About the Institute

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS focuses on methodological techniques and approaches in the fields of materials science and materials engineering. Acting as a point of contact for industry and the public sector for all issues relating to the microstructure of materials and systems, Fraunhofer IMWS aims to enhance material efficiency, boost profitability and minimize the use of resources.

Fraunhofer IMWS | Annual Report 2022

Fraunhofer IMWS

Annual Report 2022

Research highlights

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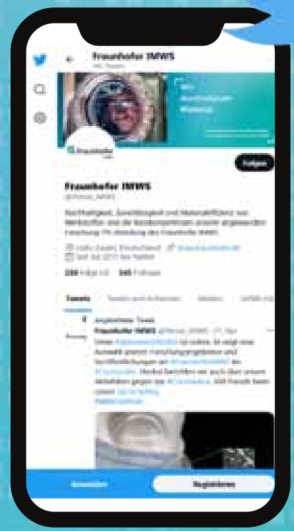

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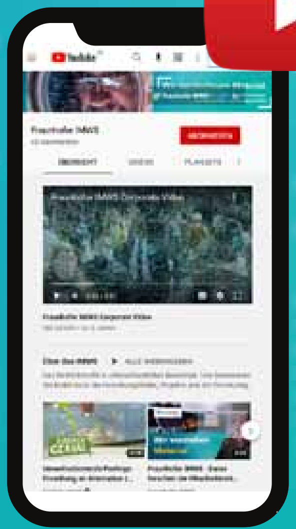

On YouTube you will find exciting videos about our work. It's worth watching!

Foreword

Dear readers,

For the first time, I have the pleasure of presenting the highlights of our research activities and summarizing the Institute's performance for the year. On February 1, I took over as Director of the Institute from Prof. Matthias Petzold. I would like to take this opportunity to thank Prof. Petzold once again for his support and for handing over of an Institute in such an excellent position. My appointment to the position of Director is accompanied by a Professorship appointment at the Martin Luther University of Halle-Wittenberg. You can find out more about me and my vision for the Institute on page 38.

Following a successful start to my tenure in February, we as an Institute quickly faced a major challenge with a cyber attack in April. During this period, solidarity and the extraordinary commitment of our employees were essential in quickly limiting the impact of the attack, which resulted in a significant loss of data. Such commitment cannot be taken for granted and has shown me that I have an outstanding team to rely on. I would also like to acknowledge the understanding and support I have received from the Fraunhofer-Gesellschaft and individual Fraunhofer Institutes, our customers and policymakers;
I extend here my utmost gratitude to them.

During the past year we have brought to bear our expertise in the microstructure of materials and material behavior in various research projects and could thus support our industry and commercial clients in finding the right solutions to the challenges they face. Some of these projects are featured over the following pages. They demonstrate that, in addition to research and innovation, we place great emphasis on technological sovereignty, sustainability, and resilience. The spin-off "matrihealth GmbH" was one of the year's most prominent highlights. Starting out as a start-up project known as "matriheal" in 2020, this spin-off has demonstrated the scalable and cost-effective production of elastin, and we are excited for the future impact of this new company. Another highlight was the establishment of the "Fraunhofer Innovation Platform for Hydrogen Energy at Korea Institute of Energy Technology" (FIP-H2ENERGY@KENTECH) in South Korea. In cooperation with five other Fraunhofer Institutes and Korean scientists, we are conducting research on the development of technologies along the entire hydrogen value chain.

This year has also seen changes in our management positions. We wish Prof. Peter Michel a happy retirement from his position as head of the Business Unit Polymer Applications and express our sincere gratitude for his dedicated work. He is succeeded by Prof. Maik Feldmann, who is also responsible for the "Polymer Processing" unit at the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau. Alongside his new role, Prof. Feldmann is an associate professor at the University of Applied Sciences in Merseburg and we look forward to strengthened interactions with this University.

