CENTRAL GERMANY AT THE FOREFRONT OF CHEMISTRY 4.0"

Interview with head of business unit Dr. Sylvia Schattauer

What was your own personal highlight from 2020?
I was very happy about my appointment to the German Federal government's National Hydrogen Council. This council brings together expertise from many different perspectives so we can support political decision-makers with implementation of the National Hydrogen Strategy and develop proposals and recommendations. For me, this appointment is also an acknowledgment of the expertise that Fraunhofer IMWS has built up in this field.

Hydrogen and carbon technologies are critical for the future and much discussed. How can companies already participate and what role does Fraunhofer IMWS play here?
There is indeed a lot happening in this field at the moment, and Central Germany is right there at the forefront. Our goal is to draw on the expertise that already exists in our field — to actively partake in creating structural change; and in particular, to use hydrogen and carbon that have been produced in a sustainable way, generating hydrogen through water electrolysis powered by renewable energies, and carbon through the chemical recycling of waste products containing plastics, which produces "green" carbon. Companies in the chemical industry, manufacturing, or energy, waste and recycling management that want to move towards a circular economy are in the right place when they come to us. These are the companies we are supporting, through our deep process knowledge, exemplary wide-reaching technology know-how, extensive digitalization expertise, attractive network, and in particular, our unique, almost industrial-scale testing infrastructure.

The Hydrogen Lab Leuna is one such plant that is set to start operation in 2021. What role will it play?
For the field we work in, it will play a key role, and in my opinion, it will also serve as a flagship project for Central Germany as a pilot region for Chemistry 4.0. Our customers will be able to use the platform to test and further develop various systems under real-world conditions. It will allow us to find answers together to various questions relating to the subsequent market ramp-up. Which technology is best for which application? Where is further optimization needed? How can we go to market quickly, at a competitive price, and on a large industrial scale?

What else is in the pipeline for 2021?
I look forward to being a part of the "Waste4Future" lighthouse project, for example. Our whole sector is really going to evolve. That applies to Leuna and also to Halle, as well as our Saxony-based branch labs in Freiberg and Görlitz, where we will be working to further optimize gasification technologies for the resource-efficient use of carbon carriers. There will also be greater focus on hydrogen applications in industrial manufacturing.

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"GREEN" HYDROGEN AS A CATALYST FOR SUSTAINABLE CHEMICAL INDUSTRY

Hydrogen is the key element to establish a sustainable chemical industry. With the Hydrogen Lab in Leuna (HLL), subject to today's festive groundbreaking ceremony, the State of Saxony-Anhalt assumes a pioneering role in achieving these goals. The pilot system will produce green hydrogen for the production of basic chemicals and fuels with low emissions as the Fraunhofer Center for Chemical-Biotechnological Processes (CBP) in Leuna and the Fraunhofer Institute for Microstructure of Materials and Systems (IMWS) in Halle (Saale) bring together their expertise.

At present, hydrogen is one of the most important ressources for more than 600 companies forming the so-called "chemical triangle" in Central Germany. Currently, hydrogen is produced from fossil ressources with correspondingly high rates of CO_2 emissions. The approach used by the new pilot system relies on sustainable resources: Electricity from photovoltaic or wind turbine systems is used to produce hydrogen from water by means of the electrolysis technique. This green hydrogen is climate-neutral and made available to the companies located here through the supply network of the chemical industry park.

Saxony-Anhalt provides ideal local conditions. Electricity is produced in enormous quantities from renewable energy sources, and, at the same time, the chemical companies here have a huge demand for hydrogen and there are an existing pipeline system and storage capacities. The Fraunhofer Hydrogen Lab Leuna (HLL) includes laboratories, offices, and a pilot plant; it is used to investigate and assess the operation and functionality of different electrolysis systems on an industrial scale. In the outdoor area, test fields are available for power-to-X- and power-to-liquid projects with up to 5 MW power supply.

Research at the HLL focuses on operating electrolyzers with fluctuating power supply from renewable energy sources, testing improved materials and optimizing infeed to the existing hydrogen pipeline, as well as developing suitable business models. Fraunhofer is supporting the establishment of hydrogen-based industry in Germany with a multitude of activities. If they courageously seize their opportunities in this emerging market, then Fraunhofer can strengthen competitiveness and the power of innovation and help to develop a model region for a sustainable industrialized society. This is an important contribution to making structural changes and climate protection successful at the same time.

The Hydrogen Lab Leuna (HLL) is designed to obtain data immediately from the application, making it possible to optimize the operation of electrolysis systems. In associated projects, the researchers further develop techniques to produce synthesis gas by means of co-electrolysis of water and carbon dioxide. As a result, not only green hydrogen, but also basic chemicals and sustainable synthetic fuels can be produced in Leuna.

The Fraunhofer Center for Chemical-Biotechnological Processes (CBP) contributes important expertise in chemical process engineering. In addition to other regenerative ressources, also investing in green hydrogen as a raw material and further improving the synthesis processes, this will contribute to a sustainable chemical industry. With the now emerging platform, the techno-economic viability systems can be demonstrated. It paves the way for large-scale production of green hydrogen to be feasible for the market. The first projects will begin in 2021.

> *Hydrogen is already one of the most important raw materials for the more than 600 companies that form the Central German Chemical Triangle.*

Dr. Markus Wolperdinger, head of the Fraunhofer IGB, Dr. Sylvia Schattauer, deputy head of the Fraunhofer IMWS and Prof. Dr. Armin Willingmann, Minister for Economy, Science and Digitalization of Saxony-Anhalt, participating in the festive groundbreaking for the Hydrogen Lab Leuna.

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INNOSYNFUELS: INITIAL RESULTS FROM THE DEVELOPMENT OF SYNTHETIC FUELS

Funded by the European Social Fund (ESF), the "InnoSynFuels" project has been running since July 2020. The goal shared by the project's seven partners is to achieve market readiness for synthetic CO2-neutral fuels. This involves investigating and comparing various process routes. A design has been drawn up for a demo system for the process that offers the greatest commercial potential.

The project is led by the Institute of Energy Process Engineering and Chemical Engineering (IEC) at the TU Bergakademie Freiberg. The project partners working on this topic, which is so important to the successful transition of the energy and transport sector, are Advanced Machinery & Technology Chemnitz GmbH, DBI-Virtuhcon GmbH, FI Freiberg Institut GmbH, Fraunhofer IMWS, Multi Industrieanlagen GmbH and UTF GmbH.

The research work carried out as part of the "InnoSynFuels" project is supported by a project advisory board made up of representatives from different organizations and companies. This advisory board analyzes industry trends and the potential success of the individual solutions, for example. This ensures that the user's perspective is embedded into the project as early as possible — the expectation being that once the technology has been fully developed, it will be market ready.

The vision shared by all of the project partners involved is to develop and commercialize innovative technologies to facilitate the imminent transformation of the energy and mobility sectors. The incorporation of different perspectives as well as the expertise and creativity of different disciplines contribute to the achievement of this shared goal: to support energy transition through the use of synthetic fuels as a way to expand electric mobility and hydrogen mobility, which is critical to achieving CO_2-neutral mobility in the future.

Prof. Dr. Bernd Meyer in conversation with the project advisory board.

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DERIVING RAW MATERIALS FROM WASTE: PARTNERSHIP FOR CHEMICAL RECYCLING

Chemical recycling has tremendous potential to make intelligent use of waste and to allow for a climate-friendly carbon cycle economy at the same time. The Fraunhofer Institute for Microstructure of Materials and Systems (IMWS) and the RECENSO GmbH have agreed to establish a strategic partnership to refine a technology to convert waste containing carbon into valuable raw materials; these can be used in the chemical industry to replace naphtha.

No matter where it comes from - yellow bin, organic or non-recyclable waste - almost all waste streams include usable carbon resources. In many cases, these materials are burnt immediately, thereby releasing huge amounts of climate-damaging carbon dioxide, or, at best, they are used for products that are only marginally challenging to produce in the context of recycling.

The reason for this is that mechanical recycling – the sorting of waste based on its source material – quickly reaches the limits of its feasibility. For one thing, sorting and separating is time-consuming and costly. Another issue is that waste such as the deriving from packaging, for example, often consists of very different material types. To determine the carbon resources it contains, complex and expensive separation techniques are needed.

For this purpose, thermo-chemical recycling methods provide a solution: the source materials are split up into their chemical components and made available again to the chemical industry as raw material in the form of synthesis gas, platform chemicals such as methanol, or so-called pyrolysis oils. These raw materials gained from recycling are characterized by three advantages: First, they reduce the demand for fossil fuels, such as naphtha, which would be required to create such products otherwise. Second, these basic materials are 'like new', so they can also be used in high-value products; thus, they are clearly more flexible and attractive as raw material. Third, carbon is maintained inside the cycle rather than being released as CO_2. As a result, carbon bound in waste is made accessible and can be used in new products.

CARBOLIQ pilot system for oiling of alternative fuels gained from domestic and industrial waste in the Ennigerloh disposal center.

The Fraunhofer IMWS and the RECENSO GmbH intend to establish solutions like these by pooling their expertise. They have experience, as well as excellent research capacities for chemical recycling and pyrolysis. RECENSO has developed the CARBOLIQ technique, which can be used to convert a wide range of waste streams into pyrolysis oil. The CARBOLIQ technique is not only highly flexible in terms of the input materials, but also offers a high yield of fluid products and limits the process temperature to 380 °C. In contrast to other thermo-chemical conversion processes, here the formation of toxic substances, such as dioxin and furan, is prevented.

The cooperation intends to further develop the CARBOLIQ technology and establish it as the cornerstone of recycling waste containing plastics, a process in which mechanical methods are limited. This opens up an enormous potential for secondary raw materials and significantly contributes to an economical consumption of resources and the reduction of greenhouse gas

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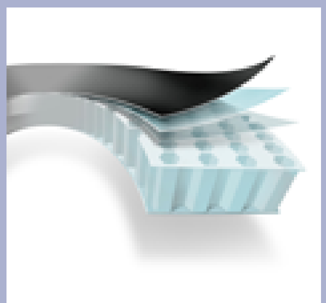
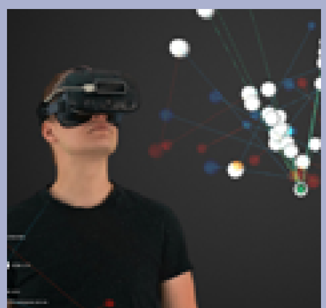


34 | Hierarchical sandwich structures help to create even more efficient lightweight design solutions.

36 | 3D printing using plastics with reinforcing fibers adapted to the component load is especially suitable for robust plastic components manufactured in small and medium volumes.



37 | Virtual reality methods make for more precise formulation and efficient processing of biopolymers.

"OUR CUSTOMERS DID NOT HAVE TO FACE ANY SIGNIFICANT RESTRAINTS"

Interview with head of business unit Prof. Dr. Peter Michel

The COVID-19 crisis has had a major toll on many industries — how has it impacted your business unit at Fraunhofer IMWS?

