Fraunhofer IMWS

About the institute

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS is a methodologically oriented Fraunhofer Institute in the material sciences and materials engineering disciplines. The Fraunhofer IMWS is a contact for industry and public clients for all issues concerning materials and systems – with the objective of increasing material efficiency and profitability and to use resources carefully.

Annual Report 2021

Annual Report 2021

Research Highlights

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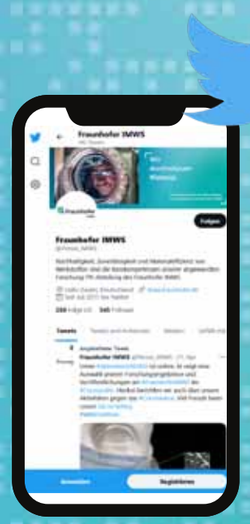

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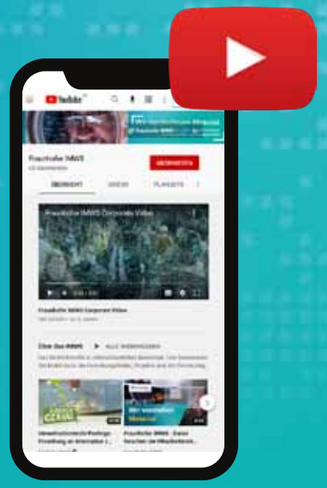

On YouTube you will find exciting videos about our work. It's worth watching!

Foreword

Dear readers,

For the third time, I have the pleasure of presenting to you some of the highlights of our institute's activities in this annual report. In my capacity as acting director, this will also be the last time. The process for the succession of the institute's management has finally been successfully completed. I am very pleased that we were able to win Prof. Dr. Erica Lilleodden to take over responsibility for the Fraunhofer IMWS from February 1, 2022.

In the past year we have worked intensively in research projects and in internal strategy processes to further sharpen the orientation of the institute and to expand our competencies in microstructure and material behavior research according to demand. Objectives and results of current work in this direction can be found on the following pages. These examples demonstrate that the value of the contributions Fraunhofer makes to its clients is not just innovation and creativity. Increasingly, the focus is also shifting to future topics aimed at sustainability and technology sovereignty in society or at the resilience of companies. In this context, too, the commissioning of our extension building at the Fraunhofer Pilot Plant for Polymer Synthesis and Processing PAZ in Schkopau, the collaboration in leading European consortia for the development of particularly reliable electronic components or the new Fraunhofer lighthouse project "Waste4Future" are among the outstanding activities in 2021. The launch of the Hydrogen Lab Leuna HLL was an important milestone for the large-scale activities on hydrogen electrolysis, which are now coordinated under the umbrella of the Fraunhofer Institute for Wind Energy Systems IWES, while at the Fraunhofer IMWS we focus our competencies on reliable materials for the hydrogen economy.

However, the fact that we were once again able to achieve a very positive economic and financial result in 2021 is not a matter of course in the second year of the pandemic. I am pleased that the new director of the institute will find a well-ordered house and that further development can proceed on a secure course. I am equally pleased that we have been able to rely continuously on your trust as our clients and partners in recent years, so that our Fraunhofer Institute will be able to celebrate its 30th anniversary in 2022. This success too, cannot be taken for granted, and so I would like to take this opportunity to express my sincere thanks to all our customers, sponsors, scientific partner institutions and employees. At the same time, I am very sure that under the new leadership of Prof. Dr. Erica Lilleodden – together with all of you – our institute will continue and successfully expand this development.

Prof. Dr. Matthias Petzold

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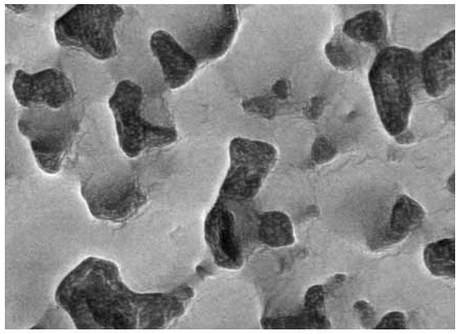

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Faces of 2021

Dr. Juliana Martins-Schalinski opened the digital event series "Materials Insights 20|21" in August. In a total of eleven sessions, the Fraunhofer IMWS presented current research highlights in a compact form. ▼

▲ *Dr. Stephan Großer from Fraunhofer CSP volunteers at the electron microscopy student laboratory. The extraordinary learning site is designed to inspire students about natural sciences and has moved into a new location at the Weinberg Campus in Halle (Saale) in 2021.*

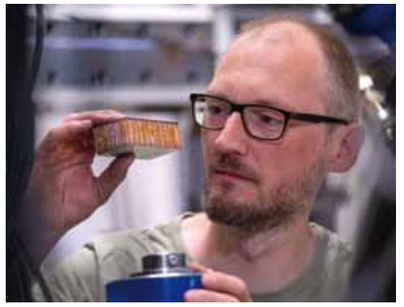
Institute Director Prof. Dr. Matthias Petzold (right) and former Institute Director Prof. Dr. Dieter Katzer (center) brought the greetings of the Fraunhofer IMWS – and a vine as a gift – to the 50th anniversary of the Fraunhofer IWM in Freiburg. ▼

▲ *Saxony-Anhalt's Minister-president Dr. Reiner Haseloff visits the cube at the Unity EXPO in downtown Halle (Saale). 36 students had built their "district of the future" with Lego bricks. The Fraunhofer IMWS showed the Hydrogen Lab Leuna (HLL) as a Lego model there on the Day of German Unity.*

◀ *The "Feminine Science Camp" of the Merseburg University of Applied Sciences was a guest at the Fraunhofer IMWS in August. The female students learned about research for better dental care and new applications for photovoltaics, among other things. Here Patrick Diehle presents the possible applications of electron microscopy.*

Stephan Hensel is part of the team that developed an industry-oriented platform at Fraunhofer CSP that combines statistical quality control and new approaches to data-based process analysis for measurement-based process control in the photovoltaic Industry 4.0. ▼

Our cooperation partner ThermHex Waben GmbH sold one million kilograms of organo-sandwichs in 2021. The lightweight material consists of two very thin, highly resilient cover layers and a honeycomb core. Here, our employee André Henkel examines a demonstrator component. ▶



▲ *A new approach to improving the efficiency of luminescent borate glasses and glass ceramics as temperature-stable light converters has been developed by Dr. Charlotte Rimbach at the Fraunhofer Application Center AWZ for Inorganic Phosphors in Soest, in collaboration with the South Westphalia University of Applied Sciences.*

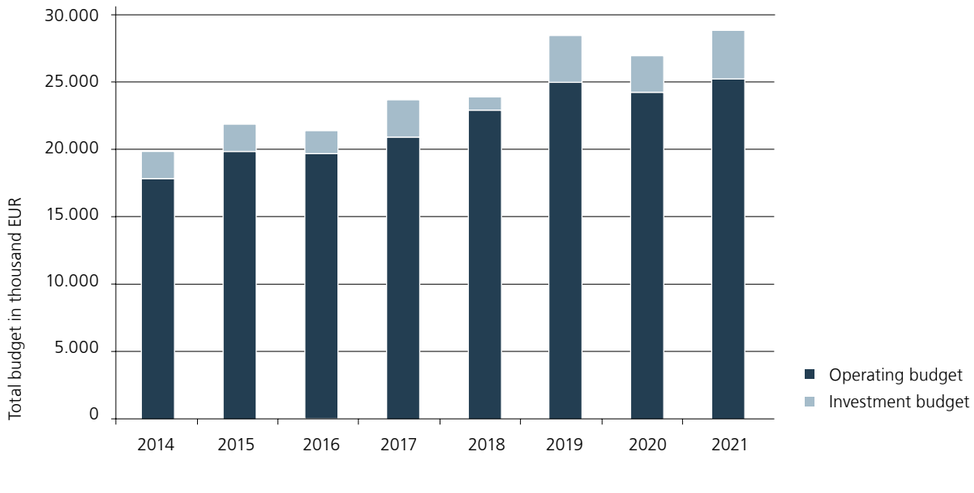
◀ *Dr. Klemens Ilse (second from right) welcomed a delegation from South Korea in October. A memorandum of understanding was also signed during the Germany-Korea Hydrogen Conference.*

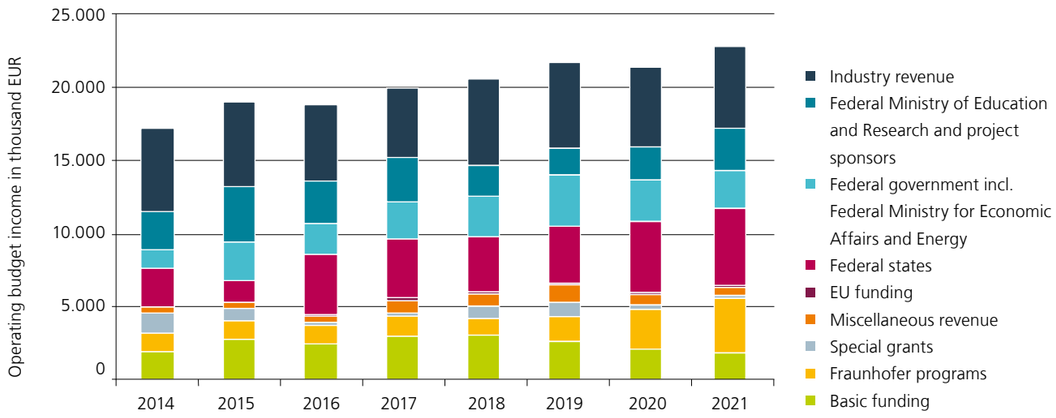
Institute in figures

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 25.1 million euros in 2021. 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 (basic funding). The share of industrial revenues in the operating budget 2021 is 24.6 percent. The 2021 investment budget amounts to 3.7 million euros.

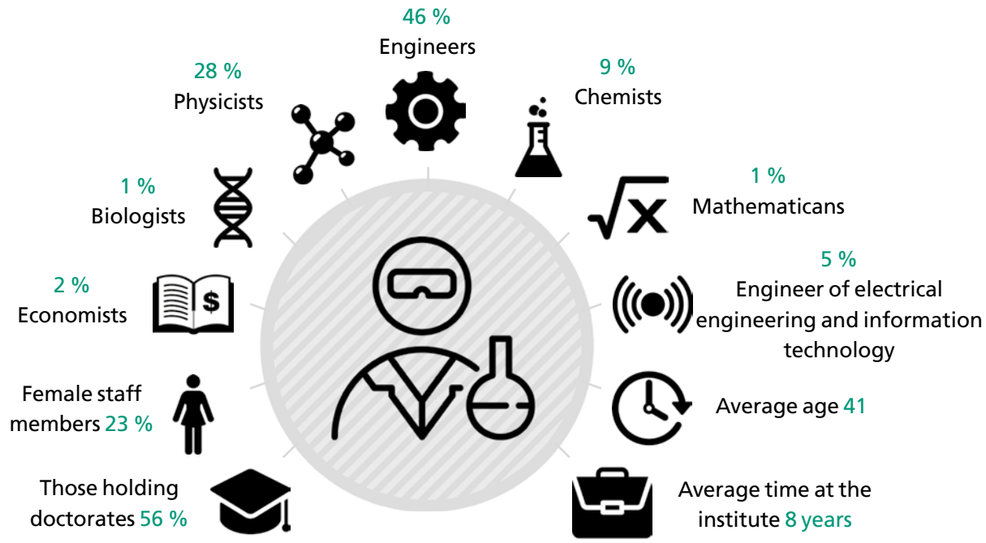




Staff

At the end of 2021, the Fraunhofer IMWS will have a total of 260 employees as permanent staff. This includes 110 scientists. Including trainees, scientific assistants as well as interns, the staff of the institute comprises 346 persons.

The scientific personnel at the Fraunhofer IMWS is comprised of:



Materials and Components for Electronics

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Efficient methods of failure diagnostics are enormously important

Interview with Head of Business Unit Frank Altmann

What were the highlights of 2021 for your business unit?

I was very pleased to see that we were again able to make important contributions to our clients within rapidly changing framework conditions, both in publicly funded, international consortia and in contract research with many component and diagnostic device manufacturers. Considering all that has changed since 2019 – new building, new business unit management, working under pandemic conditions – 2021 was a year of successful consolidation.

Recently, there has been frequent talk of the microchip crisis. How do you assess this? And how can the Fraunhofer IMWS contribute to a solution?

First of all, this term shows the large semiconductor demand especially in the automotive, industrial equipment, energy, communication and computer technology market segments. Due to supply bottlenecks, there is in-creasing pressure to bring alternative, less qualified manufacturers on board. This is where our work on quality assurance and reliability assessment of components and, increasingly, on checking supply chains for counterfeiting becomes all the more important. The enormously short development cycles also play a role here, and this is where our expertise in looking at material and process qualification and quality assurance is also crucial.

What exactly does your business unit's R&D offer to companies look like?

With our competencies and analytical capabilities, we can offer innovative solutions for improving the reliability and quality assurance of electronic components. The basis for this is our broad expertise in failure diagnostics, with which we cover the entire electronics supply chain from the semiconductor to the assembly and system level. For example, we can identify process- and application-related failure risks and evaluate the potential and limits of new component designs, materials and manufacturing technologies.

What do you expect for 2022?

The topic of trustworthy electronics is gaining enormous importance, and we are already active here in the "Velektronik" platform project, for example. The use of AI methods to automate and thus increase the efficiency of failure diagnostics, especially for complex failure modes, will also increase. Here I'm looking forward to the further progress of our "Failure Analysis 4.0" and "Intelligent Reliability 4.0" projects.