The highlight of the events calendar was the celebratory colloquium marking the 30th anniversary of Fraunhofer's activities in the city of Halle (Saale). Together with political, business and scientific representatives, we enjoyed a wonderful program with speeches from Prof. Armin Willingmann, Minister for Science, Energy, Climate Protection and the Environment and Deputy Minister-President of Saxony-Anhalt, Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft, Dr. Robert Chau, Director of Intel Europe Research and Intel Senior Fellow at Intel Corporation (USA), and Berthold Hellenthal, Head of the Competence Center "Progressive Semiconductor Program" at Audi AG, among others.

As the year draws to a close, we are pleased to report a very positive commercial and financial standing. We have successfully overcome the challenges we faced during the year and have emerged stronger. I would like to take this opportunity to express my sincere thanks to all our customers, funding organizations, scientific research units and most importantly all of our employees.

Yours,
Erica Lilleodden

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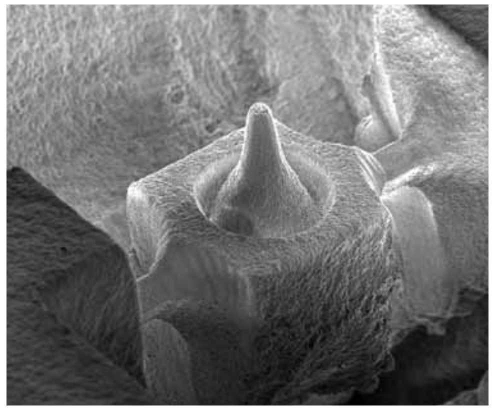
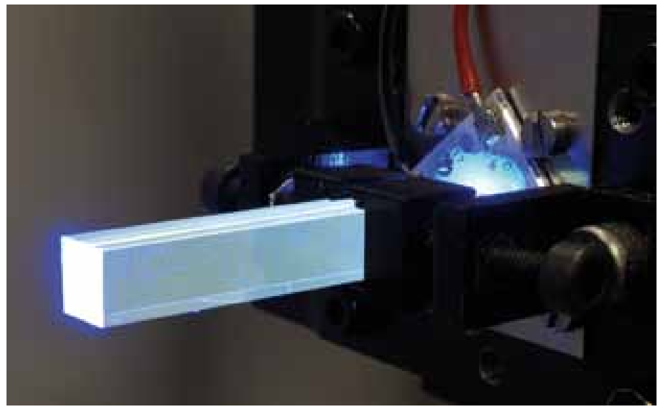
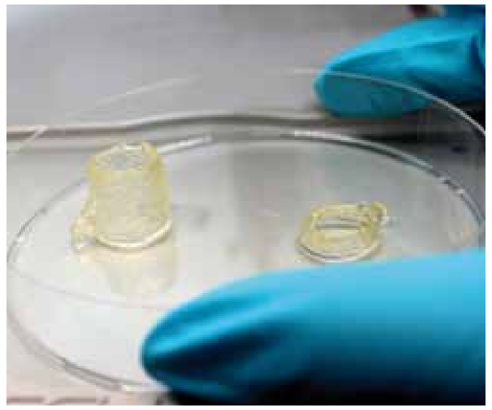


Anniversary event –
30 years of Fraunhofer in Halle (Saale)

Former Acting Director of the Institute Prof. Matthias Petzold handed over the golden key to the building to Prof. Erica Lilleodden in recognition of her new role as Institute Director. ▼

The anniversary banners in front of the building at Walter-Huelse-Strasse 1 at the Weinberg Campus. ▼

▲ *On November 2, well-wishers from the world of politics, industry and science celebrated 30 years of applied Fraunhofer research in Halle (Saale).*

▲ *Prof. Armin Willingmann, Minister for Science, Energy, Climate Protection and the Environment and Deputy Minister-President of the State of Saxony-Anhalt, delivered the welcoming address for the State of Saxony-Anhalt.*

▲ *In his keynote speech, Berthold Hellenthal, Head of the AUDI AG Progressive Semiconductor Program Competence Center, spoke about electronics and sustainability as being the drivers for the automobile of the future.*