We made working hours even more flexible, which meant that our labs and technical center could continue operating without endangering the health of our workforce. By doing so our customers didn't have to face any significant restraints. However, as partners to industry, we are seeing increased reticence across many companies. Applied research and development is focused on tomorrow's competitive advantages, yet for many markets, the task of predicting the future is still very difficult, so the level of investment is cautious. However, it is also clear that it is very market-specific. In some sectors, orders are still being canceled, while in other areas, recovery is already well underway.

Has the pandemic also created opportunities?

Definitely. In many areas, the pandemic has strengthened and accelerated transformation processes that had already begun; for example, mobility. We are seeing that our services — such as the large project initiated at the start of 2020 as part of the Lightweight Technology Transfer Program — are attracting even stronger interest from industry. The same applies to solutions for materials-cycle management, as is the case with biopolymers, for example. Also, as a very direct contribution to the coronavirus support effort, we have started a number of new projects. In spring, we manufactured protective masks in a very short time frame, and right now, we are using our expertise to develop new kinds of textiles for innovative protective clothing. New fields of work and new markets are opening up as well. Last but not least, the comprehensive innovation programs run by Saxony-Anhalt and the federal government have allowed us to prepare even more intensively for important topics of the future, so we can use our expertise to support the recovery that we all hope will take place once the pandemic has ended.

What will stay with you the most from the 2020 pandemic?

Our conference on sandwich structures in February was a great success. Together with our partner ThermHex Waben GmbH, we welcomed a large number of international visitors and made some valuable contacts at what was one of the very few in-person events of the year. The same format should definitely take place again, as soon as larger events are possible once more.

What are your expectations for 2021?

I am looking forward to work on many exciting projects, such as the optimization of rubber composites, and the use of digital methods for thermoplastic-based lightweight design. In spring, we will be able to proceed with construction of an extension building at the Pilot Plant Center for Polymer Synthesis and Processing in the German municipality of Schkopau. This will provide us with an even better opportunity to support our customers with creative, sustainable solutions.

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HIERARCHICAL THERMOPLASTIC SANDWICH MATERIALS FOR EVEN MORE EFFICIENT LIGHTWEIGHT CONSTRUCTION

Lightweight materials are used whenever high-quality products are required that offer an optimum balance between strength, weight, and reliability. Among other areas, this applies to aircraft, vehicle, ship, and container construction or the manufacture of wind power rotor blades. The Fraunhofer Institute for Microstructures of Materials and Systems IMWS and ThermHex Waben GmbH are now working together on a novel basic technology. They are focusing on hierarchical sandwich structures in which the cover layers themselves are sandwich structures in turn with the aim of making lightweight construction even more efficient.

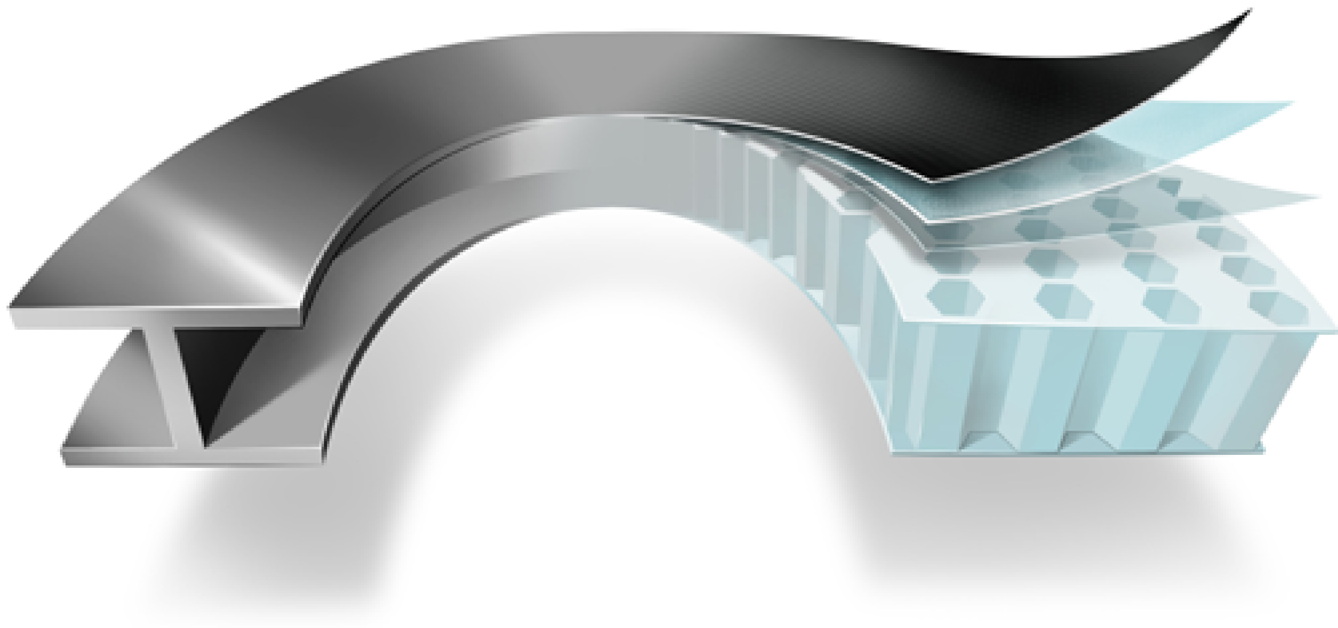
Currently, sandwich structures are particularly effective for use in lightweight construction and are especially suitable for large, flat structures. They consist of a light core and two solid thin cover layers. Plastic sandwich structures usually consist of a honeycomb core or polymer foam and cover layers made of fiber-reinforced plastics. This combination provides high bending and dent resistance with a very low weight.

The Fraunhofer IMWS and ThermHex Waben GmbH, which manufactures cost-efficient polypropylene (PP) honeycomb cores using a patented production process, have been cooperating in the field of lightweight construction with sandwich materials since the end of 2015. In the current joint project "HPHex - Basic Investigation of Thermoplastic Lightweight Sandwich Materials from Hierarchical Honeycomb and Cover Layer Structures for High-Strength and Cost-Effective Lightweight Structures", sandwich materials with novel hierarchical structures are being studied with the aim of achieving a significant increase in mechanical performance.

High-performance and cost-effective core materials are already available in the form of the thermoplastic honeycomb cores currently used in lightweight construction. However, their mechanical performance is limited, especially compared to more cost-intensive honeycomb cores, making them more suitable for use in less heavily stressed trim and interior components. This is where the innovative approach of cooperation partners ThermHex Waben GmbH and Fraunhofer IMWS comes in. They intend to overcome the hitherto low buckling strength of thin thermoplastic honeycomb cell walls by using a hierarchical material design. The honeycomb cell walls themselves are formed by a honeycomb sandwich, thus significantly increasing the stability of the honeycomb core while maintaining or even reducing its weight. The project will also explore the approach of hierarchically structured cover layers, which offer advantages in terms of load distribution and surface quality. The investigation of such sandwich structures will then allow further physical properties to be described and evaluated. The project partners already have a EUREKA label entitled "Hierarchical Hexagonal Sandwich Honeycomb Core (HiHex)".

Project leader Dr. Ralf Schlimper and ThermHex GmbH can advance and coordinate the development of cost-efficient and high-performance hierarchical sandwich structures in the long term. The novel thermoplastic honeycomb structures will ensure a high degree of automation in production and low material costs as an alternative to previous cost-intensive construction methods.

The improvement of material properties, especially the increase of weight-specific properties by means of hierarchical structuring, is an approach that is becoming increasingly important worldwide. This topic and other trends and technological developments in sandwich construction were also discussed at the Composite-Sandwich Conference in Halle (Saale) on February 5th and 6th of February 2020.



Operating principle and structure of a sandwich structure with a honeycomb core.

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3D PRINTING WITH FIBER-REINFORCED PLASTICS DESIGNED FOR LOAD PATHS

Automation, Sonder- und Werkzeugmaschinen GmbH (ASW), the Forschungs- und Beratungszentrum e.V. (FBZ), an affiliated institute of Merseburg University of Applied Sciences, and the Fraunhofer Institute for Microstructure of Materials and Systems (IMWS) are looking to develop new areas of application for plastic-based and fiber-reinforced 3D printing through a cooperative project. They focus on an innovative manufacturing technology that aims to produce light and stable components with complex geometry without expensive tooling. Such solutions are in demand above all for robust plastic components in small and medium quantities.

In the project, which is scheduled to run for two years, the competencies of ASW in the field of plant and mechanical engineering, the extensive experience in additive manufacturing at the FBZ and the expertise of the Fraunhofer IMWS in reinforced polymer materials and corresponding processing methods will be combined in order to break some of the limits that currently exist in the booming field of 3D printing. For example, the use of fiber-reinforced plastics in additive manufacturing processes is still not very widespread. This approach, through the integration of high-stiffness and high-strength fiber systems made of glass, carbon or other materials can enable very good mechanical properties that are often not yet achieved with current 3D printing processes.

One particular advantage that this idea has: In 3D printing, the components are usually created using a layered structure. The print head moves along an X and Y axis and creates a plane of the desired component. Then the next plane is placed over it. The connection between the individual planes (Z axis) is often comparatively weak and reduces the mechanical properties in this direction. This problem could be solved with trajectory-based generative manufacturing.

The project partners therefore intend to set up a test facility with a 6-axis portal system that enables free movement of the 3D print head within space and thus arbitrary trajectories of movement. The filament and fiber strands are to be placed on adapted support structures, which may have to be removed from the component at a later stage. Research is also being conducted into the combination of layered and trajectory-based 3D printing processes and the load-path-compatible design of highly stressed 3D printed components with short- and continuous-fiber-reinforced thermoplastics.

This means that in the future it will be possible to produce not only prototypical demonstrators, but also components for industrial use for individual and small series production, which can be customized to the specific application loads by means of fiber-composite compatible designs.

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POLYMER APPLICATIONS

VIRTUAL REALITY METHODS FOR THE BIOPOLYMER-BASED PLASTICS INDUSTRY

Biopolymers offer enormous potential for improving the sustainability of plastic products as they are bio-based, while some biopolymers are even fully biodegradable. When it comes to developing plastic composites, polymers are therefore a special area of focus today. Scientists at Fraunhofer IMWS together with prefrontal cortex - Kirsten Freitag Herbst GbR and Exipnos GmbH are now embracing virtual reality (VR) methods to ensure more precise formulation and more efficient processing of these innovative new plastics.

VR-based visual representation of a data space for the process-dependent properties of various plastics.

The joint "DigiLab-VR" project is a follow-up to the "DigiLab" project and is tasked with researching the use of VR systems in the formulation and processing of new types of plastics composites from technical polymers. The "DigiLab" project involved researching a virtual development platform for the formulation and processing of plastics. The result was an app that can be used to adjust ingredients and processing steps to the precise required properties of a material. This software solution will now be extended to include VR technology as part of the "DigiLab-VR" project. The new solution will offer virtual tools for the optimum formulation and processing of technical polymers that were not possible or could not be identified based on conventional analog approaches.