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Improved power electronic components for energy generation in offshore wind parks

Components improved for use in harsh environments

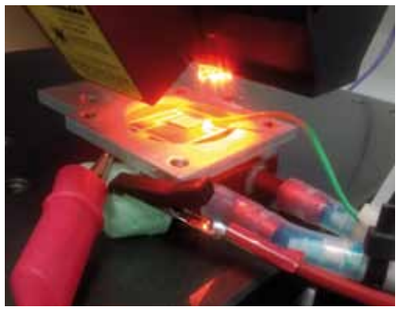
The components of offshore wind turbines are subjected to extreme stress.

Power electronics in wind turbines ensure that the fluctuating energy generated is fed evenly into the grid. The materials and components used in this process are exposed to extreme stress. Together with partners, the Fraunhofer Institute for Microstructure of Materials and Systems IMWS has now developed an approach for significantly more robust solutions. The new components from the chip to the system level, tested on a megawatt test bench, reduce switching losses, improve power density and reliability, and enable a 50 percent increase in life time.

Service life of components increases by **50%**

More than a quarter of the electricity generated in Germany now comes from wind power. A significant proportion of this is generated offshore. To make the wind turbines used in this process even more efficient and robust, Infineon Technologies AG, SEMIKRON Elektronik GmbH & Co. KG, Freqcon GmbH, nanoAnalytics GmbH and the Fraunhofer IMWS have significantly improved the power electronics components used in offshore wind turbines in a joint research project.

Power electronics have a central task in wind turbines: the stronger the wind blows, the higher the rotor speeds and the voltage generated in the generator. Power semiconductors compensate for these fluctuations and ensure that energy is transmitted evenly to the power grid. The components used are subjected to extreme stresses due to the heat generated during switching operations, external temperature changes, humidity, salt, high voltages as well as mechanical forces. Defects in power modules are therefore frequently involved in wind turbine failures, resulting in corresponding yield losses and maintenance costs.



Laser triangulation test of the surface deformation of an Insulated Gate Bipolar Transistor (IGBT) under thermal stress. This method of deformation measurement enables the determination of the intrinsic and thermomechanical stresses in the semiconductor and the joint after the sintering and soldering process.

The project partners' approach enables optimization in a wide range of areas, such as energy efficiency by reducing switching losses while increasing power density and reliability. It supports grid stability and increases the plants' resistance to environmental influences such as humidity and salt. The service life of the components can thus be increased from 20 to 30 years, which significantly reduces the costs of the overall system.

The Fraunhofer IMWS primarily contributed its expertise in materials characterization and developed improved methods for materials testing of packaging technology, both for the semiconductor components used, such as transistors and diodes, and for the various contacting concepts of the semiconductor chips. Only with targeted diagnostic procedures and analysis methods can the reliability and material properties be evaluated and defect mechanisms and failure risks identified at a very early stage. This enables the components to later withstand the stresses of use in wind turbines over the longest possible periods of use, during which they must undergo hundreds of thousands of thermal and electrical cycles.

Methods of high-resolution, nanoanalytical material characterization such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were used, and the applicability of new approaches to acoustic microscopy as a non-destructive alternative for corresponding questions was also investigated. In this way, the project partners were able to gradually select materials and manufacturing processes for new contact systems as well as the power modules based on them, which do not involve microstructural defects such as voids, delaminations, diffusion mechanisms or cracks. At the same time, new preparation methods were developed for the morphological and chemical analysis of the interfacial processes in the bonded joints, and a defect catalog for the identified defect mechanisms was formulated together with the partners.

The development work of the partners focused on double-sided sintered systems instead of wire bond and solder joints in order to make higher chip temperatures possible, the improvement of module cooling in the system or the further development of corrosion-resistant chip edge terminations. In parallel with development, it was possible to gain a profound understanding of sintered power electronics systems based on the new contact material systems, which is elementary for reducing defects and reliability risks.

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Data platform to increase efficiency and sustainability of copper alloy materials

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS wants to provide a platform with data on copper alloy materials along the entire life cycle together with partners. The data, which is linked by means of ontologies, connects materials characterization, alloy development, performance and service life through to recycling. This enables accelerated material development as well as the analysis of entire product cycles to make them both more sustainable and more productive - with full data sovereignty.

Digitalization offers considerable opportunities for the development of new copper alloys, more efficient use of the metal and better recycling options. The Fraunhofer IMWS wants to tap into these together with partners in the project "CopperDigital". The consortium relies on publicly accessible ontologies, i.e. a formally ordered representation of data and the relationships existing between them, to describe research, production and process data. Exchanging data between the partners in a machine-understandable way will significantly accelerate development cycles for new alloys and products, but also for defect detection.

The "digital material twin" will take into account material, testing, production process, simulation and recycling data that cover the entire life cycle of copper-based materials. Prerequisites for the development of a suitable ontology and a powerful data ecosystem in a virtual material data space are a suitable structure of the data and metadata as well as a systematization of the handling of hierarchical, process-dependent material data. The Fraunhofer IMWS is in charge of the sub-project "Microstructure and property correlation" and contributes, for example, its expertise in systematic microstructure analysis, theoretical finite element modeling as well as mechanical and standard-compliant characterization of copper and copper alloys to the digital data space.

The resulting data room can be used, for example, to simulate how new alloys behave over multiple scales and life stages, which promises to accelerate the development of new alloys with significantly different properties. The energy and raw material consumption of production processes can be optimized, and recycling sources and routes can be better evaluated. The approach can also be transferred to other materials such as steel or aluminum.

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Research projects for trustworthy electronics

In order to use electronics safely and reliably, it must be possible to trace where electronic devices come from, whether they function correctly and that they leave no backdoors for so-called hardware Trojans. The platform project "Velektronik" aims to develop new solution concepts. In the project "nanoEBeam", the Fraunhofer IMWS is also working on new methods for defending against cyber attacks at the hardware level.

A future-oriented society must be able to rely on electronic components whether in critical infrastructures, Industry 4.0 or in medical devices. Electronics are trustworthy when they meet all our expectations in terms of functionality, and at the same time do not leave any backdoors or vulnerabilities for attackers and manipulations. Whether this is really the case cannot always be answered unequivocally so far due to the complex and international value chains.

To use electronics safely and reliably, you have to understand what they do and how they are built.

In the "Velektronik" project, research institutes and companies established a networking platform for trustworthy electronics for Germany. The aim is to develop solution concepts for all areas of electronics development and production. The Fraunhofer IMWS contributes its competences in material diagnostics and development of methods for the verification of counterfeit protection and the detection of hardware Trojans. For example by evaluating suitable analysis methods for electronic components of different integration levels, the development of qualified analysis workflows and the verification of technology-specific features should make it possible to identify whether counterfeit components or backdoors have been smuggled in, so that companies can detect this at later stages of the value chain.

The "nanoEBeam" project is also developing strategies against hardware attacks of integrated circuits. The miniaturization of technology nodes below 20 nanometers means that the optical techniques most commonly used by attackers today are reaching their limits. Here, high-resolution electron beam probing and imaging techniques offer completely new possibilities for identifying vulnerabilities of ICs and exploiting them for hacker attacks. The findings of the project will be used to secure a knowledge advantage over attackers in the case of novel, nanotechnological components and, at the same time, to further develop failure diagnosis methods such as e-beam probing for the next chip generation.

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Fraunhofer Center for Silicon Photovoltaics CSP

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“We have the entire value chain in view”

Interview with Head of Business Unit Prof. Dr. Ralph Gottschalg

What were the highlights in 2021 for your business unit?

We have once again been able to expand our technical capabilities. With the industry-oriented measurement and classification platform “MK4”, we can offer even better support for process and data analytics in high-performance photovoltaic production. In the “Mon-KI” project, we have shown that we are very good at the “AI + PV” formula and how it can be used to optimize condition analysis and prediction of PV systems, better calculate energy yields and reduce maintenance work. We have established methods for material determination and quantification with LIBS and Thermo-GCMS, which can also quantify additives in polymers.

What R&D offerings can companies take advantage of in collaboration with Fraunhofer CSP?

Our core business is to support the photovoltaic industry in quality assurance and in optimizing their products in terms of performance, lifetime and reliability. We can provide recommendations on material selection, optimize production processes, and advise on installation, operation management, and IP conflicts. This helps to avoid risks and thus optimize yields. We have excellent technical equipment in solar cell diagnostics and metrology, failure diagnostics and root cause analysis of defects and degradation processes, as well as for polymer and chemical analysis and process evaluation and automation.

Most recently, the climate conference in Glasgow and the goals of the new German government were described as a new start for the energy transition. What role can photovoltaics play in this?

Providing the energy for a green power supply and new applications such as electromobility, heat pumps and green hydrogen is only possible with a greatly accelerated expansion of PV. A sustainable energy system needs good quality assurance. This is where we can support the industry.

What do you expect for 2022?

We have many ideas on how we can use our know-how to help optimize existing PV systems. I also expect the internationalization of our business unit to continue, for which we are very well positioned through our existing networks, cooperation with universities, collaboration on industry guidelines in the European industry association Solar Power Europe, or participation in the new “PV Camper” data platform.

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Current-based repair process for new solar cell technologies

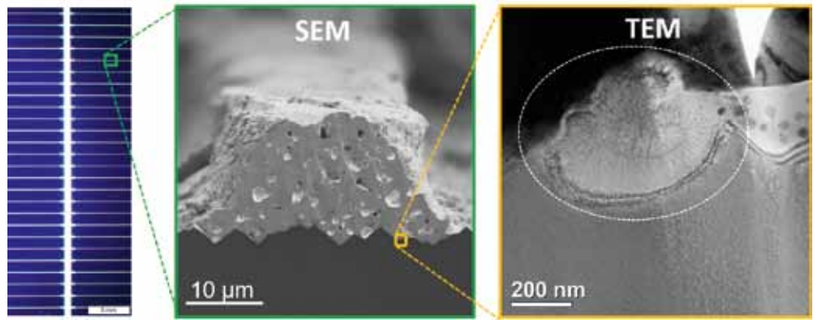
Reducing the series resistance of crystalline solar cells and thus increasing the efficiency

The next generation of solar cells will contribute significantly to a sustainable power supply on a global scale. For state-of-the-art technologies such as PERC (passivated emitter and rear cell), a team from the Fraunhofer Center for Silicon Photovoltaics CSP has now researched an active mechanism that can be used to optimize high-performance cells.

PERC stands for passivated emitter and rear cell. This enable greater luminous efficacy in the rear area of the cell and thus a higher current yield. PERC technology currently dominates the market, can be implemented in inexpensive mass production and enables even more powerful photovoltaics.

Since the highly efficient solar cells of new generations are not yet as well researched as standard technologies that have been established for decades, new causes of defects, degradation processes or risks of failure can also be associated with them. The team of the "Diagnostics and Metrology" group at Fraunhofer CSP wants to create solutions for this at an early stage. In a recently completed project, the diagnostics team collaborated with CE Cell Engineering GmbH, a company specializing in technologies and processes for optimizing crystalline solar cells.

Together, the project partners tested a new process for solar cell technologies, with the main aim of reducing the series resistance of crystalline solar cells and thus increasing efficiency. Contacting surface structures (emitters) of solar cells with high sheet resistance is currently technically possible, but costly. The series resistance of the contact structure on the solar cell increases due to high contact resistances, which significantly reduces the efficiency of a solar cell. In the project, however, the partners were able to reduce the series resistance by using laser-assisted current treatment and to elucidate the active principle.



In the project, power losses occurring in the area of high-impedance contacts were significantly reduced using the LECO process, and the associated mechanism of action was elucidated at the microstructure level. The figures show details of the contact points using scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The research team used a special test platform to examine faulty semiconductor-metal contacts.

The subject of the investigations was faulty semiconductor-metal contacts in the cells, where insufficient electrical contact was formed between the metal and the semiconductor. The team tested whether and to what extent the use of laser-assisted current treatment at the contact points improved the performance of the solar cell contacts. By elucidating the microstructure, the previously unknown physical mechanism of action of contact formation by the Laser Enhanced Contact Optimization process, also known as the LECO process, was identified at the interface between the metal and the silicon wafer. The LECO process represents a downstream process that improves the metal-semiconductor contacts, thereby increasing the yield of production. The optimization of the contacts is achieved through a large number of microscopic current-fired contact points, which enable a very low series resistance between the metallic silver contact finger and the doped silicon wafer.

The researchers at Fraunhofer CSP also applied for patents on novel methods for electrical characterization and evaluation of LECO process parameters. The conducted studies on the stability of the solar cells showed that the applied LECO process did not lead to any damage of the solar cells.

R&D activities form an important part of increasing the efficiency of solar cells and thus improving the competitiveness of solar energy and saving CO_2. The results of the research project are a helpful building block for the development and production of innovative machine technology for the world market.

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Material analysis of surfaces by laser-induced plasma spectroscopy

Laser-induced plasma spectroscopy, also known as laser-induced breakdown spectroscopy (LIBS), is an innovative optical surface analysis method with a wide range of applications.

LIBS makes it possible to determine the elemental composition of solid, liquid or gaseous substances without contact. At Fraunhofer CSP, LIBS technology is used in combination with powerful evaluation algorithms to perform precise multi-element analyses very quickly.

The application possibilities of the spectroscopic measuring method LIBS for qualitative and quantitative elemental analysis are manifold and range from basic elemental analysis in vacuum to the classification of raw materials for recycling. The principle is based on the spectral analysis of element-specific emission lines. A high-energy short-pulse laser beam knocks out a tiny amount, typically a few µm, from the sample surface, whereupon a light-emitting plasma is formed under local heating of up to 10,000 °C. The plasma glows with a material-specific light spectrum, and the spectral distribution of the light is recorded immediately in real time. From these data, the exact element distribution at the measurement point can be determined.