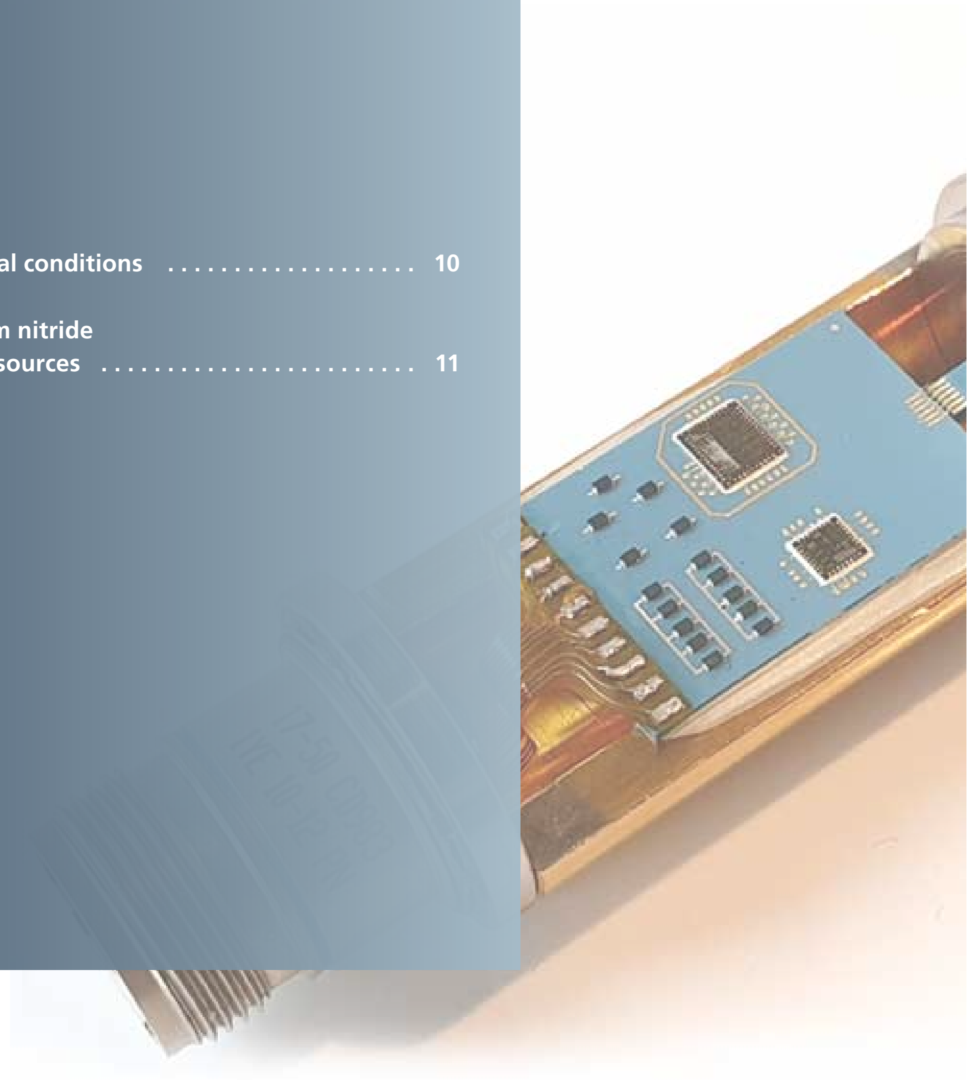
Dr. Robert Chau, Director of Intel Europe Research and Intel Senior Fellow, intel Corp. (USA), gave a keynote speech on "Semiconductor and Packaging Research to Drive Moore's Law and Beyond". ▼

Egbert Geier, Mayor of Halle (Saale), delivered the welcoming address on behalf of the city. ▼

▲ *Among others, Dr. Robert Chau, Director of Intel Europe Research and Intel Senior Fellow, intel Corp. (USA), Egbert Geier, Mayor of the City of Halle (Saale), Prof. Armin Willingmann, Minister for Science, Energy, Climate Protection and the Environment and Deputy Minister-President of Saxony-Anhalt, Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft, Prof. Claudia Becker, President of Martin Luther University Halle-Wittenberg, and Berthold Hellenthal, Head of the AUDI AG Progressive Semiconductor Program Competence Center (from left to right) congratulated Institute Director Prof. Erica Lilleodden (center) on the occasion of the 30th anniversary.*

Electronic Materials and Components

Selected research success stories



"AI methods are becoming increasingly important in the context of failure diagnostics"

Interview with Head of Business Unit Frank Altmann

What were the highlights of 2022 for your Business Unit?