A key feature of the project concept was the extensive level of digitalization within the process steps thanks to the use of VR technology. This includes researching the relationships between process parameters and polymer microstructures, as well as the associated physical properties of technical biopolymers in the case of compounding, injection molding and additive processing. There are also plans to research sustainable pigments for color-matching new plastic composites based on technical biopolymers. The results can then be transferred to a VR-enabled development platform.

The project takes into account the entire value chain of products based on polymer materials. This enables the close alignment of the individual stages of the life cycle, from concept to development, manufacturing and use, right through to recycling. For the scientists involved, the use of innovative digital tools to accelerate the development of technical biopolymers for the widest possible range of applications is key to establishing a sustainable plastics industry.

There are no comparable solutions currently available on the market. The findings of the research project should provide the plastics industry, as well as other industrial sectors with complex processing methods, with validated approaches for developing new virtual tools aimed at enabling the rapid and cost-efficient optimization of materials and processes.

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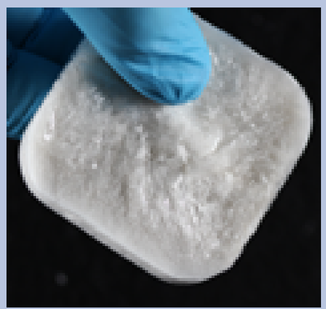
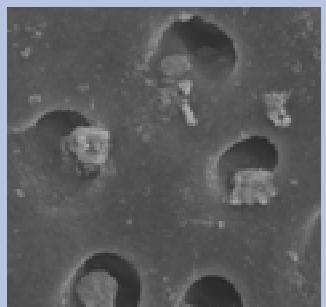
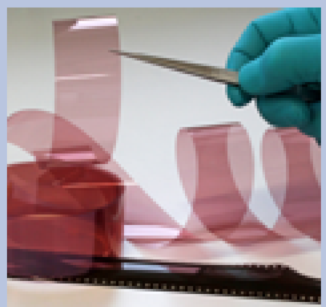


41 | Fraunhofer IMWS is working on a pulse lavage system to help large and small wounds heal more quickly, based on the use of use innovative coatings and flexible pulsating wound dressings.



42 | Dentin hypersensitivity can be reduced by incorporating functional mineral particles into toothpaste.



43 | Microfilm allows data to be stored for centuries at a time. A new project will research additional protection mechanisms for preventing biochemical changes and microbiological influences.

"THE PANDEMIC HAS HIGHLIGHTED THE DIRECT IMPACT OF OUR WORK"

Interview with head of business unit Dr. Christian Schmelzer

What will you remember most about your business unit in 2020?
That would be the consequences of the pandemic. I am, however, not referring to the impact on the economy and society, nor to the sometimes significant changes in our operations at the institute. I am referring to our own scientific work as it relates to COVID-19. In spring 2020, we were already working closely with the city of Halle's crisis management team and local hospitals to develop solutions in a spontaneous and flexible way; for example, solutions for disinfecting protective clothing or for assessing the quality of the so called community face masks. This led to the creation of ambitious projects, projects we are working on right now. Even though we had to improvise a lot and completely disregard our established processes, it is hugely motivating to see the level of commitment of colleagues involved, and the degree to which our research work can make a direct, positive impact.

What projects for combating the coronavirus are currently in progress?
As part of a large Fraunhofer consortium, we are working on the development of next-generation protective textiles. These textiles combine robust filter capabilities with a high degree of comfort as well as functionalizations such as integrated antiviral properties. Based on feedback from our partners during the first wave of the pandemic, we identified a strong demand for such textiles. As part of a second project, we would like to develop safety gloves that protect exposed areas of the skin from hazardous materials.

What other topics are you focusing on in the business unit? What makes collaboration with your department attractive to companies?
We research and improve materials for products in the health and personal care field with the goal of improving people's quality of life. In particular, we support our customers in the medical, personal care and environment sectors by developing new products that focus on the use of innovative materials as well as quality control. These are areas in which we have extensive know-how, first-class technical infrastructure and a deep understanding of our customers' needs that has been built up over many years. Typical applications include improving tooth paste, developing materials for implant surfaces and exploring sustainable raw materials for use in cosmetic products.

Which topics will characterize the year 2021?
The project to combat the coronavirus pandemic will deliver its initial results, which I am very much looking forward to. I am also excited about the next phase of the "matriheal" project, which we plan to establish as a startup. The team is developing materials for innovative wound dressings that can be used for treating extensive wounds, for example. Last but not least, I am looking forward to many good conversations with colleagues and partners in industry and science — and hopefully, these conversations will soon be happening on a regular, face-to-face basis once again.

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PULSATING WOUND DRESSINGS TO HELP EXTENSIVE WOUNDS HEAL MORE QUICKLY

Negative-pressure and oxygen therapy are currently well-established and methods that promote the healing of chronic, extensive wounds. Up until now, though, there have not been any application systems available that offer a combination of these two effective treatment methods. This is the starting point of the joint project "ProTect". Together with the 1+ Steri Medizinprodukte GmbH in Halberstadt and the University Clinic of Halle (Saale), Fraunhofer IMWS is working on a pulse lavage system intended to help large and small wounds heal more quickly using innovative coatings on a pulsating, flexible wound dressing.

When caring for wounds, dressings are used to absorb blood and wound fluids and simultaneously protect the wound from dirt, bacteria, and mechanical irritation. Dressings also influence the humidity and temperature conditions of the wound and therefore aid the healing process. Depending on the size and type of injury, there are various types of wound dressings available on the market.

A particular challenge is posed by patients who often stay in bed due to their immobility. Due to the increased pressure of the dressing, they often experience circulatory problems in the skin and therefore have a higher risk of chronic wounds, poorly healing, and very deep tissue damage, which is also referred to as decubitus. Various methods are used to treat such wounds at the present time.

Negative-pressure drainage systems are used in particular for very deep, extensive, and infected wounds. A sponge-like wound dressing that does not fuse with tissue is inserted into the wound to aid the healing process. A drainage hose is attached and adhered to the skin surrounding the wound with an adhesive film. At the end of the drainage hose, a negative pressure is created by a pump system, which then allows the wound fluids to be evacuated.

A disadvantage of this method, though, is its complexity and expense because it has to be applied under sterile conditions and the material costs are very high. In hyperbaric oxygen therapy, patients breathe pure oxygen under high pressure. This enriches the blood with oxygen, which in turn helps promote the healing process in the tissue of the wound. This type of therapy is an established method for treating diabetic foot syndrome. There is still no system currently available on the market, though, that simultaneously links negative-pressure therapy with an increased supply of oxygen to the tissue of the wound.

The joint project "ProTect" intends to change this situation. Within two years the researchers want to develop an innovative pulse lavage and wound dressing material that allows various types of treatment to be applied in parallel, especially to chronic wounds, while simultaneously eliminating the disadvantages of commonly used systems. Since this dressing is flexible, it will be easier to adapt it more precisely to the geometry of the wound. At the same time, oscillating between high pressure and low pressure like in a sine wave stimulates the metabolism and deforms the wound, which in turn promotes healing of the wound. Through the integrated labyrinth chambers, which are isolated from the pressure chambers, wound exudate can then be evacuated by connecting a vacuum pump. New and innovative coatings based on biological materials like chitosan, elastin, collagen, and gelatin applied to the plastic film of the wound dressing are intended to aid the healing process, for example by binding excess enzymes in the wound exudate. In addition, the dressing should be significantly more comfortable, and thus reduce the suffering experienced by patients.

The researchers see good opportunities for the innovative product on the market since it eliminates many of the disadvantages of currently available systems used to treat chronic wounds. Due to the demographic transition, the demand for such treatment methods is growing. In addition, the wound drainage to be developed will also be applicable without the additional advantages of the protein coatings, so that it can be assumed that further products for wound treatment will be developed on the basis of the results.

Elastin-based protein sponges imitate the properties of the skin and are very suitable for the treatment of deep wounds due to their high absorption capacity.

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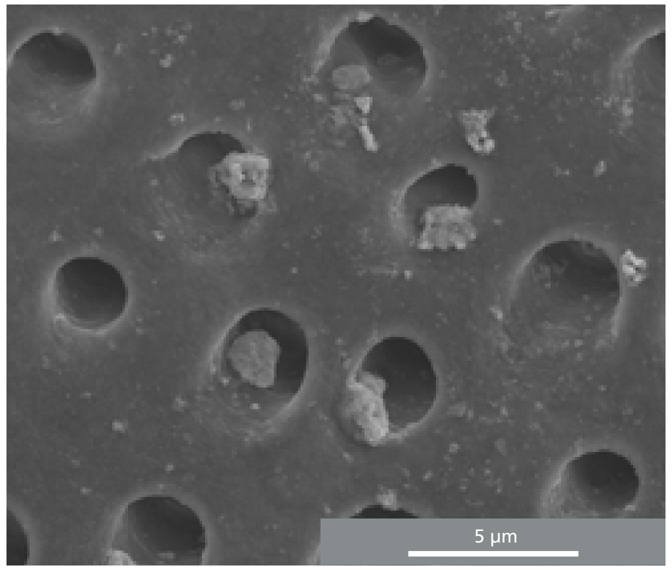
FRAUNHOFER IMWS SUPPORTS THE DEVELOPMENT OF TREATMENT METHODS FOR DENTIN HYPERSENSITIVITY

When cold or hot food and drinks, sweets, sour or salty foods cause pain in the teeth, this is called dentin hypersensitivity, which is mainly caused by exposed tooth necks. On behalf of Omya International AG, one of the world's leading suppliers of industrial minerals, scientists from the Fraunhofer Institute for Microstructure of Materials and Systems IMWS tested functional mineral particles that possess desensitizing properties in a toothpaste and can thus prevent symptoms.

The cause of hypersensitive teeth is receding gums due to chronic inflammation or incorrect brushing habits. As a result, the neck of the teeth, which is made of dentin permeated by tubules (tubules), is exposed without protection. The liquid-filled tubules form a connection to the inside of the tooth, through which external stimuli are transmitted to the dental nerve. The oral and dental care industry is therefore working on the development of pain-reducing or pain-relieving dental care products, which contain e.g. silica particles and cause the mechanical closure of the tubules.

Omya International AG's novel particles are suitable for the desensitization of sensitive teeth. Omyas patented technology functionalizes calcium carbonate particles with a shell of hydroxyapatite, which is the main component of enamel and dentin. The particles thus penetrate the tubules during the brushing process and effectively seal them.

During the development process of the particles, the Fraunhofer IMWS provided support by evaluating their mode of action. Through in vitro tests and microstructural investigations the researcher performed, it was shown that the particles in a toothpaste formulation interact with the tooth surface. Using scanning electron microscopy and calorimetric flow measurements, they were able to show that the tubules are filled with the particles and are even entirely sealed in some cases. Conversely, an interruption of the stimulus transmission can be deduced from this for the clinical situation and a desensitization can be concluded.



The novel Omyadent particles, tested in a toothpaste formulation.