Since 2019, LIBS has been successfully used at Fraunhofer CSP for the analysis of element contents and distributions. The researchers support customers and partners from industry as well as public clients with their expertise in the field of plasma spectroscopy and help to control coating processes, optimize recycling processes or develop in-line capable material control. In doing so, they exploit the advantages that LIBS offers over competing methods: Analysis is non-contact, sample removal is low, and little sample preparation is required.

The powerful evaluation algorithms of the LIBS system enable fast and precise analyses of the occurrence and concentrations of the elements in the measuring spot of the investigated sample.

Fraunhofer CSP has demonstrated the performance of this method for determining the loss of fluorine content in the melting of bioactive glasses and glass-ceramics in a study together with employees of the Otto Schott Institute for Materials Research. Among the analytical methods, LIBS was chosen because it allows fluorine quantification with reduced analysis time and with a high spatial resolution.

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Colored solar modules in building facades for improved energy balances

Photovoltaic modules have been making a significant contribution to improving the energy balance of buildings for years. Now that the acquisition costs of modules have fallen rapidly, new demands are being placed on the design and construction of solar modules.

A joint project of the Fraunhofer Center for Silicon Photovoltaics CSP is pursuing new approaches. The project partners want to develop coloring concepts for facade solar modules with aesthetically sophisticated and individual design options as well as reduced color-related energy yield losses.

Placing solar modules on a flat roof has two decisive advantages: First, the solar radiation is highest there. Second, they do not interfere with the overall aesthetic impression of a building. If one wants to open up additional areas for the generation of solar power, the demands on the design possibilities increase.

The joint project "Light management and manufacturing concepts for colored photovoltaic modules in building facades" (Color PV) by Fraunhofer CSP, Hohenstein Isolierglas GmbH and Kogu Print & Werbetechnik GmbH & Co. KG starts at this point. The goal is a flexible display of different designs on solar modules with a wide range of colors and relatively high resolution, so that the display of photorealistic images is also possible. In contrast to most of the technologies investigated so far for coloring solar modules, which use spectrally selective coatings and thus only allow homogeneous, single-color surfaces with a very limited color selection, the project partners are focusing on digital printing processes and multicolor printing for a wide range of color shades as well as individual, semi-transparent color prints (Kogu Print). In addition, the potential of special interference-based inks with high light transmission for colored PV modules will be demonstrated and various structuring and lamination processes optimized.

Figure on the left: Retrofitting with photovoltaic modules in compliance with monument protection regulations as an application example for colored photovoltaic modules. Figure on the right: Black and colored photovoltaic modules as retrofitted facade of a residential block in Halle-Neustadt.

With the development of a colored, digitally printed facade solar module front with high light transmission in the relevant spectral range, the researchers are opening up new possibilities for facade design. The special feature of the project, which will run until January 2022, is the mapping of a complete value chain: from film and glass processing to digital printing and solar module production.

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Optical Materials and Technologies

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“We live disruption”

Interview with Head of Business Unit Prof. Dr. Thomas Höche

What were the highlights of 2021 for your business unit?

We succeeded in systematically exploiting opportunities that arose to strategically sharpen our activities. We have both sharpened the scientific lead and intensified our work with our industrial customers. We can now draw on a portfolio that we hope will provide a solid basis for our future development. With the disruptive approaches we are now pursuing, the know-how and creativity of our team, as well as our extremely powerful equipment, we have created the best conditions for repeating the development successes we have achieved together with 3D-Micromac AG with the preparation tool microPREP™ PRO in other areas.

So device development has become an important mainstay of the business unit alongside contract research?

In any case, for us it offers a very good opportunity to bring our methodological expertise directly into applications together with our partners. When a device like the microPREP™ PRO outshines solutions from established players worldwide, creates a veritable “community”, and is used by a very large number of many well-known companies, such as from the microelectronics industry. It makes us very proud and conveys the indescribable feeling that we have made a real contribution. Such an important contribution to industry makes the Fraunhofer idea tangible in the best sense.

Where do your customers come from and what are the advantages of working with your business unit?

Our customers come mainly from the the optical industry, special machine construction and the coatings industry. They use our know-how in research and development, especially in the application of microstructure diagnostic analysis techniques. Our microstructure expertise provides an important basis for the accelerated development of new materials. Increasingly, our experience in the field of materials development and microstructure-based process development are in demand.

What do you expect for 2022?

I am looking forward to the new institute director, who I have already had the opportunity to get to know as a member of the appointment committee. In our business unit we want to continue to set disruptive impulses, to continue to develop innovative solutions for the needs of industry, or even to create this demand.

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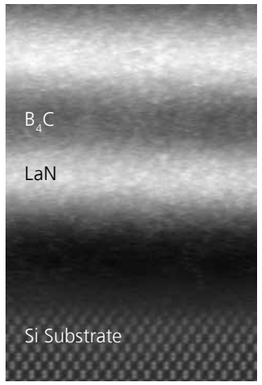
Sub-nanometer resolution analysis of optical devices

Modern optical devices such as highly reflective laser mirrors or bandpass filters are based on multilayer thin film structures. Modern surface analysis methods can be used to elucidate the nature of such multilayer stacks. This avoids impurities or unwanted crystallization and ensures the most accurate architecture of the structures and homogeneity of the layers.

In multilayer thin-film structures for optical components, materials with alternately high and low refractive indices are stacked on top of each other. In doing so, the optical properties of the multilayer stack can be tailored by adjusting the single layers film thicknesses. The increasing demand for higher reflectance, longer life cycles and accessibility of shorter wavelength ranges is leading to new requirements for these devices and thus for the nature of the thin films. In particular, there is a demand for higher purity of thin film materials, very high uniformity of film thicknesses, reduction of individual film thicknesses, and an increase in the number of pairs of films within the stack.

To make this possible and to ensure the necessary quality in new processes and applications, the corresponding analysis techniques for a detailed insight into the nanostructure of multilayer stacks must also become increasingly powerful. At the Fraunhofer IMWS, a combination of analytical high-resolution transmission electron microscopy (TEM) and time-of-flight secondary ion mass spectrometry (TOF-SIMS) was used to investigate the properties of EUV reflective devices based on multilayer stacks of La or LaN and B_4C.

Both the entire stack (homogeneity information) and individual layers down to the sub-nm range (layer thickness determination) were imaged in the TEM. An EDX system for elemental analysis allows elemental distributions to be mapped with sub-nm accuracy. Process-related changes, such as oxidation of the uppermost layers or interdiffusion effects (due to heat treatments, for example) can thus be detected. The additional analysis in ToF-SIMS allows depth profiling of element and compound distributions with sub-nm accuracy and very high detection sensitivity (trace analysis), even for the entire stack. Overall, it could be shown that the combination of these methods meets all analytical requirements for the investigation of thin film multilayers in optical devices.



With the improved resolution of the aberration-corrected STEM HF5000, LaN within B_4C becomes visible in the microstructure.

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Acceleration of sample preparation using focused ion beams

Highly integrated microelectronic circuits are essential for a large number of modern future technologies. Focused ion beam technology (FIB), among other techniques, has proven to be useful for failure analysis of such devices. The Fraunhofer IMWS and point electronic GmbH are investigating an innovative approach for nanometer-accurate high-throughput sample preparation using FIB to simplify the previous device-dependent methods.

Autonomous driving, smart home and artificial intelligence are just a few examples for which microelectronic circuits are indispensable. To ensure functionality and reliability, the components used in these applications are subjected to comprehensive microstructural characterization during development, production and deployment control. For this purpose, they are analyzed using transmission electron microscopy (TEM), for example, in order to detect even the smallest defects in dimensions of tens to hundreds of nanometers.

The decisive factor for success is the quality of the samples, which usually have to be prepared in a complex process using focused ion beam technology (FIB): The ion beam removes material from the sample until the area to be analyzed is thin enough to be examined by TEM. The systems used for this purpose are characterized by target and process accuracy. However, they cannot achieve high precision and a high ablation rate at the same time. This is because precision can so far only be achieved by very finely focused and spatially limited beams, whereas a high ablation rate is achieved by an intense beam that is inevitably less accurate.

To solve this problem, a novel method for nanometer-accurate high-throughput sample preparation using focused ion beam technology is being researched. An already developed method for the targeted, local increase of material removal during ion beam thinning of planar surfaces is to be transferred to the FIB preparation of TEM samples. The iNotch™ technology developed at the Fraunhofer IMWS forms the basis for this new preparation workflow. With systems for digital imaging as well as for controlling electron-optical columns, point electronic GmbH provides important know-how and would like to develop a special solution for controlling the ion-optical system of FIB equipment in the course of the project. In this way, a significantly more powerful method for sample preparation can become possible.

Devices producing focused ion beams are used to achieve the precise ablation of materials.

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Hydrogen Technologies
Carbon Cycle Technologies

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“We want to set benchmarks for the hydrogen economy”

Interview with Head of Business Unit Dr. Sylvia Schattauer

What were the highlights of 2021 for your business unit?

The fact that we were able to commission the first section of the Hydrogen Lab Leuna in May was of course the outstanding event. Not only because this brings many years of preparation to their temporary culmination, but also because we can now actually begin to support industry with a unique offering in an future technology. The first ongoing projects such as ECo_2Met or our part in the launch of the reference factory for an electrolyzer mass production facility prove this. Being able to cut the ribbon at the grand opening in Leuna really felt like a major development boost for the hydrogen economy, and serves as an important step for Central Germany.

A great number of facilities and regions want to participate in the hydrogen boom right now. What are the chances for Central Germany to be at the forefront?

The region is currently in a pioneering role. With our activities in Leuna – also in Görlitz, at other locations and with a powerful Fraunhofer network – we want to help expand this further. It is impressive to see how much support and drive there is for this topic, both in local industry and in politics. This puts us in an excellent position to set the pace in the development of H_2 technologies suitable for mass use, also with a view to successfully shaping structural change in the chemical industry and beyond.

What range of services customers can find in your business unit?

We support our clients with a profound understanding of processes and a unique research infrastructure for practical performance and load tests on an industrial scale, embedded in the material network of the Leuna Chemical Park. This is a decisive step for scaling up electrolyzers to new performance classes, developing high-performance and cost-effective components suitable for series production, and testing operational reliability in actual application – and thus for market ramp-up. Our broad technology expertise also includes extensive digitalization expertise.

What do you expect for 2022?

A large part of our activities will be continued and expanded in 2022 under the umbrella of Fraunhofer IWES. I am looking forward to future cooperation with Fraunhofer IMWS and the first results in projects such as “Waste4Future” or the BMBF joint project “H_2Mare”.

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Hydrogen Lab Leuna has started operation

With its cluster of pilot plants, Fraunhofer creates a globally unique offering

The chemical region in Central Germany consumes about **100,000** standard cubic meters of hydrogen per hour.

Green hydrogen is a key element for a sustainable supply of raw materials for industry and the achievement of climate targets. With the Hydrogen Lab Leuna, the first pilot plant for testing and scaling the necessary electrolysis systems which is fully integrated into a chemical park started operation in May 2021. This supports the required market ramp-up of H_2 technologies, which the Fraunhofer Gesellschaft intends to further accelerate by bundling its hydrogen activities in Northern and Eastern Germany: The Hydrogen Labs in Leuna, Görlitz and Bremerhaven and an application center in Hamburg will be linked. This will create a globally unique range of pilot plants along the entire value chain of the hydrogen economy.

When hydrogen is produced by electrolysis using electricity from renewable energy sources, the result is a climate-neutral raw material that is available as an energy carrier and storage medium as well as for material use as an alternative to fossil raw materials. This offers significant potentials for industrial processes and mobility with a large-scale renunciation of fossil raw materials as well as for the implementation of the energy transition. The Fraunhofer IMWS, the Fraunhofer Institute for Wind Energy Systems IWES and the Fraunhofer Institute for Machine Tools and Forming Technology IWU are pooling their expertise to transfer this approach more quickly into application. With the Hydrogen Lab Leuna and the pilot plants currently being built in Görlitz, Bremerhaven and Hamburg, they cover the entire process from CO_2-neutral power generation by offshore and onshore energy production, through testing and optimization of electrolysis and production of the equipment used in the process, to storage, transport and use of green hydrogen.

The first Fraunhofer Hydrogen Lab in Leuna addresses the transfer of hydrogen technologies from the laboratory to safe and effective industrial-scale applications. The Hydrogen Lab Leuna offers modular usable test areas for electrolysis systems, power-to-X and power-to-liquid projects up to 5 MW connected load. The direct integration into the infrastructure of a chemical park offers access to the local chemical industry in addition to the connection to the H_2 pipeline network of Central Germany. At the pilot plant in Leuna, not only electrolyzers are tested and further developed, but also further issues of power-to-X technologies are addressed, for example in an already ongoing project with a high-temperature electrolyzer of the 1 MW class in combination with the production of green methanol.

The three megawatt-class Hydrogen Labs have clear unique selling points: In Leuna, the pilot plant is directly connected to the pipeline of the regional chemical industry.

Ceremonial commissioning of the Hydrogen Lab Leuna. From left to right: Gerd Unkelbach (Head of Fraunhofer CBP), Prof. Dr. Matthias Petzold (Head of Fraunhofer IMWS), Dr. Markus Wolperdinger (Head of Fraunhofer IGB), Joachim Heider (Head of Sales Region Northeast, Linde Gas), Thomas Behrends (TOTAL Raffinerie Mitteldeutschland GmbH), Prof. Dr. Reimund Neugebauer (President of the Fraunhofer-Gesellschaft), Dr. Sylvia Schattauer (Deputy Director Fraunhofer IMWS) Prof. Dr. Thorsten Posselt (Director Fraunhofer IMW), Dr. Willi Frantz (TOTAL Raffinerie Mitteldeutschland GmbH).