Being able to resume the international CAM-Workshop "Innovation in Failure Analysis and Material Diagnostics of Electronics Components" after a two-year hiatus was certainly a highlight. Professor Michael Pecht talked about "Physics of Failure" concepts in his keynote speech. The workshop was rounded off by presentations on new failure analysis techniques in power electronics, an equipment exhibition and a panel discussion. The event was very successful once again, attracting 162 participants, almost 80 percent of whom were from the industrial sector.

Utilizing AI methods to automate and therefore increase the efficiency of failure diagnostics is becoming more and more important. What steps have you taken in this regard?

We are seeking to use Artificial Intelligence methods to detect and classify defects in components more effectively and more quickly. To this end, we are working with semiconductor and device manufacturers to develop more efficient failure analysis tools and workflows as part of the European "FA4.0" project. We are also developing concepts for correlative data evaluation in order to better identify the causes of failures. What's more, we are also using these methods to detect counterfeit semiconductor devices. This is, unfortunately, a growing issue, due in part to the current supply bottlenecks in electronics manufacturing.

What R&D expertise can your Business Unit offer to clients?

Our core competencies are in broad-based and highly efficient failure diagnostics in microelectronics, which enable us to draw conclusions about the material behavior of components and about electrical functionality. On that basis, we develop innovative solutions for improving the reliability, service life and quality assurance of electronic components. Our spectrum of customers covers the entire electronics supply chain from semiconductors to components right through to the system level.

What are your expectations for 2023?

We intend to continue and further expand our long-standing cooperation with the "Research Fab Microelectronics Germany" (FMD) in the context of the Intel facility being set up in Magdeburg. In terms of events, we are going to chair the leading international failure analysis conference ISTFA in the USA, and we will continue with our CAM-Workshop. We are also looking forward to the start of new projects. These will include joint projects for the development of high-performance, automotive-qualified high performance processors for demanding control tasks in the vehicle (central car server), innovative protection concepts for self-controlled IGBT-based power converters, grid connection of regenerative energies, and research into the reliability of sensors and electronic components in hydrogen atmospheres.

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Robust sensors for harsh environmental conditions

Sensors that function reliably even at extremely high temperatures or in corrosive environments are in demand, for example, for use in energy technology such as geothermal energy or turbine applications. In a collaborative project, eight Fraunhofer Institutes have developed a technology platform for realizing suitable and robust sensor systems. Fraunhofer IMWS contributed its expertise in materials analysis and developed new ways of characterizing materials in the high-temperature range.

Powerful sensors are just as important for running processes and systems efficiently as they are for early failure detection and quality assurance. They monitor condition parameters such as temperature and pressure levels during operation, thereby enabling energy-efficient process regulation or detecting unusual operating conditions that may be indicative of failures.

Conventional sensor components and materials are not suitable for extremely harsh environments, such as the interior of a power plant or aircraft turbines or geothermal wells, where high temperatures and pressure levels prevail and aggressive gases and liquids, or even dirt, can affect the sensors. Eight Fraunhofer Institutes therefore decided to pool their expertise to develop particularly robust sensors using new technological concepts for extremely harsh environmental conditions. The outcome of this was two demonstrators — one for use in engines/ turbines and one for drilling for geothermal energy. Fraunhofer IMWS was responsible for evaluating the materials and sensor elements used, such as heat-resistant ceramic substrates or joining materials. Properties such as critical thermo-mechanical loads, wear resistance and susceptibility to cracking or corrosion were investigated at very high temperatures and pressure loads. In addition, parameters for reliability assessment and for understanding potential failure mechanisms were determined. To this end, numerous diagnostic procedures were adapted to suit the relevant material systems and new test methods and test setups were developed.