The Omya collaboration, which has existed since 2016, demonstrates that the Fraunhofer IMWS is not only an attractive research and development partner for customers in the dental care end product sector, but can also make important contributions to the development processes of raw materials in collaboration with the R&D departments of suppliers.

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OPTIMIZED MICROFILMS FOR LONG-TERM DATA STORAGE

For long-term archiving of data, analog media like microfilms are still among the most favorable storage systems. However, the films can be damaged over time by microbiological and biochemical degradations or layer ablation. In a joint research project, Fraunhofer IMWS and Filmotec GmbH Bitterfeld-Wolfen are working on implementing new material solutions for a longer lifespan.

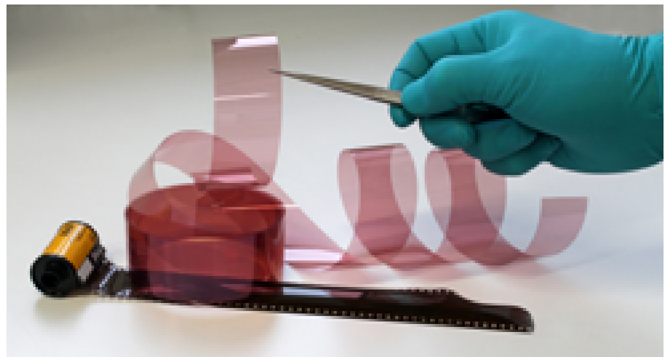
Due to their short shelf life and constant technological development, data stored on digital media can become unreadable within just a few years or have to be repeatedly converted to other data processing systems at high cost and with data loss. Long-term archiving of sensitive data is therefore still preferably carried out on analog media such as microfilms. With a predicted lifespan of several hundred years, if stored under certain temperature and humidity conditions, these are extremely stable over the long term and are also absolutely forgery-proof.

The films consist of an approximately 100 µm thick transparent film carrier made of polyethylene terephthalate (PET) with an approximately 10-15 µm thick emulsion coating containing silver halides in several layers. The emulsion layer is covered at the top by a gelatin protective layer and may be enclosed at the bottom by an antihalation layer.

However, the bond between these ultra-thin layers is susceptible to disruption: they can detach from each other or be damaged by microbiological attack. The individual layers can also potentially stick together, which can destroy the films if they separate. The joint project aims to significantly improve the resistance of the films to these mechanical, chemical and biochemical environmental influences and thus their long-term stability.

To achieve this, the surface of the PET base is modified by atmospheric plasma treatment with added nitrogen-based adhesion promoters to demonstrably improve the adhesion of the emulsion layers. In addition, environmentally compatible biocides are added to the emulsion layers to prevent biochemical attack and material destruction by microorganisms. For this, selected essential oils have been proven to be a very effective alternative to phenol, which is otherwise frequently used, since the latter is classified as hazardous to health and environment.

Within the project, extensive morphological, chemical and mechanical, as well as functional investigations are performed at the partner FilmoTec GmbH, to ensure the suitability of the adapted and optimized film materials for their target application.



Analog microfilms are used for long-term archiving. Research and development work should lead to longer long-term stability.

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"WE SUPPORT COMPETITIVENESS IN THE LIGHTING INDUSTRY"

Interview with head of business unit Prof. Dr. Stefan Schweizer

What were the most important research results at the Fraunhofer Application Center in Soest in 2020?
Our patent for measuring temperatures using phosphors was issued. This solution, which is described in more detail on the next page, has great potential for many fields of application, which in turn creates many possibilities for commercialization. We have also achieved further advancements in the use of luminescent glass for lighting technology, such as extending the service life of white LEDs. I am delighted that our masters student, Michelle Grüne, received the Budde award from the South Westphalia University of Applied Sciences and that she is staying with us as a new doctoral candidate.

What markets are you focusing on, and how can companies benefit from cooperating with Fraunhofer AWZ Soest?
Since our founding in 2013, we have established ourselves as a research partner for the lighting industry in this region and for companies in related sectors all over Germany, in close cooperation with the South Westphalia University of Applied Sciences. We provide comprehensive optical and spectroscopic analyses, thermal measuring techniques and laboratory-based performance testing for the assessment and development of phosphors, phosphor systems and materials. Through these services, we are supporting the future viability and competitiveness of the lighting industry.

What will be the central focus of your work in 2021?
With the application center in Soest having successfully completed its start-up phase, we are now in the process of further developing our strategy. Our industry partners have been sharing many valuable indications of their future needs with us, as well as the ways in which we can support those needs through our research expertise. At the same time, we intend to open up new research areas, such as applications in the area of medical treatments. To give you an ongoing example, we are currently running a project to develop an individually adjustable lamp that will provide optimal lighting conditions for patients with macular degeneration or even retinitis pigmentosa. We also intend to intensify our activities on the topic of infrared thermography.

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TEMPERATURE MEASUREMENT WITH PHOSPHORS

A research team at the Fraunhofer Application Center for Inorganic Phosphors Soest has developed and submitted a patent application for luminescent glass systems that change color according to the temperature. Theses glass systems can thus be used for temperature measurements.

Phosphors are by no means limited to applications in light engineering and lighting technology. A patent recently issued to the Fraunhofer Application Center Soest shows that they are useful for temperature measurements. The researchers developed a class of luminescent glasses which change their luminous color with temperature. This change is reversible, so the glass resumes its initial color when it cools. Luminescence is optically stimulated in the ultraviolet or blue spectral range, using an appropriate LED or a distant test laser, for example.

The invention has many possible fields of application, such as the indication of hot panes of glass. This could be, for instance, the glass window in an oven door or a ceramic hob. One advantage of luminescent glasses over conventional temperature measuring strips or thermochromic paint is that they can be molded in arbitrary shapes, expanding the range of design possibilities. The fact that luminescent glasses are colorless and transparent when they are inactive is another design advantage.

In the glass system developed by the Fraunhofer experts, two (or more) different metal ions from the rare earths group are optically activated. The different ions each have their own characteristic luminescence. When the temperature changes, the intensity ratio between the two rare earths changes accordingly, creating a different color impression. For example, when a glass system containing europium and terbium ions is used, the glass fluoresces red at room temperature (typical for europium), while showing a rich green fluorescence (typical for terbium) at a temperature of 500 °C. A continuous transition from red via orange and yellow to green occurs in between these two extremes.

Dr. Bernd Ahrens
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Luminescent glasses enriched with various metal ions under excitation with ultraviolet light.

"QUALITY ASSURANCE IS INCREASINGLY IMPORTANT FOR 3D PRINTING"

Interview with head of business unit Andreas Krombholz

The "Design and manufacturing" group was founded in 2019. What are its objectives and responsibilities?
Firstly, we are an internal service provider within the institute. Many of the research activities carried out at Fraunhofer IMWS require special test setups and other highly customized solutions for preparing or processing samples — these test beds and solutions are provided by our team. Then, as a group ourselves, we take part in research projects with industry partners and public customers. One area of focus here is new manufacturing technologies, especially additive manufacturing processes such as 3D printing. A second area of focus involves bio-based materials for applications in the construction sector.

3D printing has really taken off. How can Fraunhofer IMWS bring in its expertise in this rapidly growing market?
We focus on quality assurance on the one hand. This is an area where we have in-depth knowledge and decades of experience with many different types of materials. In the case of additive manufacturing technologies, quality assurance as a topic is still largely ignored. This also includes norms and standards for component inspection as well as suitable processes for material diagnostics. On the other hand, we work on the optimization of materials, either to improve existing materials or to make entirely new materials available for additive manufacturing. We develop new or improved "inks" for 3D printers, as it were.

What was the highlight of the work carried out by your team in 2020?
I was very happy to see how rapidly the demand for our expertise came into play — both internally and externally. In the case of additive manufacturing in particular, there are already many business units within the institute that are involved in this space, which means that our support can help create real value-added synergies. We also kick-started a number of projects, especially with SMEs based in Saxony-Anhalt. As a Fraunhofer Institute, our goal is also to help pool and expand existing 3D-printing expertise in the region. One of my personal highlights for 2020 was therefore the funding approval we received for our "QualiLab-3D" project. Our aim here is to build an infrastructure that will bring together many stakeholders in the region.

How exactly will this "QualiLab-3D" venture support companies in their use of additive manufacturing processes?
In 2021, we will be building an unrivaled lab; we will also be investing in new technology here, and we plan to cooperate closely with other research institutions too. The close ties between industry and science will help us tailor our services to industry requirements even more effectively; and conversely, our focused research and development will help create long-term competitive advantages for companies across the region. We will also be focusing on improving the reliability and service life of 3D-printed components, the development and modification of materials as well as the networked digitalization of materials and components in digital twin format.

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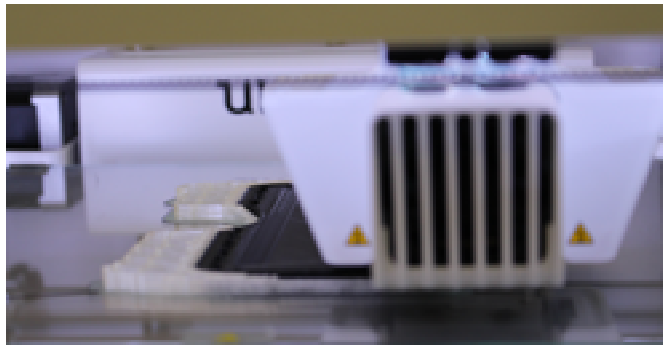
3D-PRINTED ANTIFOULING PACKING

Fraunhofer IMWS and the Staßfurt-based 3P Präzisions-Plastic-Produkte GmbH intend to develop new solutions for process engineering, such as for water treatment, using 3D-printed, electrochemically active polymer packing. They are focusing on a plastic that can conduct electricity and thus prevents the growth of microorganisms on the packing.



3D printing can be used to manufacture packing for use in water treatment.

Various technical processes are used to separate mixtures of substances; some well-known examples include absorption and distillation processes. The fields of application range from the petrochemical industry to the production of spirits. Water treatment is one particularly important area of application. In process engineering, tall, cylindrical containers known as columns are often used for separating substances. They are designed to allow for optimal separation of the materials they contain. In certain processes, the columns contain additional packing made of glass, ceramics, metal or plastics. They are generally only a few centimeters in size, but their special shape further improves the separation process by ensuring good distribution of the liquid and turbulence of the gas flow within the column.

While the system is in operation, the packings are exposed to the surrounding media. For example, during wastewater treatment or in desalination plants, the water also contains bacteria and microorganisms such as algae, as well as single-celled organisms and fungi, which gradually settle on the packings. This "biofouling" reduces the efficiency of the packing and thus of the columns as well, ultimately leading to a breakdown of the process. The cooperating partners intend to develop a solution for this problem in a project set to run until April 2022. They are focusing on electrochemically active packing that is manufactured via 3D printing.

The aim is to produce the packing from electrically conductive polymers, which can be used in corrosive media. The conductivity of these polymers is the key to sufficiently eliminating biofouling. The first stage will therefore be to develop a suitable plastic compound and use it to create a filament that can function as a base material for 3D printing. As a printing method, the project partners are focusing on the established fused deposition modeling process (FDM, also known as fused filament fabrication).