In Görlitz (12.3 MW connected load; planned start-up: end of 2022), the focus is on the generation, storage and use of hydrogen for mobile as well as stationary fuel cells, especially for mobility and to supply neighborhoods and industrial sites. In Bremerhaven (initially 2 MW connected load, expandable to 10 MW; start-up: 2023), the special feature is the connection to a MW wind turbine and to the virtual replica of an electricity supply grid in order to investigate electrical properties of electrolyzers. The laboratories will be complemented by an application center in Hamburg, where research will be conducted on the modeling and control of decentralized, local energy systems.

At each of the four locations, the specifics of regional industry will also be addressed, e.g. in offering specific test procedures for newly developed technologies. The joint orchestration of activities by the three institutes enables, for the first time, a cross-sector demonstration of renewable energy generation towards the impact and modeling of the interaction of large regional energy generation, storage and consumer units. Plant engineers and component manufacturers are given the opportunity to test new equipment developments on an industrial scale. The close cooperation ensures an intensive exchange of experience, complementary development and facilitated access for industry.

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Guidelines for hydrogen safety

A hydrogen safety guide to be used for future hydrogen projects has been developed by experts as part of a joint research project of the "Hydrogen Power Storage & Solutions East Germany – HYPOS" initiative. The guide contains safety-related and organizational information that enables the safe operation of plants for hydrogen production, transport, storage and utilization. The Fraunhofer IMWS contributed its expertise in risk analyses for electrolysis systems.

The safety of hydrogen handling is a fundamental prerequisite for hydrogen application projects. With the goal of analyzing specific hazards of hydrogen technologies as well as developing a methodology for an integrative safety assessment of the technical-technological value chain of power-to-X technologies, TÜV SÜD, the Technical University of Dresden, Dr.-Ing. Veenker Ingenieurgesellschaft mbH, Otto von Guericke University Magdeburg and Fraunhofer IMWS collaborated in the "INES" project.

Saftey is a prerequisite for establishing a hydrogen economy.

The Fraunhofer IMWS contributed its expertise on risk analyses for electrolysis systems and their safety-related material and system requirements. The individual electrolysis systems were examined on the basis of location factors, components and materials used, and safety-related special features were worked out for the various technologies (alkaline electrolysis, PEM electrolysis and high-temperature electrolysis). This analysis also included factors that influence or limit the operating possibilities of the various systems. These findings are incorporated into test cycles for electrolysis systems, such as those produced by the institute as part of the Hydrogen Lab Leuna (HLL) and used for system testing in an existing hydrogen infrastructure.

The focus of the project was to accompany further HYPOS projects with regard to safety issues, so that a uniform approach to the recording and evaluation of risks is available, which has now been brought together in a guide. The guide provides users, manufacturers or project developers not only with an initial orientation, but also with concrete advice on how to get started with the topic of hydrogen safety at all the value-added stages under consideration, thus forming an important building block for adapting and optimizing the existing and newly emerging hydrogen infrastructure in Germany.

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International logistics for the import of green hydrogen

Together with Korean research partners, the Anhalt University of Applied Sciences and the Fraunhofer IMWS are investigating and researching the possibilities and requirements of a future import of green hydrogen.

In the project "H_2DeKo" the study program "Logistics and Air Traffic Management" at the Anhalt University of Applied Sciences and the Fraunhofer IMWS cooperate to establish a German-Korean research network. The joint project will be funded for five years by the German Federal Ministry of Education and Research (BMBF) and is intended to initiate cooperative German-Korean research projects and educational networks on the logistics of green hydrogen. To this end, a joint research presence is to be established in Korea, accompanied by annual workshops and intensive exchange of scientific personnel. After completion of the funding, the aim is to establish a sustainable presence of the German partners in the Korean research landscape by integrating possible industry funding.

In order to achieve CO_2 neutrality of the national economies in Germany and Korea, the generation of H_2 by means of electrolysis with renewably generated electricity is a necessary prerequisite. Existing and planned photovoltaic and wind power capacities in both Germany and Korea are not sufficient to meet all the needs of industry or private households. Substantial import volumes of H_2 from countries where sufficient capacity of renewably generated electrical energy can be made available are mandatory for both countries. Therefore, both countries have a similar need for research on necessary preconditions and requirements for the entire logistic chain of green H_2 from the producing country to the relevant transport routes to the destination country and domestic distribution.

The optimization of electrolysis is a prerequisite for a sufficient supply of green hydrogen.

The master's program "Logistics and Air Traffic Management" at Anhalt University of Applied Sciences has a research focus on hydrogen logistics. Like the Fraunhofer IMWS, the University has a long and successful tradition of cooperation with research-strong partners in South Korea. On the part of the Fraunhofer IMWS, cooperative research projects as well as projects on hydrogen logistics are to be initiated in order to leverage synergy potentials between the two countries and to provide German industry with improved access to these markets through the emerging networks.

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“Our infrastructure in Freiberg is unique”

Interview with Head of Business Unit Prof. Dr. Martin Gräbner

What were highlights in 2021 for your business unit?

After I took office in April 2021, I was impressed by the performance of the business unit, and equally pleased by the great demand on the part of industry. That’s another reason why the launch of a pyrolysis platform was an important milestone. We will soon be able to offer an open technology platform on an industry-relevant scale, for example for the development of innovative solutions for direct pyrolysis or oiling, as well as for feedstock processing by torrefaction/liquefaction with the subsequent option of gasification. The platform will also play an important role in the Fraunhofer lighthouse project “Waste4 Future”.

What exactly is your contribution in “Waste4Future”?

In the lighthouse project, seven Fraunhofer institutes are working together to create new recycling options for tapping secondary carbon sources – as an important contribution to Chemistry 4.0 and a circular rather than linear carbon economy. In this effort, we are developing a novel entropy-based assessment model to identify the optimal recycling pathways. Through new possibilities in pyrolysis and gasification technologies, we aim to use plastic waste materially instead of energetically in the “Chemical Recycling” subproject and thus save CO_2. Together with other business units, we also contribute expertise in the degradation of plastics and the recycling of solvolysis residues.

Which industries and topics are the focus of your business unit?

Our particular expertise is integrated technology development for the effective and sustainable use of carbon carriers. This includes processes for extraction and solvolysis, pyrolysis, gasification, gas purification and wastewater treatment, as well as CO_2-tolerant and CO_2-based syntheses or solutions for residual waste preparation, conveying and feeding systems. The basis for this is first-class analysis of carbon carriers and their conversion products. Our infrastructure in Freiberg is unique, with pilot-scale facilities for testing various feedstocks in different conversion concepts under near-industrial conditions.

What do you expect for 2022?

I am looking forward to seeing the pyrolysis platform in action, as well as to completing the first projects I was able to get involved in. Now that the phase of getting to know each other has been completed after my start in the business unit, I would like to focus on strategy development in 2022.

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From waste to raw material: “Waste4Future” paves new ways for plastics recycling

Seven Fraunhofer institutes, including the Fraunhofer IMWS, are pooling their expertise in the lighthouse project “Waste4Future” to develop new solutions for plastics recycling. With innovations from the raw material base to material flows and process engineering to the end of a product’s life cycle, they aim to increase energy and resource efficiency.

The basic idea: plastics contain carbon. When products made of plastic are no longer needed, this often ends up in the atmosphere as CO_2. The chemical industry, on the other hand, needs carbon as a resource. If it could use plastic waste instead of fossil raw materials, the carbon would remain in the cycle. The result would be less need for crude oil and natural gas, fewer CO_2 emissions and less plastic waste, and greater security of supply for the industry. To achieve this, it would have to be possible to better identify carbon-containing components in waste, recycle them more effectively and use them to produce high-quality materials again. This is the path the partners want to take in the “Waste4Future” lighthouse project, which will run until the end of 2023: Today’s waste becomes tomorrow’s resource.

Specifically, the project plans to develop an entropy-based evaluation model that will reorganize the recycling chain, which has been process-led to date, into a material-led chain (entropy = measure of the disorder of a system). A novel sorting system identifies which materials, and in particular which plastic fractions, are contained in the waste. Based on this analysis, the total stream is separated and a targeted decision is then made for the resulting sub-streams as to which recycling route is the most technically, ecologically and economically sensible for this specific waste quantity. What cannot be further utilized by means of mechanical recycling is available for chemical recycling, always with the aim of preserving the maximum possible amount of carbon compounds.

Research objectives include the evaluation of both input materials and recyclates according to ecological, economic and technical criteria. Material recycling must be optimized, and processes and technologies for the key points of material utilization of plastic fractions – this is one of the focal points of the Fraunhofer IMWS in the project – must be established. In addition, suitable sensor technology must be developed, also using machine learning methods, which can reliably identify materials in the sorting system. Last but not least, an economic evaluation of the new recycling process chain as well as comprehensive life cycle assessment studies will be carried out.

Carbon becomes accessible for circular use in the “Waste4Future” project.

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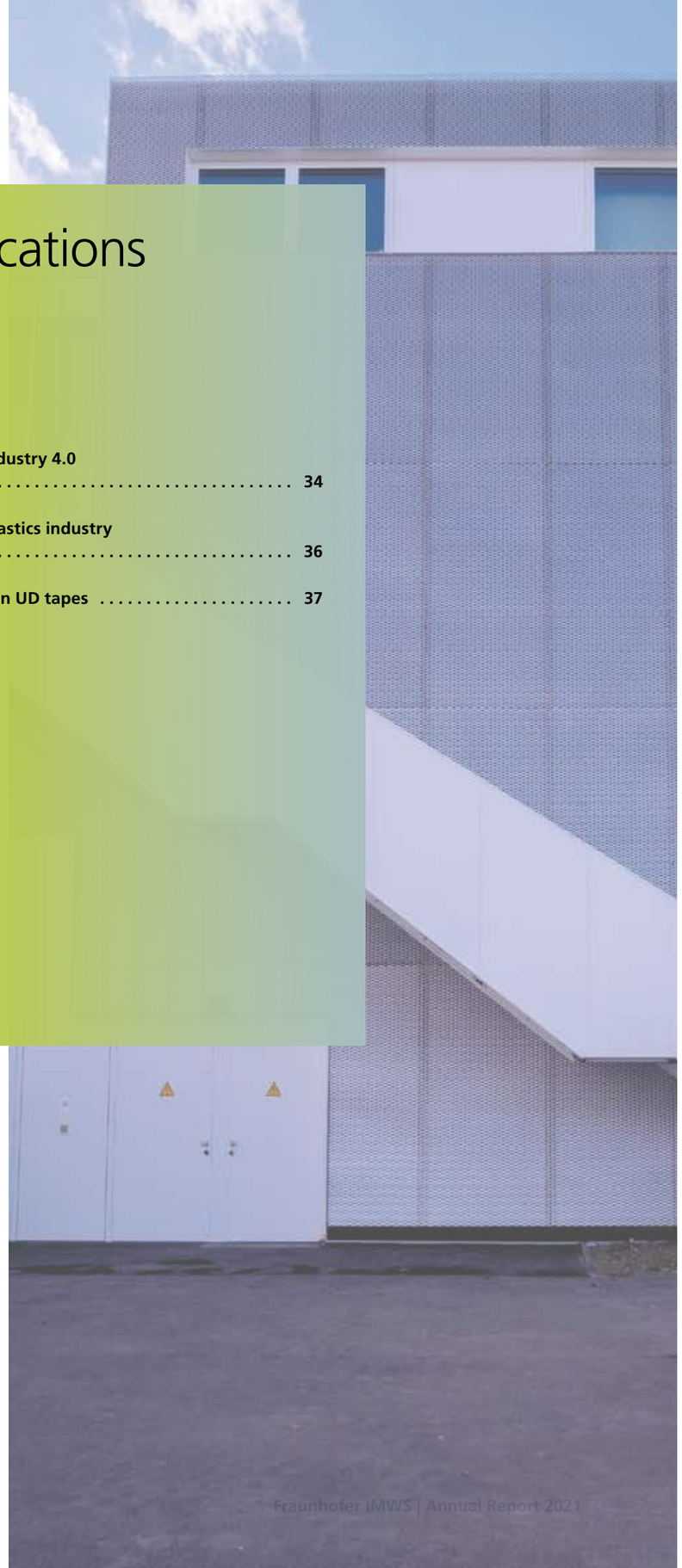

Polymer Applications

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“New equipment strengthens sustainable development in plastics processing”

Interview with Head of Business Unit Prof. Dr. Peter Michel

What were the highlights in 2021 for your business unit?

The opening of the extension building at the Fraunhofer PAZ in Schkopau for the polymer processing area was outstanding. The experimental possibilities for the development of new materials and processes in the field of automated manufacturing of thermoplastic-based lightweight products reach a technical level at the very latest state of the art and beyond. The basis for extended innovations is the unique possibilities from semi-finished component production, forming and integrated injection molding processes. A second focus is on innovative rubber technologies. We are particularly proud of the introduction of a tandem kneader line, which gives us a unique position in the field of rubber research.

Sustainability and plastics – that still seems to be a contradiction for many people in view of buzzwords such as plastic waste and microplastics. What do you think about it?

Polymer processing can make many contributions to increasing sustainability and the intelligent use of limited natural resources. In our business unit, these include lightweight construction activities, new solutions for plastics recycling, circular economy and the use of biopolymers, or the 2021 Hugo Junkers Award-winning development of BISYKA rubber, which reduces rolling resistance and thus fuel consumption as well as abrasion and thus the input of microplastics into the environment.

What special competencies can your business unit offer customers?