The sensor elements for pressure or temperature measurements that were developed as demonstrators during the project combine both sensor and evaluation electronics. This ensures greater stability and lower susceptibility to sensor signal interference, as well as improved integration of the sensor elements. The ceramic sensors can be used at temperatures of 500 °C and pressure levels of up to 200 bar. The electronic interior is designed to withstand temperatures of around 300 °C.

The demonstrator for turbine applications developed during the project.

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Power semiconductors made of gallium nitride increase energy efficiency and save resources

In the EU-funded "Ultimate GaN" project, 26 partners from nine European countries conducted joint research on the next generation of gallium nitride (GaN)-based power semiconductors. The consortium of industry and research partners developed compact, cost-effective and energy-efficient components based on gallium nitride that open up new possibilities especially in the areas of smart mobility, smart grids and 5G communications.

Digitalisation in industry and private households, the expansion of electromobility as well as the growing demand for sustainable and affordable energy are currently dominant topics. Efficient generation, control and use of energy are required if we are to overcome these challenges. Power semiconductors play an important role in this. Conventional silicon-based semiconductors are reaching their limits and are increasingly being replaced by GaN semiconductors. GaN semiconductors offer more performance in a smaller space, save energy and thus minimize the carbon footprint.

That said, with high electric field strengths and enormous electrical current and power densities with correspondingly high material loads in these very compact components, even GaN semiconductors with large band gaps still leave many questions unanswered.

In the recently completed "Ultimate GaN" research project, a consortium of 26 European partners from science and industry set themselves the task of harnessing the benefits of GaN technology along the entire value chain, from process development, design, components and interconnection technologies right through to integrated system solutions.

With high-resolution analysis procedures and innovative failure diagnosis methods the Fraun-hofer Institute for Microstructure of Materials and Systems IMWS contributed to process and manufacturing optimization as well as to increasing the reliability of the GaN devices.

Following reliability testing, leakage current paths were localized and investigated from a microstructural perspective to determine their cause. A new defect signature could thus be identified, leading to the premature electrical breakdown of novel semi-vertical GaN transistors. Moreover, nanoindentation combined with acoustic emission techniques revealed hidden microcracks under the metallization layers of bond pads and the related defect structures were investigated by electron microscopic analysis.

The European project "Ultimate GaN" ran for three and a half years. The project volume of 48 million Euro was financed by investments from industry, grants from the individual participating countries and the European Joint Undertaking ECSEL (Electronic Components and Systems for European Leadership).

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Fraunhofer Center for Silicon Photovoltaics CSP

Selected research success stories

"We assist with quality assurance along the entire value chain"

Interview with Head of Business Unit Prof. Ralph Gottschalg

What were the highlights of 2022 for your Business Unit?

For us, the significant event was the launch of the Fraunhofer Innovation Platform for Hydrogen Energy at the Korea Institute of Energy Technology FIP-H2ENERGY@KENTECH (FIP). For an initial term of five years, five Fraunhofer Institutes, together with their partners from South Korea, are conducting research on the development of technologies along the entire hydrogen value chain. The general management of the project lies with Fraunhofer IMWS.

Furthermore, our research and industry workshop "PV Days" finally took place again in October after a hiatus caused by the pandemic.

In the wake of the energy crisis, many people are talking about the German solar industry making a comeback. What opportunities do you think exist for Fraunhofer IMWS in relation to these developments?

We can expect to see a great deal of activity in the solar industry and in the use of green hydrogen over the next few years. In terms of photovoltaics, this means that we will be adapting our Business Unit to meet the new demands of the market. On the one hand, we expect to see a rapid increase in the number of new installations. On the other hand, that increase can only be achieved if Germany massively expands its production capacity. As in any fast-growing market, quality assurance along the entire value chain will be essential, and we will support German industry and business with our expertise in cell diagnostics, material analytics, failure prediction, root-cause analysis of unexpected failures, and the identification and assessment of problems in the field.

What are your expectations for 2023?

We expect the PV market to grow by 20 to 40 percent compared to 2022. This will also have a positive impact for us: We will support manufacturers by conducting high-quality scientific work in the areas of quality assurance, problem prevention and diagnostics. We will also show operators and investors ways to maximize the return on their investments. One area we will focus on will be the integration into energy systems in order to optimize the usability of photovoltaic energy.