In addition to developing compounds and filaments, the project also aims to find packing geometries that are particularly suited for use in columns. After a coating system has been applied to the packing to achieve an electrochemical antifouling effect in aqueous media, their efficiency is tested in terms of mechanics, electrochemical behavior, flow behavior and media resistance. During the research project, a digital twin of the newly developed packing will also be created to speed up the process.

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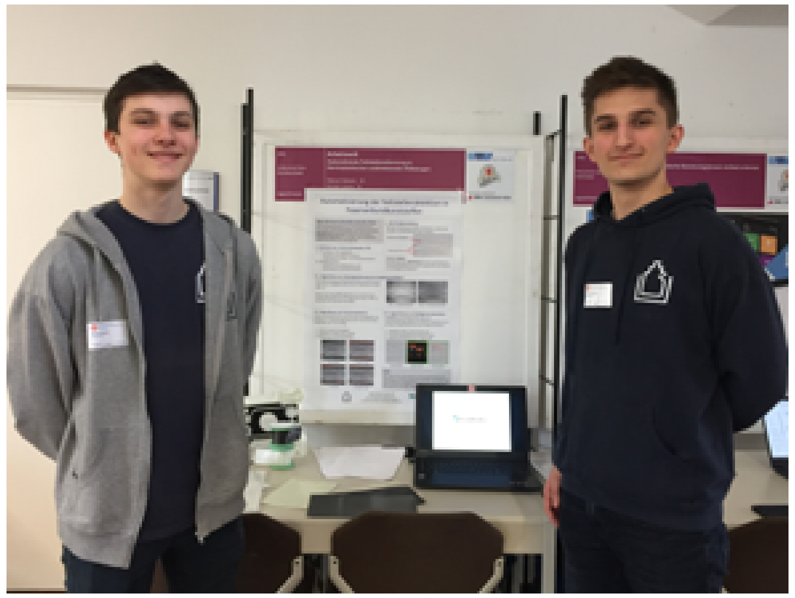
FACES 2020

In the "LignoDur" research project, ***Sven Wüstenhagen*** *is investigating the use of renewable natural fiber composite plastics (NFCs) as semi-finished products for lightweight design applications. This new type of NFC is intended to advance the sustainable industrial use of bio-based composite plastics, and could replace or supplement conventional fiber-reinforced plastics (FRP).*

In January 2020, the Center for Economics of Materials CEM, previously located at Fraunhofer IMWS in Halle, was transferred to the Fraunhofer Center for International Management and Knowledge Economy IMW, a customized location for its specialist field. Through applied socioeconomic research (center), ***Dr. Frank Pothen*** *and his now Leipzig-based team are developing solutions to support the long-term success of its customers and partners from the realms of business, industry, research and civil society.*

Roman Lezovic *and* ***Marius Erdmann*** *have won the regional competition of "Jugend forscht". At the Fraunhofer IMWS they programmed an algorithm for quality control of UD tapes.*



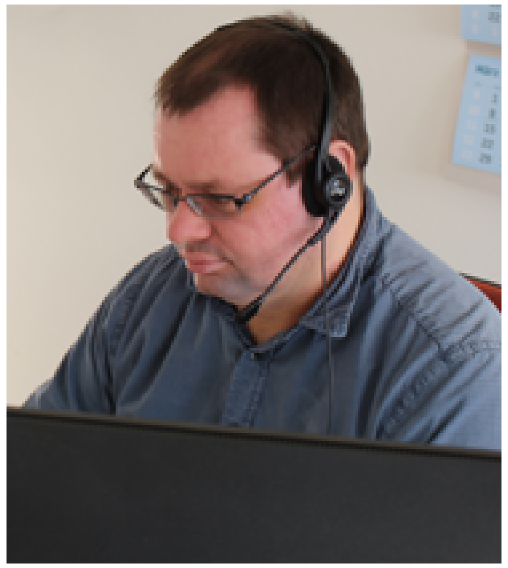
Together with Adele Ara from Lightsource BP, ***Prof. Dr. Ralph Gottschalg****, director of Fraunhofer CSP, runs SolarPower Europe's O&M and Asset Management Task Force. The task force focuses on creating innovative solutions and achieving maximum quality in operation and maintenance of photovoltaic systems.*

Dr. Sylvia Schattauer*, deputy head of institute, was elected to the board of the hydrogen network HYPOS e.V. for two years.*

Chemical recycling can be a key factor in reducing CO_2 emissions. At the invitation of the NK2 Network for a Circular Carbon Economy, over 30 business and science experts, as well as representatives from NGOs came together in Freiberg to discuss important questions on chemical recycling with network coordinator ***Roh Pin Lee****: What can technology achieve in this domain, both now and in future? What recycling sources and pathways will we need? And how can we quantify the contribution this approach can make to climate protection and a sustainable chemical industry?*

In September, a promotional video was shot for the Hydrogen Lab Görlitz (HLG), featuring appearances from ***Luisa Mehl*** *and* ***Maciej Satora****, among others. The HLG is a research platform aimed at developing innovative solutions along the hydrogen value chain. To achieve this, the HLG leverages synergy effects from the research expertise of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS and the Fraunhofer Institute for Machine Tools and Forming Technology IWU.*

At the Virtual Bioeconomy Day on October 1, 2020, ***Stefanie Celevics*** *discussed the fields of application for algae-based composites.*



Jörg Santilian *was one of the employees who found themselves especially in demand for the implementation of remote work in 2020. The institute purchased 97 web cams and 235 headsets.*

"OUR DAY-TO-DAY WORK CHANGED ENORMOUSLY AND AT GREAT SPEED"

At the end of February 2020, Fraunhofer IMWS was already responding to the COVID-19 pandemic by setting up a crisis management team. Head of administration Thomas Merkel reports on the challenges encountered and the effectiveness of the measures taken.

How was the decision made to respond to the COVID-19 pandemic by setting up a crisis unit?
In February, as more and more news started coming in about the new disease and its growing spread, it was clear to us that as an institute with worldwide connections we should be prepared for a pandemic situation. We already had a pandemic plan from the swine flu outbreak in 2006, which we were able to fall back on with some adaptations. To make up the crisis unit, we appointed representatives from the institute management team, the human resources department, the works council, the deputy equal opportunities officer and experts in occupational safety and crisis communication. Everyone exchanges information as needed — at the peak of the pandemic, it was several times per week — and is available as a point of contact for the workforce. This team composition and way of working very quickly proved its worth.

What were the biggest challenges?
Finding the right response to developments as they happened, and then communicating this response in a way that was easily understandable. Our primary goal is to protect the health of our employees. At the same time, we aim to stay available to our customers with the least restrictions possible. It's not always easy to strike that balance, especially not when external conditions such as the events of the pandemic or official and government requirements, are developing dynamically. I think we achieved good results. Our customers hardly had to face any restrictions in project work, and our internal hygiene and prevention measures worked well.

How did people respond to the measures?
When we had to restrict access to the buildings or largely put a stop to business trips, for example, almost all the institute's customers and partners responded in a very understanding way. It quickly became apparent that in this kind of crisis situation, we're all in the same boat. The regulations put in place by the crisis management team also received exemplary support internally, because we had focused on transparency. We ran a survey to determine the degree of acceptance and were pleasantly surprised. It certainly wasn't always easy for everybody, but we all pulled together regardless.

How much did your day-to-day work change at the institute during the pandemic?
In one sentence: enormously, and at great speed. Within a very short space of time, we implemented many new digital solutions, shifted from working on-site to working remotely, adjusted regulations for working hours and developed solutions for childcare — all with great commitment and flexibility. I can only thank everyone who has supported us with this, and contributed to us coming through the coronavirus crisis so well so far. We will definitely be keeping many of the new processes and tools in place for the long term.

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PRIZES AND AWARDS

Ranked one of the "Most Innovative Companies in Germany" by Capital and Statista
Fraunhofer IMWS
3/1/2020 Hamburg/Germany

"German-African Innovation Incentive Award (GAIIA)"
Ralph Gottschalg
"SoDeCo" project to detect pollution and optimize cleaning operations in photovoltaic applications in deserts and desert-like regions in North Africa.
6/12/2020 Berlin/Germany

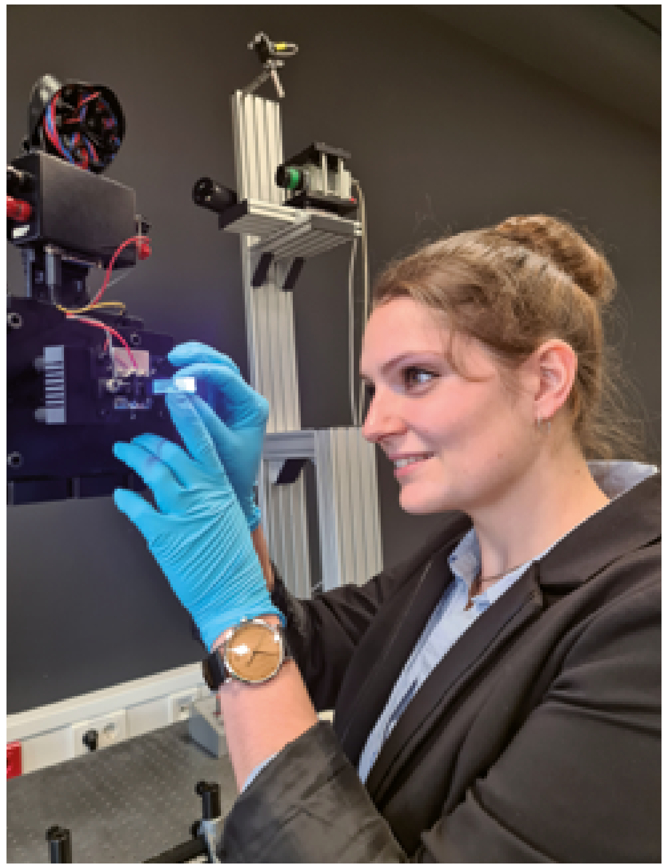
IQ innovation award for Central Germany (Overall award and life sciences cluster award)
Perio Trap Pharmaceuticals GmbH
The award was presented for a gentle and effective treatment for periodontitis, developed in cooperation with Fraunhofer IMWS (adhesion, wetting and rheological properties of the developed formulations).
6/26/2020 Halle (Saale)/Germany

IQ innovation award of the City of Halle (Saale)
Maria Gaudig from the Microstructured Material Design specialist group at the Institute of Physics at Martin Luther University Halle-Wittenberg
The award was presented for the development of new bipolar plates in fuel cells, supported by Fraunhofer IMWS through investigations of the microstructure of the titanium composite material, as well as its electrical, mechanical and electrochemical properties.
6/26/2020 Halle (Saale)/Germany

Oral-B blend-a-med prophylaxis prize 2020 from the German Society of Pediatric Dentistry and P&G Oral Health
Andreas Kiesow und Maria Morawietz
"Impact of self-assembling peptides in remineralization of early enamel lesions adjacent to orthodontic brackets detected"
7/2/2020 Hamburg/Germany