We bring our expertise in plastics processing and optimization of polymer materials to improve energy and resource efficiency in the use of the materials and processes developed by us, right up to industrial scale. For our customers from the mobility sector, the plastics industry and mechanical engineering, for example, we look at the entire value chain, from the microstructure of the material to the customized component. We can provide support in the selection of raw materials as well as in the adaptation of processing technologies, characterization of materials and components, modeling and simulation, or process development.

What do you expect for 2022?

For myself, I will be retiring in the spring. I am looking forward to handing over to my successor to the first results in large sustainability projects such as “RUBIO” or “Waste4Future”.

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Lightweight construction, tires and Industry 4.0 as future technologies

11 million euros invested in expansion of polymer processing at Fraunhofer PAZ

With 1000 m² of additional space and new facilities for thermoplastic-based lightweight construction, sustainable tire applications, and digital component development and production in plastics processing, the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau has been expanded. Funds from the European Union, the state of Saxony-Anhalt and the Fraunhofer Gesellschaft were used to invest a total of a good 11 million euros in the extension building of the polymer processing area.

28

people are employed in polymer processing since the expansion

As a joint facility, the Fraunhofer PAZ Schkopau combines competencies in polymer synthesis from the Fraunhofer Institute for Applied Polymer Research IAP (Potsdam) and polymer processing from the Fraunhofer IMWS in Halle/Saale. The focus of the research facility is on scale transfer, i.e. the transfer of new results and ideas from research to scales that are relevant for industry. Companies such as polymer manufacturers, plant engineers or from the automotive industry are thus supported in the commercialization of new products and manufacturing processes.

In particular, the expanded premises and newly installed equipment in the polymer processing area offer significantly improved possibilities for the large-scale production of thermoplastic fiber composite components. This technology is particularly important for lightweight automotive construction - the lighter a vehicle is, the less fuel it consumes or the greater its range in e-mobility. The research work is aimed at producing highly resilient plastic components in cycle times of less than one minute. To this end, high-speed handling equipment and machines are now available in all production steps (preforming, hot handling and injection molding). Likewise, the integration of sensors is now possible at various stages of the manufacturing process. This is a crucial prerequisite for digital component development and digital production processes in the context of Industry 4.0. By linking data obtained at different levels, new, application-specific configurations of components are possible, as can new tools for defect detection and sustainable production in plastics processing. A high degree of automation and suitability for series production through high reproducibility is also achieved.

Solutions for the entire value chain of continuous fiber-reinforced components are now available at the expanded Fraunhofer PAZ. The existing UD tape facility has also been expanded, as have the options for using biopolymers and renewable raw materials, both as reinforcing fibers and in the plastic matrix, in order to meet the significantly increased demand from industry and make a significant contribution to the circular economy.

Prof. Dr. Peter Michel, Prof. Dr. Armin Willingmann, Prof. Dr. Michael Bartke and Prof. Dr. Matthias Petzold (left to right) opened the extension building.

A second focus of the expanded profile is on innovative rubber technologies that offer optimization in adhesion (rolling resistance), wear and abrasion (reduced microplastic impact on the environment) of tires, as well as improved opportunities for circular use (retreading, recycling). Pilot-scale compounding technologies for innovative rubber compounds (internal mixer, vulcanizer, extruder, rolling mill) are available in the new pilot plant, again including consideration of digital capabilities. Fraunhofer PAZ is the only research facility in the world with a tandem kneader, which makes it possible to produce improved rubber compounds with novel morphologies on a pilot scale. In addition, the 28 employees in the polymer processing department are now ideally equipped for testing and applying novel elastomers, fillers and additives, and will be even more involved in the further development of synthetic rubber, including from bio-based sources.

The additional competencies and equipment provide an outstanding research infrastructure for the regional chemical industry, as well as for other clients. In this way, the Fraunhofer PAZ supports companies in mastering the megatrends of digitalization and sustainability and in seizing the associated opportunities. In parallel, the expansion of the polymer synthesis unit is underway in Schkopau, also with a new building and new facilities. Commissioning is planned here for 2022.

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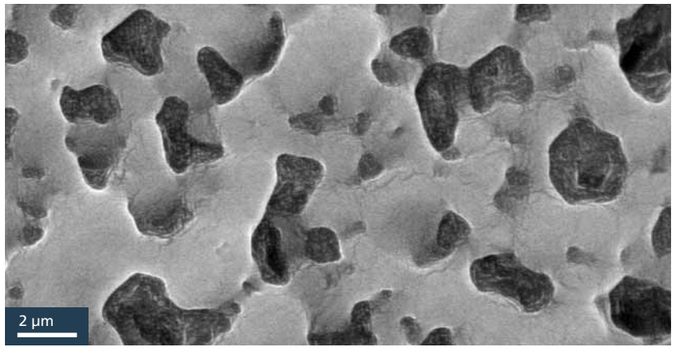
RUBIO provides bio-booster for the plastics industry in Central Germany

Regionally available raw materials are to be turned into plastics that can be used in a variety of ways, thus making Central Germany a showcase region for green chemistry: With this goal in mind, 18 partners have joined forces in the "RUBIO" project to bring bio-based and simultaneously biodegradable plastics to market within three years.

The participating institutions will work together in five fields of competence on solutions for extraction and digestion of bio-based regional resources, formulation, processing methods up to the annual double-digit kiloton range, and recycling processes. The Fraunhofer IMWS contributes its experience in high-resolution structure elucidation and numerical simulation for the formulation and process development of bioplastics. In addition, processing and application properties are analyzed here in order to be able to implement efficient development cycles. The institute will also provide support in upscaling, as well as with competencies in thermomechanical, oxidative and hydrolytic degradation processes of plastics and reactive extrusion of recyclates for recycling.

The RUBIO consortium is focusing on polybutylene succinate (PBS). This bioplastic enables a wide range of variants and has good processing properties, for example for applications such as packaging, technical textiles and geosynthetics. Last but not least, it is readily available regionally: The RUBIO process starts with cellulose and lignocellulose-containing materials that were previously by-products or not utilized at all, such as wood, grasses, residues from the paper industry or fermentation residues from biogas plants. Carbohydrates



Microstructure of a biopolymer blend of polybutylene succinate (PBS) and polylactide (PLA, dark particles in the image).

are extracted from these materials using biotechnological digestion processes. These are converted by fermentation into the starting materials for PBS, namely succinic acid and 1,4-butanediol. The PBS polymers are synthesized from these monomers by polycondensation. The RUBIO project also aims to develop suitable processes for compounding and manufacturing processes such as injection molding, as well as suitable recycling processes with which materials containing PBS can be filtered out of the waste stream and recycled again.

The desired material properties should be able to be adjusted very precisely for the respective requirements. If this is successful, the CO_2 balance of the manufactured products as well as the energy consumption during processing can be halved compared to the plastics currently used.

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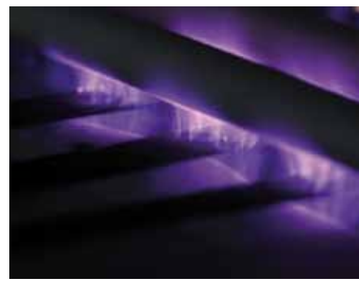
Optimization of carbon fibers for use in UD tapes

Increasing the mechanical performance of composite materials is what Polymer Service GmbH Merseburg (PSM) and the Fraunhofer IMWS want to achieve in a joint research project. They are focusing on the surface treatment of carbon reinforcement fibers to better adapt them for use in thermoplastics. Small and medium-sized companies in particular could benefit from these optimized material systems to produce semi-finished products with better performance and less development effort.

Unidirectional fiber-reinforced plastics have proven their worth in many areas of lightweight construction. The reinforcing fibers, usually glass or carbon fibers, are introduced into a plastic matrix in such a way that their orientation corresponds optimally to the subsequent load profile in the component. This approach is usually implemented with thermoset systems, in which the plastic components, once produced, cannot be deformed later. This has various disadvantages. The manufacturing process is costly and time-consuming, and thermoset material systems cannot be recycled.

The new project is therefore focusing on thermoplastics, in particular the potential applications of carbon fibers in this area. If carbon fibers are used instead of glass fibers in thermoplastic-based material systems with unidirectional reinforcing fibers, so-called organosheets or UD tapes, even better mechanical properties can be achieved. So far, however, carbon fibers have been designed primarily for use in thermoset systems. In the project, they are to be optimized for thermoplastics by means of atmospheric plasma treatment so that the strengths of UD tapes can be ideally combined with the strengths of carbon fibers.

This requires, for example, adaptation of the fiber surfaces and fiber impregnation so that the reinforcing elements embed well and uniformly in a thermoplastic matrix and bond optimally to this matrix. The aim is to find a solution that allows individual surface treatment of the fiber, which is tailored to the respective matrix material and can be integrated directly (inline) into the UD tape production process. This could benefit small and medium-sized companies in particular, such as automotive suppliers, because standard carbon fibers can then be used for their applications instead of having to develop their own sizing of the fibers that is precisely tailored to the respective thermoplastic matrix at great expense.



Atmospheric plasma treatment of carbon fibers.

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Biological and Macromolecular Materials

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“We want to improve people’s quality of life”

Interview with Head of Business Unit Adj. Prof. Dr. Christian Schmelzer

What were highlights in 2021 for your business unit?

I was very pleased with the positive development of our “matriheal” project, which is about to be spun off and won several awards in 2021. The team has developed materials that can be used to treat complex wounds and should soon be on the market in the form of hydrogel sponges and nanofiber fleeces. We were again able to expand our equipment, for example in the area of dental care, and have identified exciting starting points in an Anti-Covid-19 project. On a personal level, the successful completion of my habilitation was also a milestone for me.

In the Anti-Covid-19 project, “Next generation protective textiles” are to be developed. What exactly is happening there?

We are working in a large Fraunhofer consortium on the development of protective textiles that combine a strong filter effect with high wearer comfort and functionalizations such as antiviral properties. In other words, there should be a better protective effect than with available masks. So far, for example, we have used 2D and 3D morphological analyses to identify important parameters for filtration efficiency, breathing resistance, leakage, and also speech intelligibility. We are also testing decontamination methods for protective masks. The results should be available in 2022.

Which customers can benefit from the offerings in your business unit?

Our focus is on materials research for products in the medical and personal care sectors. Here we cooperate - often from the idea through to approval - primarily with customers from the medical device industry and the personal care and environmental sectors. Particularly when it comes to the use of innovative materials and quality control, we are able to offer a wide range of services thanks to first-class know-how, top-level technical equipment and a deep understanding of our customers’ needs. Our expertise is applied, for example, in the testing of sustainable raw materials for cosmetic products or in the optimization of implants through the functionalization of surfaces. So, through better materials, we ultimately want to improve people’s quality of life.

What do you expect for 2022?

We would like to support “matriheal” in successfully entering the market, and I am excited about the utilization potential from the “Next generation protective textiles” project. In addition, we have restructured the “Biofunctional Materials for Medicine and the Environment” group, where we want to provide impetus for biomodels and protein-based materials, among other things.

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Materials research for dental care

Toothpastes, toothbrushes and dentures can be optimized on the basis of microstructure

How do toothpastes or mouth rinses work? How does the microstructure of teeth, dental prostheses or even mouthguards differ before and after care? What shape should the bristles of toothbrushes have for optimum cleaning performance? Such questions are investigated by employees in the dental care team at the Fraunhofer IMWS. Their material science studies are the basis for characterizing and improving medical and cosmetic care products.

The group focuses on application-oriented and materials science questions on behalf of research and development partners from the dental care end-product sector and the supplier industry.

Cleaning processes, such as the interaction of bristle tip, tooth and toothpaste can be analyzed at the micro and nano level, where tiny friction processes take place. By elucidating such mechanisms of action, new materials and surface technologies can be developed to improve biofunctional properties. In turn, this information can help in the development of products with new, improved material characteristics. This also enables the development and testing of improved materials with, for example, optimized structural and surface compatibility or tailor-made functionalities for medical applications and tissue engineering. All this helps to improve people's quality of life.

The focus of the "Characterization of Medical and Cosmetic Care Products" group at the Fraunhofer IMWS, which has been in existence since 2012, is always on application-oriented and materials science issues on behalf of research and development partners from both large-scale industry and small and medium-sized companies from the dental care end-product sector and the supplier industry.

The team supports product development by characterizing dental care products and elucidating their interaction with biological surfaces as well as prosthetic, orthodontic, restorative and implant materials. This is complemented by the development of new methods, special experimental setups, test procedures and models. Top-level technical equipment and an understanding of the needs of customers, with whom the institute has often been cooperating for many years, complete the range of services. Current application examples include the investigation of the enamel fluoride uptake of new toothpastes, of cleaning effects on dental prostheses, of the tubules-occluding properties of suitable particles in toothpastes to reduce pain sensitivity, or on the development of microplastic-free and biocompatible abrasive particles as well as on research approaches to counteract age-related dry mouth (xerostomia), which often contributes to the development of caries and periodontitis due to the associated change in the oral flora.

Special expertise includes the investigation of products that are effective in terms of de- and remineraization, tooth erosion, hypersensitivity, and tooth discoloration and cleaning. The researchers use these preclinical product evaluations to help companies prepare for elaborate clinical trials. Interdisciplinary collaboration with partners from the R&D sector, such as universities and other research institutions, results in further synergies.

For this porpose, the scientists use state-of-the-art technologies to elucidate the structures of materials down to the atomic level. With its equipment in the field of material science, the Fraunhofer IMWS is one of the leading research institutions in Europe. Various methods such as 3D x-ray allow non-destructive defect localization in dental care issues. The analysis of natural tissue samples is possible in the so-called "environmental scanning electron microscope". The virtual information from the electron microscope can also help to elucidate mechanisms of action. In addition, in vitro tests and calorimetric flow measurements are carried out.