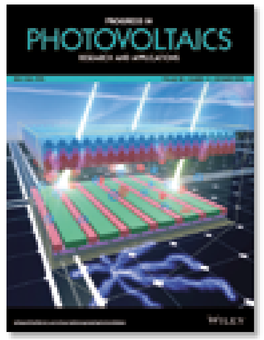
EU PVSEC "Best Poster Award"
Hamed Hanifi
"Novel PV module interconnection design and mounting orientation to reduce homogeneous soiling losses in desert regions"
9/14/2020, virtual conference

South Westphalia University of Applied Sciences Budde award
Michelle Grüne
Master's thesis on the application of luminescent glasses for light and illumination technology
11/30/2020 Soest/Germany



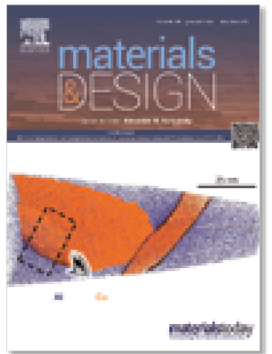
PUBLICATIONS

Highlight-Papers



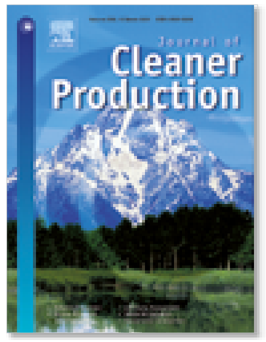
Salis, E.; Gerber, A.; Andreasen, J.; Gevorgyan, S.; Betts, T.; Blagovest, M.; Gottschalg, R.; Kodolbas, O.; Yilmaz, O.; Leidl, R.
A European proficiency test on thin-film tandem photovoltaic devices

Progress in Photovoltaics Research and Applications 28/12 (2020) 1258-1276



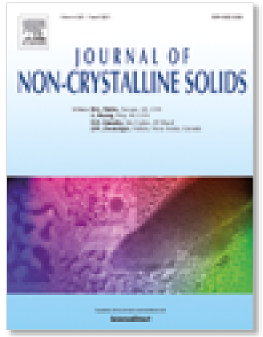
Zscheyge, M.; Böhm, R.; Hornig, A.; Gerritzen, J.; Gude, M.
Rate dependent non-linear mechanical behaviour of continuous fibre-reinforced thermoplastic composites – Experimental characterisation and viscoelastic-plastic damage modelling

Materials and Design 193 (2020)



Meyer, B.; Lee, R.P.; Keller, F.
Life cycle assessment of global warming potential, resource depletion and acidification potential of fossil, renewable and secondary feedstock for olefin production in Germany

Journal of Cleaner Production 250 (2020)

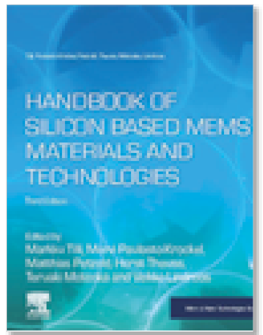


Briese, L.C.; Selle, S.; Patzig, C.; Hu, Y.; Deubener, J.; Höche, T.
Compositional study on the size distribution of Nickel nanocrystals in borosilicate glasses

Journal of Non-crystalline Solids 549 (2020)

de Oliveira, C. S.; González, A. T.; Hedtke, T.; Kürbitz, T.; Heilmann, A.; Schmelzer, C. E.; de S. e Silva, J. M.
Direct three-dimensional imaging for morphological analysis of electrospun fibers with laboratory-based Zernike X-ray phase-contrast computed tomography

Materials Science and Engineering C 115 (2020)

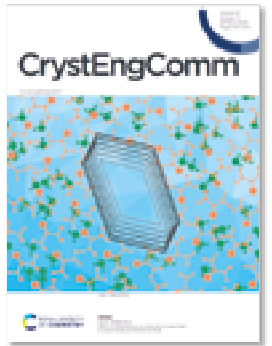


Tilli, M.; Paulasto-Krockel, M.; Petzold, M.; Theuss, H.; Motooka, T.; Lindroos, V.
Handbook of silicon based MEMS materials and technologies, third edition

Elsevier, Oxford, England (2020)

Grüne, M.; Rimbach, A.C.; Steinbrück, J.; Schweizer, S.
Colour shift of Dy3+-doped lithium aluminoborate glass

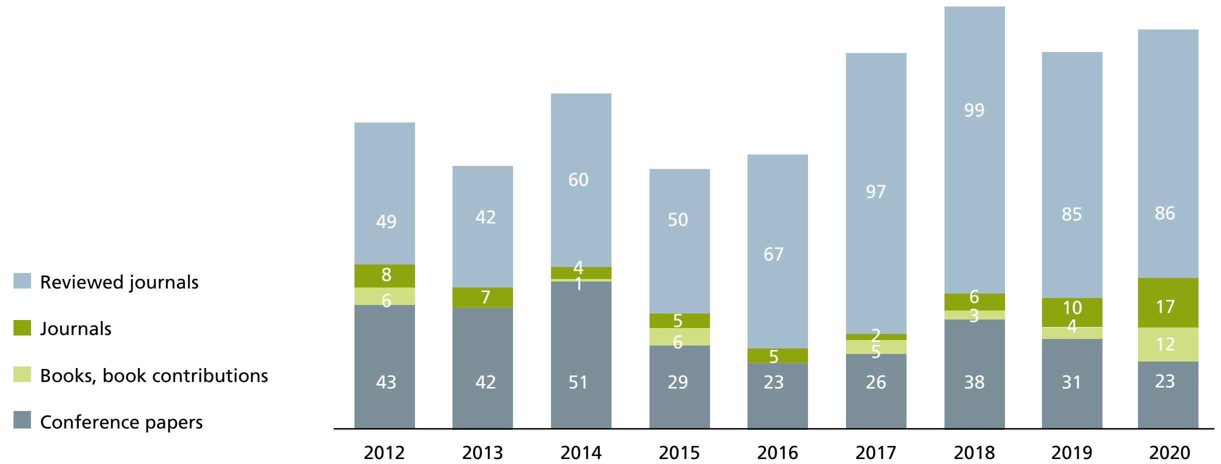
Journal of Luminescence 223, 117215 (2020)



Thieme, C.; Thieme, K.; Höche, T.
Tunable pore size in diopside glass-ceramics with silver nanoparticles

CrystEngComm 22 (2020) 2238-2246

Publications total



PATENTS AND DISSERTATIONS

Granted patents 2020

Nolte, Peter / Ziegeler, Nils Jonas / Schweizer, Stefan
Method for determining the spatially resolved thermal structure function and/or time constant spectra of an object
Patent-Nr. DE 10 2019 214 472.1

Glaubitt, Walther / Hagendorf, Christian / Ilse, Klemens / Mirza, Mark / Naumann, Volker
Surface coating and method for reducing the susceptibility of an object surface to contamination
Patent-Nr. EP 3 431 200

Dissertations

M. Sc. Varun Danke
Martin Luther University Halle-Wittenberg
Structure formation in nano-layered comb-like and linear precision polymers

M. Sc. Victor Gonzalez
Technical University Bergakademie Freiberg
Experimental investigations on lignite char gasification kinetics using a pressuniced drop tube reactor

Engineer Marco Götze
Martin Luther University Halle-Wittenberg
Laser-based structuring and fabrication of biomedical nanofiber nonwovens from electrospun polymers

M. Sc. Klemens Ilse
Martin Luther University Halle-Wittenberg
Microstructural investigation and simulation of natural soiling processes on PV modules

M. Sc. Magdalena Jablonska
Martin Luther University Halle-Wittenberg
Functional wet coating of generation of antifouling properties of netting materials in reverse osmosis filters.

M. Sc. Nicole Sonnenberger
Martin Luther University Halle-Wittenberg
Crystallization behavior of polymorphic pharmaceuticals in nanoporous CPG: influence of pore size and surface modification.

TECHNICAL INFRASTRUCTURE

NEW EQUIPMENT

Fraunhofer IMWS supports its customers with a unique and extensive range of services for failure analysis and material characterization. This includes technical equipment of the highest standard — within the Fraunhofer-Gesellschaft, Fraunhofer IMWS has the most comprehensive equipment for microstructure analytics. The institute's technical equipment is constantly being expanded and modernized so as to offer high-tech and first-class service to customers. Here is a selection of the new equipment introduced in 2020.

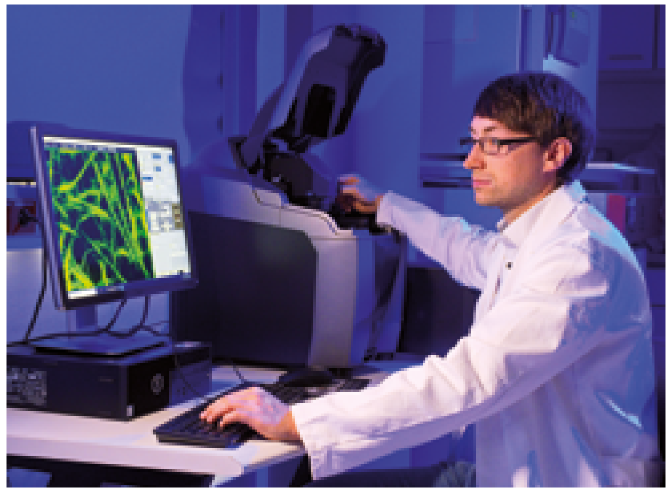
RECENSO pyrolysis test plant

The plant is suitable for applying catalytic tribochemical conversion (CTC) and for carrying out series of tests aimed at creating a reaction model or evaluating different feedstock and process parameters. The CTC process is a special pyrolysis process that is designed for use with liquid products, and differs from other conventional pyrolysis processes in the following ways:

- It can be applied to a wide range of feedstock and substance combinations
- The process temperature is under 400°C, which means it generates fewer pollutants
- Its only source of energy is friction, and includes the possibility of integrating renewable or surplus electricity
- The product has high liquid content
- It uses a catalyst as a consumable

Keyence compact fluorescence microscope BZ-X800E

The BZ-X800E is an inverted fluorescence phase-contrast microscope with an optical sectioning image mode to eliminate fluorescence blur. The motorized image stitching and the option of overlaying multiple fluorescence channels and/or phase-contrast imaging in real time allows large sample areas to be imaged. This will be used at Fraunhofer IMWS for inspecting biofilm on surface-modified materials, in particular. When viewing the distribution of fluorescence-labeled microorganisms in foams, images can be processed using the Z-stack and displayed as 3D volumes. Merging the Z-stack images enables the generation of fully focused images to capture multiple focal planes in an image and eliminate blurring due to uneven/non-planar sample surfaces. Thanks to the simple structure of the microscope with its built-in darkroom and intuitive controls, research findings can be generated efficiently.