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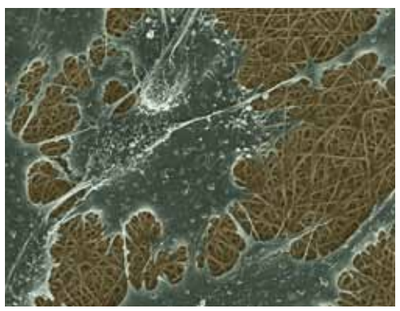
Collagen fiber coatings of implant plastics improve biocompatibility

The high-performance plastic polyetheretherketone (PEEK) is used to manufacture implants in the fields of spinal surgery, traumatology and orthopedics. Yet, owing to the surface characteristics of PEEK, problems can arise during the ingrowth of the implant into the surrounding tissue. In a joint research project of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS and SpinPlant GmbH, it is now possible to functionalize the surface of PEEK implants with the aid of collagen nanofibers so that the biocompatibility is significantly improved during ingrowth into the tissue.

The material from which implants are made must be durable, flexible and biocompatible with human tissue. Metals such as titanium or cobalt-chromium were the favorites for a long time. Since the late 1990s, polyetheretherketone (PEEK) has been used as a high-performance plastic. It has better mechanical characteristics, approaching those of human bones, and is x-ray and MRI compatible. A disadvantage, however, is the inert surface property, which makes implant integration into the surrounding tissue difficult or even impossible.

For this problem, the Fraunhofer IMWS in collaboration with SpinPlant GmbH researched a solution for the surface modification of PEEK in the project "SpinCoat", which improved the osteoconductive and bioresorbable interactions of the human tissue and the implant surface. The materials science research focus was to enable a stable, firmly adherent, biocompatible nonwoven fiber coating of electrospun protein nanofibers on an inert PEEK surface.

During the fabrication of the electrospun collagen nonwovens, the research team determined an optimal mixing ratio of collagen and solvent for spinning, and the process of spinning collagen into nanofibers preserved the native structure of the collagen. By testing and incorporating additives with no pharmaceutical effect and nanoparticles, the project team was able to improve the texture of the collagen nonwovens. During the incorporation of the particles, nanocrystalline hydroxyapatite was used to provide consistent viscosity and conductivity behavior. The researchers performed the microstructural investigations at the Fraunhofer IMWS using scanning electron microscopy (SEM) and micro-computed tomography (µCT).



SEM image of a collagen fleece on a PEEK surface colonized with cells of the osteosarcoma cell line SW1353.

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Improved protective masks through an integrated approach with innovative protective textiles

Mouth-to-nose protection has become commonplace in the COVID-19 pandemic. But many of the available products are not suitable for such use cases. In the "Next Generation Protective Textiles (NGST)" project, ten Fraunhofer institutes are working on improved solutions that combine high protection with optimized comfort.

Until the beginning of 2020, FFP2 masks were primarily used to protect employees in the construction industry from fine dust, for example. Since the COVID-19 pandemic, such and similar masks have become a mass product and are now even mandatory in many areas of public life. However, the available products have not been designed for use by everyone and over a long period of time. This leads to shortcomings, such as increased breathing resistance, diminishing protective effect when soaked, or leaks through which virus particles can move because the masks are not suitable to different face shapes.

The NGST consortium has therefore been working since November 2020 on high-quality protective textiles that can be used in masks as well as in complex filter systems. The aim is to develop textiles with a better protective effect and/or superior wearing comfort, especially for long-term wearers, comprehensive analysis of performance parameters of textile protective equipment, and solutions for the production of corresponding protective textiles. To this end, textiles are being tested that in addition to their effective filtering effect can also deactivate viruses adsorbing on the surfaces of individual mask layers.

The Fraunhofer IMWS evaluates the materials used and thus identifies suitable materials for use in protective textiles. In addition, high-resolution imaging techniques, breathing resistance, particle retention, speech intelligibility measurements and material modification by means of reactive plasma activation are used to test the functional, safety and health requirements of the novel protective masks. Based on virtual design studies, the team eventually produces and evaluates prototypes via 3D printing.

Initial results show that the newly developed nonwovens have significantly lower breathing resistances, improved filtration efficiency due to electrostatic charging of the materials, and reduced mask leakage due to the fit optimized in the project. Full results will be available in 2022.

Various mask designs are being tested in the project for example with regard to their fit.

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“We stand for more than phosphors”

Interview with Business Unit Manager Prof. Dr. Stefan Schweizer

What were the highlights of 2021 for your business unit?

We successfully developed luminescent glasses for product protection in cooperation with the company Tailorlux from Münster. This provides a new class of materials for marking products such as plastics, fibers or resins. The marking can be very individualized and designed in such a way that it is also machine-readable – products are thus given an optical fingerprint, so to speak. We have been granted a new patent for the “Method for determining the spatially resolved thermal structure function and/or time constant spectra of an object” that we have developed and in which we see great potential for commercialization. With the ongoing development of an individual LED light as an aid for people affected by age-related macular degeneration, we are meeting with great interest. I was very pleased to see the successful completion of Charlotte Rimbach’s dissertation and the award for our PhD student Michelle Grüne. This underlines our very good cooperation with the South Westphalia University of Applied Sciences.

Which markets do you focus on and how do companies benefit from a cooperation with the Fraunhofer AWZ Soest?

We are a competent and creative research partner for the lighting industry and related sectors. Our services include complex optical and spectroscopic analyses, thermal measurement methods, and performance measurements in the laboratory for the evaluation and development of phosphors, phosphor systems, and materials. This enables companies from the lighting and illumination industry – many of which are based in the direct vicinity of the Soest AWZ – to bring their innovative ideas to market more quickly and thus increase their competitiveness.

What do you expect for 2022?

Together with our Industry Advisory Board, we want to continue to adapt the strategy of AWZ Soest to the needs of the markets, with a focus on the lighting industry, but also looking at opportunities for other applications where we can support with our know-how and infrastructure. For example, we will further develop measurement methods for Raman spectroscopy, together with the company S & I Spectroscopy & Imaging in Warstein. These will enable a combination of time-resolved Raman and photoluminescence spectroscopy. We intend to further expand our activities in the field of infrared thermography for the evaluation of power semiconductor modules.

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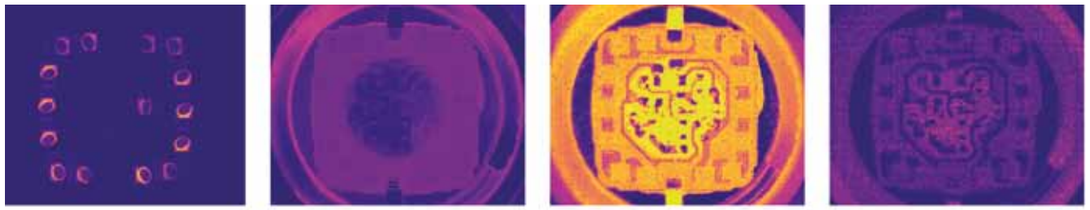
Infrared thermography for analysis of the heat conduction path

Sufficient cooling of heat-sensitive components is essential in many areas of technology, such as LEDs. A patented process developed by the Fraunhofer Application Center for Inorganic Phosphors together with the South Westphalia University of Applied Sciences in Soest is designed to help detect and evaluate weak points.



Images of individual components of the thermal path of an LED light source.

Although modern white LEDs are highly efficient at generating light, a significant amount of electrical energy is converted into heat. These increased temperatures accelerate aging processes. Thermal management is therefore an important part in the development of a luminaire. While the internal structure of the LED is already optimized by its manufacturer in terms of heat transport, the other components of the thermal path are the responsibility of the luminaire manufacturer.

A common way to qualify the thermal path of LED modules is to measure the operating temperature of the LEDs at specific reference points. While thermocouples are widely used for this purpose, infrared thermography provides a non-contact and efficient method to obtain the required temperature information. Although static temperature images make it possible to locate excessively warm areas of a device under test, they do not provide detailed information on which component of the thermal path is the weak spot.

To meet this challenge, an imaging method was developed at the Fraunhofer Application Center for Inorganic Phosphors in collaboration with the South Westphalia University of Applied Sciences that detects and evaluates the weak points of a heat path. To do this, the LED module is operated until a equilibrium temperature is reached. The power supply is then switched off and the cooling is recorded with a high-speed thermographic camera. These images are then processed by a specially developed algorithm to separate the individual components of the heat path. This technique allows the analysis of slight changes in the thermal path. Thus for instance, inhomogeneous or defective soldering leading to insufficient thermal contact between LED and board can be detected.

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“We offer quality assurance for 3D printed components”

Interview with Group Manager Andreas Krombholz

What were highlights in 2021 for the “Design and Manufacturing” group?

We started two exciting projects on the use of natural materials, namely on fiber-reinforced semi-finished products made of hemp fibers for lightweight construction and on a bio-based epoxy resin based on rapeseed husks that can be used as an insulating material, for example. Great progress has also been made in the development of the “Cargo Cruiser II”. This is a cargo bike with electric motor support for the logistics sector, especially for the last mile, i.e. parcel delivery to the front door. Among other things, we supported our project partners here with the construction of the modularly designed body made of high-performance natural fiber laminates. With a top speed of up to 50 km/h in the L7e vehicle class and a three-cubic-meter cargo space, the “Cargo Cruiser II” has clear unique selling points. The first test drives were very promising.

What does your group offer customers?

One focus of our research projects with partners from industry and public-sector customers is new manufacturing technologies, in particular additive manufacturing processes such as 3D printing. A second focus is on bio-based materials for applications in lightweight structural engineering. Here, we can provide support in material development as well as characterization and quality testing of materials and components. In addition, we also offer environmental assessments such as Life Cycle Analysis (LCA). Last but not least, we are an internal service provider within the institute. So, we support the business units, for example, with special test setups or in scientific equipment construction.

What do you expect for 2022?

Our group will be integrated into the “Polymer Applications” business unit at the beginning of the year. This offers many advantages, because there are great synergies in the area of 3D printing, for example. In particular, we want to contribute and expand our expertise here for quality assurance in additive manufacturing, both for the materials used and for 3D printed components, where there is still a lot of need for research and more attention on the application side as well. As part of the business unit, we can offer our customers an even better range of technical equipment and R&D expertise.

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Faster recovery after a fall: App aims to improve care for pelvic ring fracture

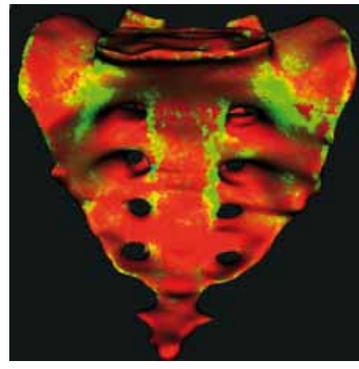
Visual impairments, declining routines in daily life or occasional dizziness cause older people to fall more often. Around half of such falls result in an injury to the pelvic ring. In a joint project with the BG Klinikum Bergmannstrost Halle (gGmbH), the Fraunhofer IMWS aims to develop a numerical model to improve both surgical care and rehabilitation after fractures of the pelvic ring.

Especially people beyond retirement age are affected by fractures of the pelvic ring. This is due on the one hand to the greater tendency to fall in older age, and on the other hand to declining bone quality. In the case of bone loss (osteoporosis) or decreasing bone density as a precursor to this (osteopenia), even a fall from a standing position can be sufficient to cause injuries to the pelvic ring (fragility fractures).

To date, there is no consensus on how best to surgically treat age-related pelvic fractures. There is a lack of knowledge about the effects of individual surgical methods or implants, as well as precise knowledge about the mechanical behavior of a pelvic ring affected by osteoporosis in interaction with ligament, muscle and bone properties. Numerical models already exist to address this issue. However, these do not take into account the significant microstructural remodeling of the bone nor characteristics nor changes in the ligamentous apparatus that introduces and releases exposure into the pelvic ring system.

Therefore, the project uses the finite element method (FEM), which allows a complete, three-dimensional description of bone characteristics and stress fields in bone structures. Radiological data are incorporated into this multiphase model, so that the geometry of the bone is captured as well as its internal structure and the shape of the surrounding soft tissue. The research team links these data sets from the BG Klinikum Bergmannstrost Halle (gGmbH) with experimental micromechanical material models from the Fraunhofer IMWS. The model should then be able to name the material characteristics. For example, the exposure during walking can be realistically simulated for the pelvic ring.

The resulting model is to be available in the form of an app that will make matching surgical methods for optimal fracture care, suitable implants and adapted rehabilitation strategies possible.



Averaged bone stiffness distribution of a sacrum (part of the pelvic girdle) in elderly patients with osteoporosis. Green areas have high bone stiffness, red areas have low bone stiffness.

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Obituary for Prof. Andreas Heilmann

The Fraunhofer IMWS mourns the death of Prof. Dr. Andreas Heilmann. The physicist, who passed away in January 2021 after a prolonged serious illness, played a decisive role in shaping the research institution during his more than 20 years of activity, most recently as Scientific Director of the Business Unit “Biological and Macromolecular Materials”.

Prof. Dr. Andreas Heilmann (1960 – 2021) had a decisive influence on the Fraunhofer Institute in Halle.

Andreas Heilmann was a highly esteemed scientist who decisively shaped the institute with his scientific activities, his tireless commitment, his impulses for strategic development and, last but not least, his ability to lead and inspire.