EVENTS AND TRADE FAIRS

Professional events (co-)organized by the Fraunhofer IMWS

Theme Day of the Carbon Composites e.V. (CCeV) - Data from automation for the process analysis of the CCeV working groups
01/23/2020, Schkopau

Workshop on quality assurance from the perspective of an EPS
02/04/2020, Halle (Saale)

Composite-Sandwich Conference 2020
02/05-06/2020, Halle (Saale)

Chemical Recycling Workshop
02/25/2020, Freiberg

XRM Workshop
03/03/2020, Halle (Saale)

Quality assurance in generative manufacturing
09/08-09/2020, Halle (Saale)

InnoSynfuels project meeting
10/05/2020, Freiberg

Meeting of the network "NK2": "Chemical storage of renewable hydrogen in CO2-neutral fuels - potentials, raw materials, perspectives".
10/08/2020, Ennigerloh

Plasma Technology Workshop
12/16/2020, digital event

Experts from industry and research exchanged views on the trends and possibilities of sandwich construction with fiber-reinforced plastics in three sessions during the Fiber Composite Sandwich Conference in Halle (Saale).

Other publicity events

Handover of the grant for electrolysis test and trial platform
03/04/2020, Leuna

Groundbreaking ceremony for electrolysis test and trial platform
08/06/2020, Leuna

Dr. Markus Wolperdinger, head of Fraunhofer IGB, Dr. Sylvia Schattauer, deputy head of Fraunhofer IMWS, and Prof. Dr. Armin Willingmann, Minister for Economics, Science and Digitalization of Saxony-Anhalt (from left), completed the groundbreaking ceremony for the electrolysis test and trial platform.

NETWORKING

Fraunhofer IMWS is actively involved in numerous networks with partners from industry, science and civil society, both within Fraunhofer and with external institutions.

NETWORKING WITHIN THE FRAUNHOFER GESELLSCHAFT

- Fraunhofer Group for Materials and Components — MATERIALS
- Fraunhofer Group for Microelectronics (guest membership)
- Fraunhofer Energy Alliance
- Fraunhofer Lightweight Design Alliance
- Fraunhofer Technical Textiles Alliance
- Fraunhofer lighthouse project MaNiTU
- Fraunhofer Science, Art and Design network
- Fraunhofer Academy

As part of the Fraunhofer program for providing funding for SMEs, the following projects were started in 2020:

StressRed
This project's objective is to develop stress-reduced organic compounds that prevent intrinsic hydrostatic stresses on electronic controls and sensors when used in harsh environments.
Contact: sandy.klengel@imws.fraunhofer.de

Bio-Hybrids
The aim of this project is to strengthen a metallic new mobility component with a natural fiber-reinforced plastic based on biopolymers (BIO-NFK), which will then be post-functionalized with biopolymers through an injection molding process.
Contact: patrick.hirsch@imws.fraunhofer.de

ArtDentin
Desensitizing dental care products are tested during development for their ability to occlude exposed dentin tubules (dental canaliculi). The aim is to develop a ceramic-based material to replace natural dentin and further develop an already established testing method.
Contact: maria.morawietz@imws.fraunhofer.de

NANOINT
The aim is to establish a new innovative joining process in microelectronics that makes it possible to electronically join wafers and structural elements using extremely tightly constructed copper contacts, and thus advance the miniaturization of microelectronics.
Contact: andreas.graff@imws.fraunhofer.de

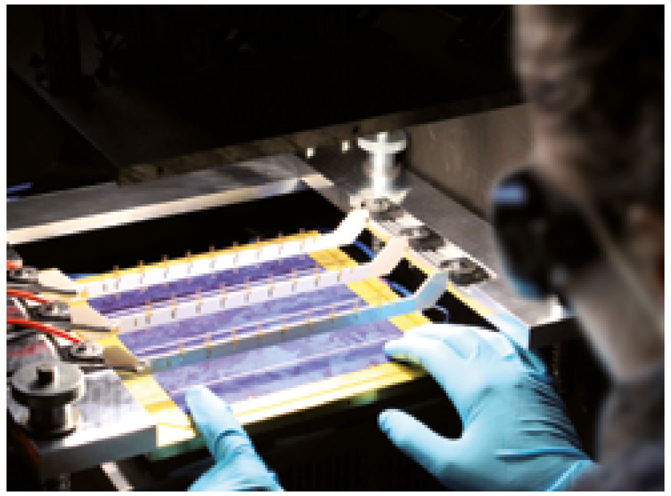
NETWORKING WITH EXTERNAL PARTNERS

- High-Performance Center: Chemical and Biosystems Technology
  www.chemie-bio-systemtechnik.de
- German research foundation (DFG) collaborative research center for polymers under multiple constraints
  www.natfak2.uni-halle.de/sfbtrr102
- BMBF BioEconomy leading-edge cluster
  www.bioeconomy.de
- BMBF Leading Edge Cluster: SolarValley Central Germany
  www.solarvalley.org
- BMBF Zwanzig20 HYPOS project
  www.hypos-eastgermany.de

OUR MISSION

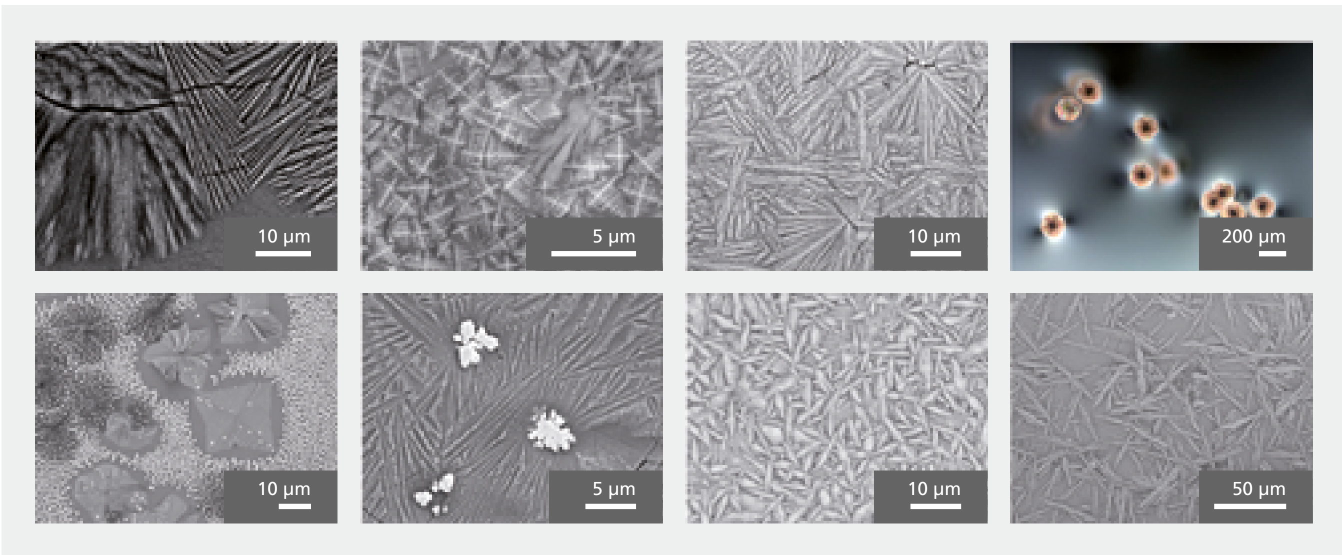
By allowing material diagnostics samples to be prepared faster and more reliably, the microPREP^{TM} device demonstrates our expertise in developing equipment and devices.

Microstructure-based technology development and diagnostics for efficient and reliable materials, components and systems.



"Microstructure diagnostics" — our core competence: A solar cell is tested in the solar simulator. This allows defects to be detected and degradation processes to be described.

The work of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle (Saale) builds on the core competencies in high-performance microstructure diagnostics and microstructure-based material design. The institute therefore researches issues related to functionality and operational behavior, as well as the reliability, safety and durability of innovative materials in components and systems. These components and systems are used in various markets and business fields that are of high importance for social and economic development. For the benefit of its industry partners and the public sector, Fraunhofer IMWS aims to contribute to the development of new materials, enhance material efficiency, boost profitability and minimize the use of resources. The institute thus plays an important role in ensuring the innovative capacity of important future fields with regard to materials and technologies, as well as to sustainability as a central challenge of the 21st century.

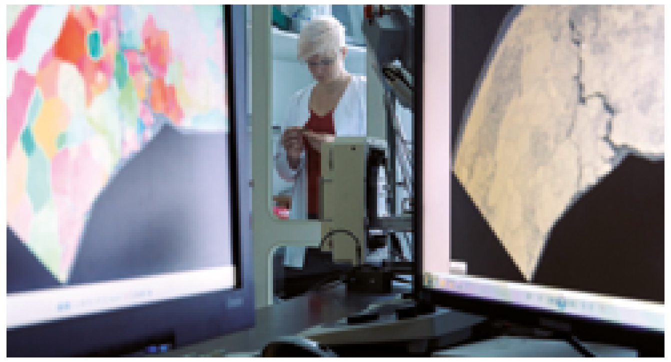


"Microstructure design" — our core competence: Homogeneous volume nucleation enabled the development of the low-expansion ceramic LEAZitTM.

CORE COMPETENCIES

Microstructure diagnostics – discovered by the Fraunhofer IMWS

The Fraunhofer IMWS possesses outstanding know-how, and within the Fraunhofer-Gesellschaft it is able to offer the most comprehensive range of equipment for microstructure diagnostics. This allows us to determine the microstructural characteristics of materials and components down to the atomic level together with the resulting properties for applications. We use the microstructure, above all the microstructure of semiconductors, polymers and biological materials, in correlation to local properties so as to harness performance reservoirs.



Using ultramodern technology we can obtain deep insights into materials and their behavior in practical use.

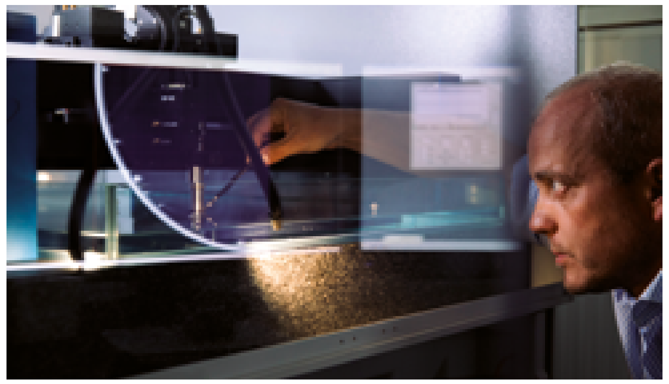
Microstructure design – designed by the Fraunhofer IMWS

Our understanding and control of microstructure allow us to intervene in fundamental material characteristics. Using microstructure design, we are able to provide our material know-how even during the development phase, and we can support our clients at the start of the value chain with materials that are perfectly designed for each application. In doing so, the Fraunhofer IMWS makes an important contribution to resource efficiency and competitive strength of its clients; allowing for more high-performance materials and opening up new application fields.

UD tapes made from fiber-reinforced plastics are processed to obtain exceptionally lightweight and robust components.