After studying physics at the Technical University in what was then Karl-Marx-Stadt, Andreas Heilmann worked there as a scientific assistant until 1992. He received his doctorate in 1988 in the field of experimental physics, and in 1993 he was awarded a DFG post-doctoral fellowship at the Chair of Gas Discharge and Ion Physics at the Institute of Physics at the university, which has since been renamed TU Chemnitz-Zwickau. He completed his habilitation in 1997. This was preceded by research stays at the University of Oulu/Finland and Helsinki University of Technology (1990), at RWTH Aachen (1996–1997) and at Stanford University/USA (1994, 1995).

Since 1997, Andreas Heilmann worked for the Fraunhofer Institute in Halle (Saale), initially as a research associate in the “Division 5.1 Microsystems Technology”. In 1999 he was appointed Head of the then service area “Biological and Biomedical Materials and Implants”. Since June 2006 he was honorary professor for the Department of Micro- and Nanotechnologies at Anhalt University of Applied Sciences, and in 2009 he became Head of the Business Unit “Biological and Macromolecular Materials”, of which he was most recently Scientific Director since 2018. His scientific career has produced more than 400 publications and abstracts in books, journals, and conference proceedings, 13 patents, and 135 junior research papers supervised by him.

Without his outstanding commitment, the institute would not be what it is today. In particular, Andreas Heilmann has rendered extremely valuable services to the development of the business unit “Biological and Macromolecular Materials” with his great technical competence, his persistent drive to research and his untiringly high level of identification with the institute’s mission. We will keep a special memory of his personality and his merits.

Board of Trustees

Tasks of the Board of Trustees

The Board of Trustees of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS consists of personalities from politics, economy and science, who are close to the institute and meet once a year.

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Human Resources & Travel Management Constanze Pälecke	**Legal Issues & Compliance** Thomas Merkel			

Awards and Honors

Award in the Ranking of "Germany's most innovative Companies" by "Capital" Magazine and Market Research Service provider "Statista"
Fraunhofer IMWS
22.02.2021, Hamburg

Hugo Junkers Award of the State of Saxony-Anhalt, 1st Place in the Category "Most innovative Projects in applied Research"
Mario Beiner
The award was given to the project "BISYKA", in which a biomimetic synthetic rubber was developed together with four other Fraunhofer institutes.
29.03.2021, virtual award ceremony

Hugo Junkers Award of the State of Saxony-Anhalt, 2nd Place in the Category "Most innovative Projects in applied Research"
Christian Schmelzer, Tobias Hedtke and Marco Götze
The award was given to the project "matriHEAL", which enables the provision of high-performance and biocompatible materials for innovative wound dressings
29.03.2021, virtual award ceremony

First Place in the Evonik Challenge in the Category "Boosting the performance of long-chain polyamides"
Magdalena Jablonska and Nicole Michler, together with Harald Rupp from Martin Luther University Halle-Wittenberg
"Compatibility and adhesion improvement of long-chain polyamides"
01.04.2021, virtual award ceremony

Materials Award of Schott AG
Klemens Ilse
"Microstructural investigation and simulation of natural soiling processes on PV modules"
11.06.2021, virtual award ceremony

IQ Prize of the City of Halle
Christian Schmelzer, Tobias Hedtke and Marco Götze
"matriHEAL – innovative Wound Dressings"
25.06.2021, virtual award ceremony

Anniversary Award of the Austrian Association of the Automotive Industry
Johannes Höflinger
"Efficiency and operating strategy assessment of a fuel cell range extended electric vehicle"
05.11.2021, Graz/Austria

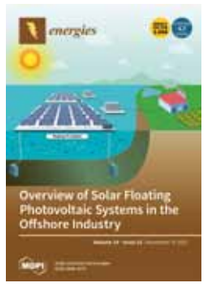
"Soroptimist Sponsorship Award for outstanding final Theses of female Graduates in MINT subjects" of the South Westphalia University of Applied Sciences
Michelle Grüne
"Dysprosium oxide doped lithium aluminoborate glass for LED light guides"
25.11.2021, Soest

Dissertation Award of the Anhalt University for Applied Sciences
Klemens Ilse
"Microstructural investigation and simulation of natural soiling processes on PV modules"
29.11.2021, Köthen

Publications

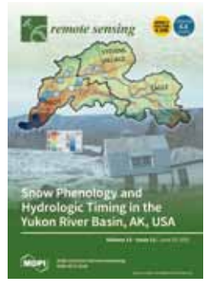
Highlights

Poganietz, W-R.; Lee, R.P.
Systems Analysis
Technology assessment, handbook for science and practice.
Nomos Handbuch (2021), 276-285

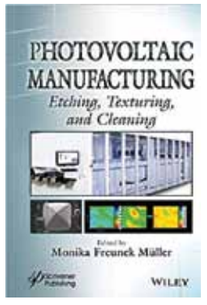


Ziegeler, N. J.; Nolte, P. W.; Schweizer, S.
Quantitative performance comparison of thermal structure function computations
Energies
Volume 14, Issue 21 (2021)

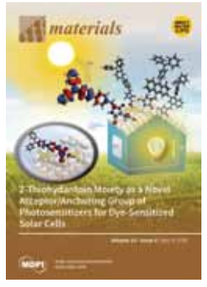
Omar H.; Smales, G.J.; Henning, S.; Li, Z.; Wang, D.-Y.; Schönhals, A.; Szymoniak, P.
Calorimetric and dielectric investigations of epoxy-based nanocomposites with halloysite nanotubes as nanofillers
Polymers
Volume 13, Issue 10 (2021)



Torres, B.M.; Völker, C.; Nagel, S. M.; Hanke, T.; Kruschwitz, S.
An ontology-based approach to enable data-driven research in the field of NDT in civil engineering
Remote Sensing
Volume 13, Issue 12 (2021)



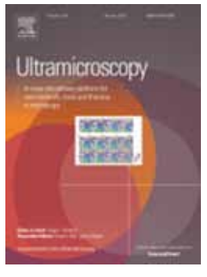
Wahl, S.; Meyer, S.
Analytical techniques for wet processing
Photovoltaic Manufacturing
Wiley (2021), 161-180



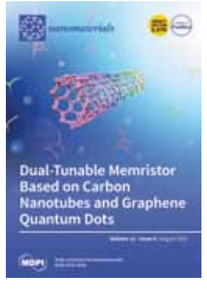
Mukherjee, K.; De Santi, C.; Borga, M.; Geens, K.; You, S.; Bakeroot, B.; Decoutere, S.; Diehle, P.; Hübner, S.; Altmann, F.; Buffolo, M., Meneghesso, G.
Challenges and perspectives for vertical GaN-on-Si trench mos reliability: From leakage current analysis to gate stack optimization
Materials
Volume 14, Issue 9 (2021)

Friedmann, A.; Baertel, A.; Schmitt, C.; Ludtka, C.; Milosevic, J.; Meisel, H.-J.; Goehre, F.; Schwan, S.
Intervertebral disc regeneration injection of a cell-loaded collagen hydrogel in a sheep model
International Journal of Molecular Sciences
Volume 22, Issue 8 (2021)

Jeanne, A.; Sarazin, T.; Charlé, M.; Kawecki, C.; Kauskot, A.; Hedtke, T.; Schmelzer, C.E.H.; Martiny, L.; Maurice, P.; Dedieu, S.
Towards the therapeutic use of Thrombospondin 1/CD47 targeting TAX2 peptide as an antithrombotic agent
Arteriosclerosis, Thrombosis, and Vascular Biology
Volume 41, Issue 1 (2021)

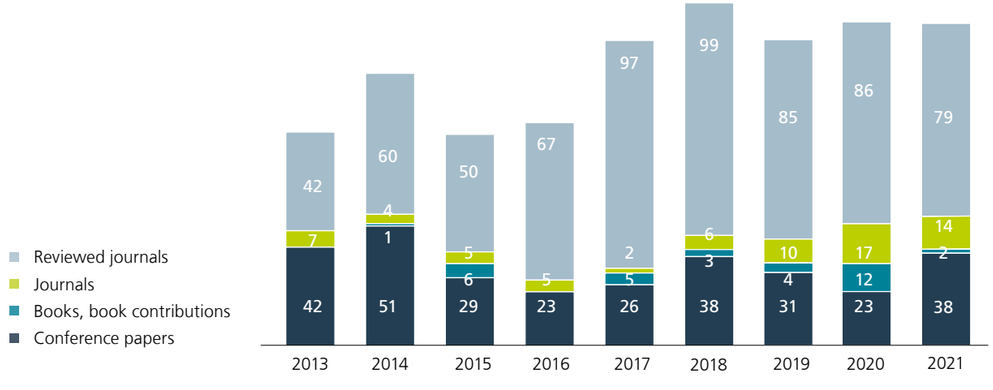


Diehle, P.; Kovács, A.; Duden, T.; Speen, R.; Žagar Soderžnik, K.; Dunin-Borkowski, R.E.
A cartridge-based turning specimen holder with wireless tilt angle measurement for magnetic induction mapping in the transmission electron microscope
Ultramicroscopy
Volume 220 (2021)



Hakeem, A. S.; Ali, S.; Höche, T.; Drmosh, Q.A.; Khan, A. A.; Jonson, B.
Microstructure evaluation and impurities in la containing silicon oxynitrides
Nanomaterials
Volume 11, Issue 8 (2021)

Publications total



Patents and Dissertations

Patents 2021

Gläßer, Thomas / Michel, Peter
Method for additively manufacturing a component
Patent-Nr. EP 3 374 157 B1

Großer, Stephan / Hagendorf, Christian / Naumann, Volker / Tänzer, Tommy
Layer system and method for determining resistivity
Patent-Nr. DE 10 202014 211 352 B4

Hagendorf, Christian / Schneider, Jens / Turek, Marko
Sensor module and method for recording external influence parameters, in particular for monitoring photovoltaic systems
Patent-Nr. DE 10 2018 204 150 B4

Höche, Thomas / Krause, Michael
Method and arrangement for manufacturing a sample for microstructural materials diagnostics and corresponding sample
Patent-Nr. EP 2 787 338 B1

Jacob, Tino / John, Marianne
Method for embedding or manufacturing a fiber optic connector in a component
Patent-Nr. DE 10 2016 213 084 B4

Dissertations

M. Sc. Hamed Hanifi
Martin Luther University Halle-Wittenberg
Design of c-Si modules for extreme desert conditions

M. Sc. Tabea Luka
Martin Luther University Halle-Wittenberg
Contributions to the elucidation of light-induced solar cell degradation under elevated temperature

M. Eng. Tim Schaffus
Martin Luther University Halle-Wittenberg
Investigation of the influence of sample preparation methods on the mechanical stress in silicon using a Raman spectrometer

Technical equipment

The Fraunhofer IMWS supports its clients with a unique and comprehensive range of services for failure analysis and material characterization. This includes technical equipment at the highest level – within the Fraunhofer Gesellschaft the Fraunhofer IMWS has the most comprehensive portfolio of instrumentation for microstructure elucidation. The technical equipment is permanently extended and modernized in order to be able to continuously offer customers high-tech and state-of-the-art. Here is a selection of the new equipment added in 2021.

Pyrolysis – Gas Chromatography – Mass Spectrometry (Py-GC-MS)
The new instruments (multifunctional pyrolyzer, single quadrupole GC-MS system and gas chromatograph) enable direct analysis of polymer materials without time-consuming sample preparation, even for the smallest sample quantities with a mass of less than 100 mg. This allows the polymer composition of samples to be determined, and also makes it possible to detect additives and/or impurities. The instruments can be used with a wide range of sample task options, for example, to analyze microplastics, determine the hydrocarbon profiles of oils, or identify previously unknown materials/compositions. Both qualitative and quantitative analyses are possible, with intelligent routine tools, accelerated reaction times, and the autosampler providing fast and reproducible results and high sample throughput. Currently, this analysis method is used at Fraunhofer IMWS to investigate degradation effects of solar modules. By examining the encapsulation polymers and in particular their additive structure, the aim is to correlate module performance degradation due to aging with changes in the polymer material.

Yizumi SpaceA-500-1100 3D Printer
The Yizumi 3D printer expands additive manufacturing capabilities at Fraunhofer IMWS. The device combines the agility of a 6-axis industrial robot with the economy of a screw extruder for plastic pellets. An integrated KUKA robot increases the degrees of freedom compared to conventional additive manufacturing systems. This provides the option of breaking

away from the limitations of two-dimensional layer buildup and manufacturing structures in space according to the load path. Processing the same industrial granulate as for injection molding applications significantly reduces manufacturing costs, making profitable product pricing possible, while retaining the usual degrees of freedom in terms of coloring and additives with the same masterbatches of injection molding. The high output and the associated printing speed also allow time- and cost-optimized production, especially of large components. With the integrated milling head, printed surfaces can subsequently be optimized to define fits or surfaces.

Events and Trade Fairs

Annika Thormann presented new research results in the "Materials Insights" event series.

Events (co-)organized by the Fraunhofer IMWS

71st Electronic Components & Technology Conference ECTC 2021
01.06.–16.07.2021, virtual event

PolyMerTech 2021
09.06.–11.06.2021, virtual event

BIOPOLYMER – Processing & Moulding
15.06.2021, virtual event

Ammonia for a sustainable and net zero economy
16.06.2021, virtual event

Laser micromachining – a change in perspective
30.06.2021, virtual event

International SPM Symposium on Failure Analysis and Material Testing – FAMT 2021
01.07.2021, virtual event

PV Days
21.10.2021, virtual event

Materials Insights 20 | 21
Within the framework of this digital event series, current highlight topics of the Fraunhofer IMWS were presented in eleven individual sessions.
24.08.–14.12.2021, virtual event series

Further high-profile Events

Ceremonial commissioning of the Hydrogen Lab Leuna
21.05.2021, Leuna

Participation in the UnityEXPO on the occasion of the Day of German Unity
19.09.–03.10.2021, Halle (Saale)

Ceremonial commissioning of the extension building at the Fraunhofer PAZ
04.11.2021, Schkopau

The cube at the UnityEXPO in Halle (Saale) contained the Lego model of Hydrogen Lab Leuna (HLL).