Developing testing equipment – engineered by the Fraunhofer IMWS

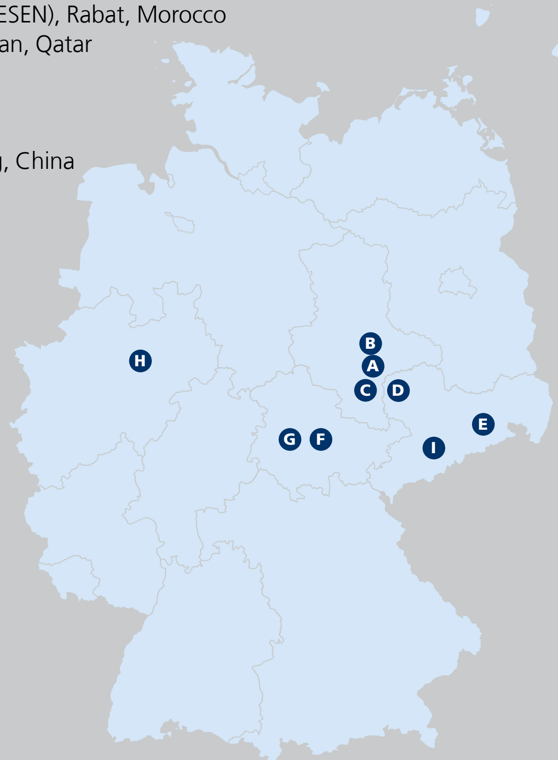
Successful microstructure analytics that meet our clients' needs is only possible through high-quality instrumentation. The complex questions posed in research and development, along with new methods and materials, require perfectly tailored equipment. And so – based on our many years of experience with existing technologies – we are increasingly working on the development of new devices. Our long-term collaborations with our industrial partners are an essential part of this.



An acoustic microscope enables the tiniest cracks in materials to be detected without destroying samples.

PARTNERSHIPS WITH UNIVERSITIES AND INSTITUTES OF HIGHER EDUCATION

1 Rensselear Polytechnic Institute RPI, Troy, New York, USA
2 CIC nanoGUNE Nanoscience Cooperative Research Center, San Sebastian, Spain
3 Institute of Scientific Instruments of the Academy of Sciences of the Czech Republic (ISI), Brno, Czech Republic
4 Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN), Rabat, Morocco
5 Qatar Environment and Energy Research Institute QEERI, Ar-Rayyan, Qatar
6 Hanyang University, Seoul, South Korea
7 Korea Institute of Energy Research KIER, Daejeon, South Korea
8 Yeungnam University, Gyeongsan, South Korea
9 University of International Business and Economics (UIBE), Beijing, China
10 Shanghai Advanced Research Institute SARI, Shanghai, China
11 Baotou Research Institute of Rare Earths (BRIRE), Baotou, Inner Mongolia, China



A Martin Luther University Halle-Wittenberg, Burg Giebichenstein University of Art and Design Halle
B Anhalt University of Applied Sciences
C Merseburg University of Applied Sciences
D University of Leipzig, Leipzig University of Applied Sciences
E Technical University Dresden
F Schmalkalden University of Applied Sciences
G Technical University Ilmenau
H South Westphalia University of Applied Sciences (Soest)
I Technical University Bergakademie Freiberg

SUSTAINABILITY REPORT

Our company cars only covered a total of around 95,000 kilometers in 2020, which is less than half the figure from the previous year. Of course, this contribution to sustainability has not been entirely voluntary — numerous symposiums, meetings with customers and other events were canceled over the year due to the coronavirus, and we also purposely reduced employee mobility to minimize infection risks.

In addition to the almost 22 tons of carbon dioxide emissions this saved, we have implemented and further optimized sustainable and efficient processes at Fraunhofer IMWS through a variety of other activities. For example, free cooling is used in the winter months in the new part of the building at our location in Heideallee. This substantially reduces energy consumption when the research equipment is operated. At the Otto-Eißfeldt-Straße location, energy consumption was reduced by 5 percent in comparison to the previous year. The energy needed for heating in buildings at the Walter-Hülse-Straße location was reduced by 8 percent in comparison to 2019; further optimization of the ventilation system and an electronic room temperature control system that had gone through successful testing contributed to this reduction.

Fraunhofer IMWS also supports the social aspects of sustainability, for instance with regard to civic engagement and citizen science. For example, the institute has founded a network for sustainability in business, in cooperation with the Halle-Dessau Chamber of Commerce and Industry, the Halle Chamber of Crafts and the Anhalt University of Applied Sciences, in order to create stronger links between topics in the fields of social innovation and sustainability. The open, independent network supports communication on an equal basis between industry and stakeholders from civil society, with the aim of evaluating and encouraging the acceptance and discovery of potential options for sustainable solutions.

An initial workshop on the public utilities for the year 2050 helped to promote additional connections between regional public utility companies and energy suppliers, with the aim of effectively harnessing the potential of the EU Green Deal for regional climate transformation. Constructive discussions were held on cross-industry collaboration in the energy sector, including in terms of its potential as a link between the energy systems of the future, issues of social involvement and regional value creation using state-of-the-art technologies.

In the network for sustainability in business, partners from the region (shown here at a workshop) are working to increase acceptance of sustainable solutions.

OUTLOOK

In the approximately 30-year history of the Fraunhofer site in Halle (Saale), groundbreaking, foundation-laying and topping-out ceremonies have been more than just welcome occasions to meet customers, sponsors and colleagues from the academic world. They are also a very visible expression of the continuous development and growth of our institute. 2021 will offer further opportunities for this, and we will also expand our service offering for customers and invest in future-oriented topics in other areas.

In spring, we will be able to proceed with construction of **an extension building at the Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau**. The additional space, combined with the extensive new research equipment, will allow us to offer our customers even better opportunities for rubber composite development and thermoplastic-based lightweight design.

Plans are underway to **commence operations at the Hydrogen Lab Leuna** by the middle of the year. As the plant offers unique opportunities for testing the use of green hydrogen on a large scale — for the sustainable production of basic chemicals and fuels, for example — it is an important building block for our activities in relation to "Chemistry 4.0." With this plant, we will be offering the first electrolysis test platform in Germany that is fully integrated into a material flow network in the chemical industry. Naturally, we hope to actually be able to celebrate this occasion appropriately on-site with the institute's key partners, if the development of the pandemic situation allows it.

In any event, COVID-19 is expected to remain a dominant subject for Fraunhofer IMWS, whether in terms of its economic impact or its adverse effects on work flows at the institute. At the same time, 2021 will bring further results from the projects in the "Fraunhofer vs. Corona" program. With these projects, we aim not only to contribute directly to the pandemic response (by improving protective equipment through quality control for example), but also to increase our customers' competitiveness through our innovative efforts. This is one of the reasons that we intend to enlarge and expand our **biolab in Halle** in 2021. With its new equipment, it will open up new possibilities for materials diagnostics in the life science sector.

In addition, at the **Fraunhofer Center for Silicon Photovoltaics CSP**, plans are in place to expand the facilities for evaluating reliability properties and the causes of defects in photovoltaic modules. Additional future investments in equipment and lab infrastructure will address the rapidly developing **additive manufacturing** field of application. In cooperation with industry partners, researchers are aiming to gain a detailed understanding of manufacturing processes and quality issues, and to develop solutions for improving the reliability and service life of 3D-printed components. We are meeting the rapidly growing requirements of digitization by expanding our server infrastructure.

We can already reveal a few specific examples that we will be working on intensively in 2021. In numerous projects and in leading European consortia, we are contributing to the development of more efficient, yet also highly reliable electronic components, and creating the advanced evaluation and diagnostic technology that this requires. For microelectronics in particular, as a key factor in the digitization of industry and society, questions of technological sovereignty and resilience have gained new importance — another consequence of the pandemic.

In collaboration with its partners, Fraunhofer IMWS is aiming to pool additive manufacturing expertise in the region, especially in relation to possible industrial manufacturing processes and quality assurance.

We will continue to advance our activities in the field of hydrogen and carbon technologies through the lighthouse project "Waste4Future." In this project, we will collaborate with six other Fraunhofer Institutes on converting carbonic waste into "green" molecules that can be used as a sustainable raw material source in the chemical industry. The Hydrogen Lab, which we are establishing together with the Fraunhofer Institute for Machine Tools and Forming Technology IWU on the Görlitz Innovation Campus, is also set to become a reality. Hydrogen and lightweight design will be the core topics in a lighthouse project that will be launched jointly with Fraunhofer IWU (Zittau location) and the Technical University of Liberec in 2021. Talks are also underway regarding "MatriHeal", another spin-off of the institute, which aims to bring improved solutions for treating chronic wounds to the market, partially in response to demographic change.

All these projects, which have only been briefly outlined here, should and will be conducted in line with our principle of customer orientation. Spin-offs are no more an end in themselves than adopting new, flexible working formats or gaining new buildings with additional equipment. They serve to fulfill our mission of providing R&D services of the highest possible quality to our customers and contracting bodies. We will continue to work on this mission in 2021. The recently established and highly successful information exchange with our industry advisory boards has served as a vital catalyst for all these topics.

ORGANIZATION CHART

DIRECTOR: Matthias Petzold*, Thomas Höche (Deputy Director), Sylvia Schattauer (Deputy Director), Thomas Merkel (Head of Administration)

BUSINESS UNITS

ELECTRONIC MATERIALS AND COMPONENTS Frank Altmann*	FRAUNHOFER CSP Ralph Gottschalg	OPTICAL MATERIALS AND TECHNOLOGIES Thomas Höche	CHEMICAL CONVERSION PROCESSES Sylvia Schattauer	CARBON CYCLE TECHNOLOGIES (FREIBERG) Bernd Meyer	POLYMER APPLICATIONS Peter Michel	BIOLOGICAL AND MACROMOLECULAR MATERIALS Christian Schmelzer
Assessment of electronic systems integration Sandy Klengel	Diagnostics and metrology Christian Hagendorf	Microstructure-based material processing Michael Krause	H2-technologies** Sylvia Schattauer	Termochemical conversion** Jörg Kleeberg	Thermoplastic semi-finished fiber composites Ivonne Jahn	Characterization of medical and cosmetic care products Andreas Kiesow
Diagnostic of semiconductor technologies Frank Altmann	Module and system reliability Matthias Ebert	Mikrostructure of optical materials Christian Patzig	Hydrogen material analytics** Nadine Menzel*	System analysis and technology transfer** Bernd Meyer	Assessment of composite systems Ralf Schlimper	Biofunctional materials for medical and environmental applications Christian Schmelzer*
	Materials and processes Sylke Meyer			Process modelling and optimization** Bernd Meyer	Polymeric material design Mario Beiner	
APPLICATION CENTER FOR INORGANIC PHOSPHORS Stefan Schweizer				Chemical processes and catalysis** Sven Kureti	Thermoplastic composite parts Matthias Zscheyge	

* acting
** currently founded

INFRASTRUCTURE

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Human resources & travel management Constanze Pälecke	Legal issues & Compliance Thomas Merkel			

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