Networking

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

Networking within the Fraunhofer Gesellschaft

- Fraunhofer Group for Materials, Components – MATERIALS
- Fraunhofer Group for Microelectronics (guest membership)
- Fraunhofer Energy Alliance
- Fraunhofer Lighthouse Project "Manitu"
- Fraunhofer Lighthouse Project "Waste4Future"
- Fraunhofer Academy
- AG Reviernetzwerk (working group on structural change)

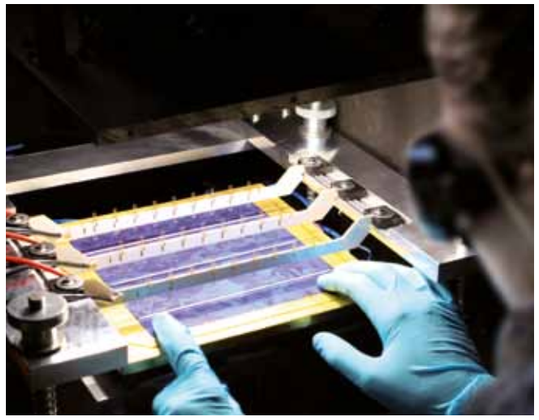
Networking with external partners

- Service and Transfer Center Chemistry and Biosystems Technology
  www.chemie-bio-systemtechnik.de
- Performance Center for Transdisciplinary Systems Research and Transfer (TransTech)
  https://s.fhg.de/transtech
- DFG Collaborative Research Center "Polymers under constrained conditions"
  http://www.natfak2.uni-halle.de/forschung/verbund/sfbtrr102/?lang=en
- BMBF Top Cluster BioEconomy
  https://www.bioeconomy.de/en/
- BMBF Leading-Edge Cluster SolarValley Central Germany
  http://www.solarvalley.org/home?lang=en
- BMBF Zwanzig20 Project HYPOS
  https://www.hypos-eastgermany.de/en/

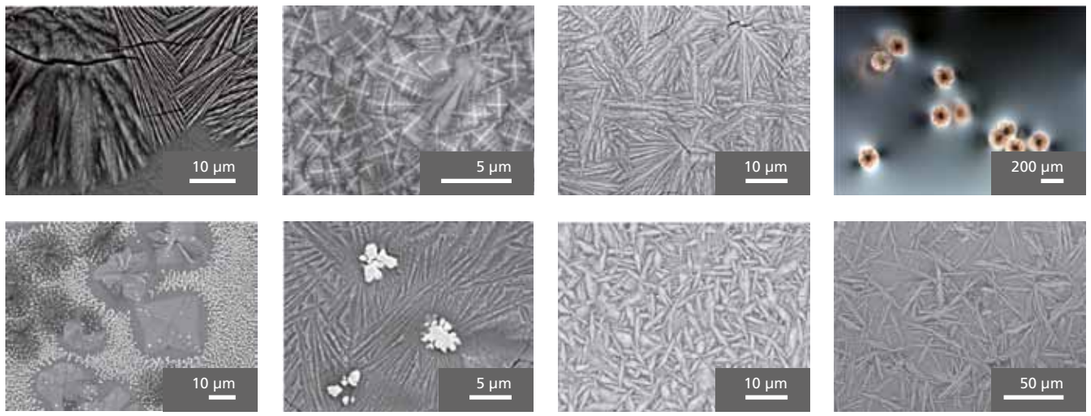
Mission

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

The work of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle (Saale) builds on its core competencies in high-performance microstructure diagnostics and in microstructure-based material design. The scientific team researches questions of functionality and application behavior as well as reliability, safety and durability of innovative materials in components and systems, with high importance for different market and business areas as well as for social and economic development. For its partners in industry and for public clients, the Fraunhofer IMWS aims to contribute to the development of new materials, to increase material efficiency, boost profitability and to conserve resources. In this way the institute contributes to securing the innovation capability of important future fields with regard to materials and technologies, and to sustainability as a central challenge of the 21st century.



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



Our core competence "microstructure design": Homogeneous volume nucleation enabled the development of the low-expansion ceramic LEAZit™.

Core Competencies

Microstructure diagnostics – discovered by the Fraunhofer IMWS

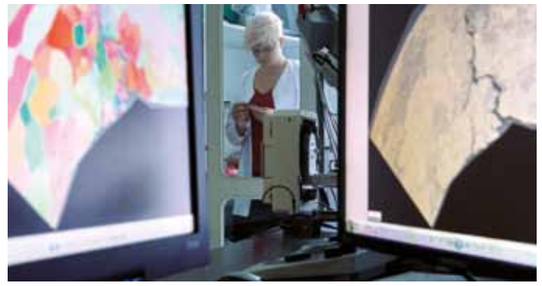
The Fraunhofer IMWS possesses outstanding know-how, and within the Fraunhofer Gesellschaft it is able to offer the most comprehensive range of equipment for microstructure diagnostics. This allows us to determine the microstructural characteristics of materials and components down to the atomic level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

Microstructure design – designed by the Fraunhofer IMWS

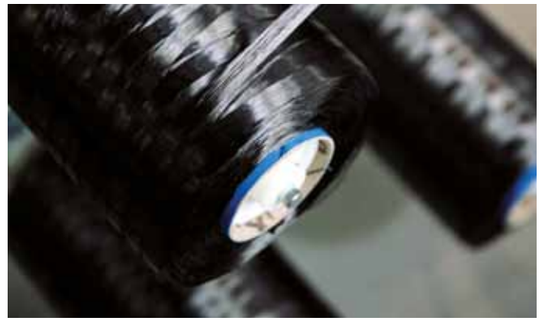
Our understanding and control of microstructure allow us to intervene in fundamental material characteristics. Using microstructure design, we are able to provide our material know-how even during the development phase, and we can support our clients at the start of the value chain with materials that 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.

Developing testing equipment – engineered by the Fraunhofer IMWS

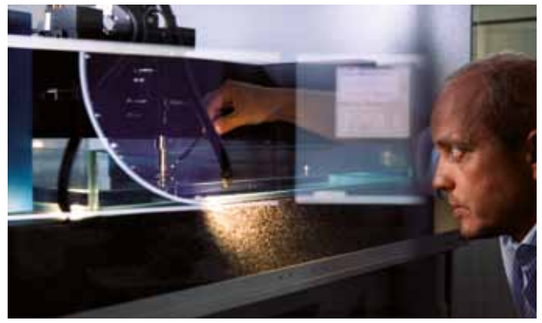
Successful microstructure investigation that meets our clients' needs is only possible through high-quality instrumentation. The complex questions posed in research and development, along with new methods and materials, require perfectly tailored equipment. And so – based on our many years of experience 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.



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



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



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

University Partnerships

1 Rensselaer Polytechnic Institute RPI, Troy, New York, USA
2 CIC nanoGUNE Nanoscience Cooperative Research Center, San Sebastian, Spain
3 Institute of Scientific Instruments of the Acadamy 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 Korea Institute of Energy Technology (KENTECH), Naju, South Korea

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

Sustainability Report

Fewer business trips within Germany (down 80 percent compared to 2019), fewer trips abroad (down 97 percent), fewer kilometers traveled in company cars (down 62 percent): the effects of the COVID-19 pandemic also contributed to further savings in resources and emissions at the Fraunhofer IMWS in 2021. Of course, efforts to increase sustainability in the institute's processes were not limited to these factors which occurred due to external circumstances. With a variety of activities, the Fraunhofer IMWS strives to think and act sustainably in its own work as well.

This includes looking at the consumption of resources in the institute's properties. For example, in the second half of 2021 a significant energy saving was achieved at the Heideallee location by optimizing the cooling water flow temperatures according to demand, and this despite the commissioning of further scientific equipment. At Walter-Hülse-Straße, ventilation operation and compressed air generation were further improved. The photovoltaic system installed next to the Fraunhofer CSP generated 93,520.88 kWh of electricity for use at the institute in the year as a whole. Thus, around 37.5 tons of CO_2 were saved compared to purchasing this amount from the average German electricity mix. A further solar plant on the roof of Walter-Hülse-Straße is being planned and will increase this effect in the future.

By using the electricity generated by the solar plant at Fraunhofer CSP, around 37.5 tons of CO_2 could be saved in 2021.

In two projects of the Fraunhofer Future Foundation, the institute's scientists are committed to goals that are closely aligned with the Sustainable Development Goals (SDG) of the United Nations. In the "INSYGMA" project, a solution for improved tire rubber developed jointly with other institutes is being brought to market that reduces rolling resistance and thus energy consumption, as well as the introduction of microplastics into the environment. As part of "myLens", a team is working on novel laser-structured eyeglass lenses for the treatment of nearsightedness in children, which is also specifically aimed at use in emerging and developing countries.

Strengthening the social aspects in the sustainability concept of the Fraunhofer IMWS also includes the company agreement on location- and time-flexible working, which was concluded at the end of 2021. Based on the good experience of a transitional solution in the COVID-19 phase, this will give employees more flexibility in the long term, make it easier to reconcile family and career, and last but not least save further resources, for example through travel that is not necessary when working at home.

The topic of sustainability is also the focus of the Fraunhofer IMWS' Life Cycle Analysis (LCA) service. Here, the ecological footprint of a product over its entire life cycle is determined for the institute's clients, starting with the extraction of raw materials, through production and use, to recycling options. On the basis of standardized processes, precise statements can be made about material and energy flows, from which recommendations for optimization can be derived. The institute's expertise also includes the modeling of material cycles, connection to standardized database systems and the comparative evaluation of pollutant emissions.

Outlook

The most important event for the Fraunhofer IMWS in 2022 was already announced at the beginning of the year: In February, Prof. Dr. Erica Lilleodden took over the leadership of our institute. The materials scientist comes from the Helmholtz Center hereon in Geesthacht, where she most recently headed the Department of Experimental Materials Mechanics for ten years. The US-born scientist's previous positions include such renowned research institutions as the University of Minnesota - Twin Cities, Stanford University, Lawrence Berkeley National Laboratory and the Karlsruhe Institute of Technology KIT. Her personal research focuses on the nano- and micromechanics of materials such as metals, ceramics and composites, for example with regard to deformation and defect formation in use, as well as the targeted development of materials with specific properties for high-performance applications. Thus, the professional experience and knowledge of our new institute director closely follows our own core competencies in the field of microstructure and will optimally complement them for the development of new market fields.

We are therefore very pleased to have won Prof. Dr. Erica Lilleodden for the position in Halle (Saale) in a joint appointment procedure with Martin Luther University Halle-Wittenberg. We are certain that under her leadership the Fraunhofer IMWS will continue to develop very successfully, building on the achievements and very good results of the institute in the past years under the acting leadership of Prof. Dr. Matthias Petzold.

New appointments are also pending in other leadership positions for 2022. Prof. Dr. Peter Michel, head of the "Polymer Applications" business unit, will retire in the spring with our sincere thanks for his dedicated work over the past years. Together with Merseburg University, the appointment process for his successor is well advanced. The joint appointment process with the Leipzig University of Applied Sciences (HTWK) has also begun for a complementary position in the management of the "Electronic Materials and Components" business unit in conjunction with a university professorship.

A highlight in the calendar of events is to be the celebratory colloquium marking the 30th anniversary of Fraunhofer activities in Halle. With many actors who have contributed to this success story, we would like to not only look back on the history of the institute, but in particular focus on the future topics of the Fraunhofer IMWS as well as the new management. The numerous projects already underway, the programs currently in the pipeline and future ideas, for example on bioeconomy solutions in plastics, trustworthy electronics, 3D printing or new functional materials for medical or optical applications offer more than enough topics that we would like to discuss, further develop and ultimately successfully implement with our partners from industry, politics and academia on this date - and of course on other occasions as well. Our hydrogen activities, which in the future will focus on our competencies in diagnostics and ensuring the safety and reliability of materials for H_2 technologies and electrochemical converters, will also play an important role. This will be done in close cooperation with our colleagues in the field of electrolysis, who are now part of the new Fraunhofer IWES branch office in Leuna that was established at the end of 2021.

Last but not least, further strategy development on the topics of carbon cycle processes will play an important role at our Freiberg site in 2022. In all these areas, we want to continue to rely on the trusting support of our successfully established industrial advisory boards as well as the Board of Trustees, which will also have a new face. Internally, the conversion of many administrative processes to an SAP solution will pose an additional challenge to our workflows – we hope that as a result we will succeed in significantly increasing the efficiency of our organizational processes.

It can be proudly stated that the acquisition cases of our business units are already well filled at the beginning of the year, resulting in a positive outlook on the economic situation for 2022. Within the framework of the now well-established "New Normal" conditions at the institute, we can thus continue to actively support the innovative and competitive capabilities of our customers and partners in applied research and project work, and specifically expand our own specialist competencies. However, for 2022 we also hope that a presentation of scientific results as well as successes in the further development of the Fraunhofer IMWS will again be possible more frequently in presence and in personal contacts at trade fair appearances and at our own events, for example at the second edition of our Thermoplast Sandwich Conference, at the long-established international CAM Workshop on Failure Diagnostics in Electronics, with the PV Days of Photovoltaics or as part of the Long Night of Science in Halle (Saale), which will take place again. We will also continue our digital event series "Materials Insights", with which we present current research highlights of the institute in a compact format.

We look forward to the upcoming collaboration and to further personal encounters with you!

Imprint

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