Hydrogen production capacities are expanding massively as well. Particularly in terms of electrolyzer manufacturing, new GW-scale factories are being built right now. We therefore expect to see an increasing demand for associated microstructure diagnostics, both in the development of new components and in the upscaling of processes, as well as in quality assurance and defect diagnostics along the entire value chain.

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Experts discuss comeback of the German solar industry

According to the federal government's plans, the share of electricity generated from renewable energies in relation to total electricity consumption is to increase from currently just under 50 to 80 percent by 2030. This not only requires significantly more solar parks and wind turbines, but also a noticeable expansion of the solar industry. The current energy crisis lends additional emphasis to this demand.

Around 70 experts discussed the opportunities and challenges associated with a comeback of the German solar industry during Fraunhofer CSP's PV Days in 2022

For this reason, a comeback of the German solar industry was the central theme of this year's PV Days at Fraunhofer CSP. During the two-day conference, around 70 experts discussed the opportunities and challenges of a changing market environment, possible new areas of application for photovoltaics, quality requirements for a successful photovoltaic market, as well as questions about supply chains and the manufacturing of photovoltaic systems. The participants expect a doubling of production capacity over the next two years and a fivefold increase in installations over the next four years. They identified global supply chains, production outages, staff recruitment and financing of capacity expansion as the biggest challenges. Both the German and international markets are growing rapidly. The experts agree that this growth will continue uninterrupted over the next ten years in order to meet installation requirements.

In the course of these developments, Fraunhofer CSP decided to reorganize itself back in 2021, now addressing a broader range of topics.

Instead of focusing on immediate technological innovations, our research is now more strongly focused on the quality assurance of materials, components and modules, and the processes for manufacturing. In addition, independent research groups are devoting their attention to the issues of intelligent photovoltaic system operation, grid integration of solar energy and the possibilities that hydrogen can offer as an energy carrier in this context. Since its foundation, Fraunhofer CSP has been a reliable research and development partner to the Central German photovoltaics industry.

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Ideal cross-linking degrees for solar modules through optimized quality control

Currently, manufacturers of photovoltaic modules provide a performance guarantee of 25 years on 80 percent of the output power. This reliability and service life is only achieved if the encapsulation of the solar cells is perfectly processed, thus ensuring protection against external influences. At points where encapsulation films are insufficiently cross-linked, delamination can occur over time, which impairs the service life of the module.

To prevent this, the solar cell composite is fixed within a solar module and encapsulated as tightly as possible. For encapsulation purposes, the solar cells are enclosed in two films of plastic. Currently, mainly ethyl vinyl acetate copolymer (EVA) is used for this purpose. EVA is transparent, has rubber-like flexibility, good tear strength and aging resistance, and good insulation and barrier properties. In solar module production, the two EVA films are heated in stages as part of a lamination process so that the EVA first melts, flows into the cavities between the cells, thereby filling them, and then cross-links. The degree of cross-linking of an encapsulation film indicates how well this process has been carried out and can be characterized.

Fraunhofer CSP conducts lifecycle-relevant studies of module encapsulation stability in photovoltaic modules.

Currently, too little is known in the industry about the relationship between encapsulation lamination and module longevity, especially about the local dispersion of the degree of cross-linking. The degree of cross-linking of EVA is insufficiently controlled when measured against its importance to module reliability. There is no industry-accepted non-destructive testing technology on the market yet. The only approach currently available is the X Link system from LayTec. This is where the recently launched "EVAplus" project comes in. Fraunhofer CSP is collaborating with industrial and academic partners to improve reliability of supply, plant performance and productivity by conducting lifecycle-relevant studies of module encapsulation stability in photovoltaic modules.

Fraunhofer CSP is contributing its expertise in polymer analytics and polymer evaluation to the project, working on issues that contribute to understanding material changes in realistic operating conditions, investigating chemical and micromechanical material properties, and modeling environmental stress-induced aging of laminates, as well as risk assessment of material and process parameter variations.

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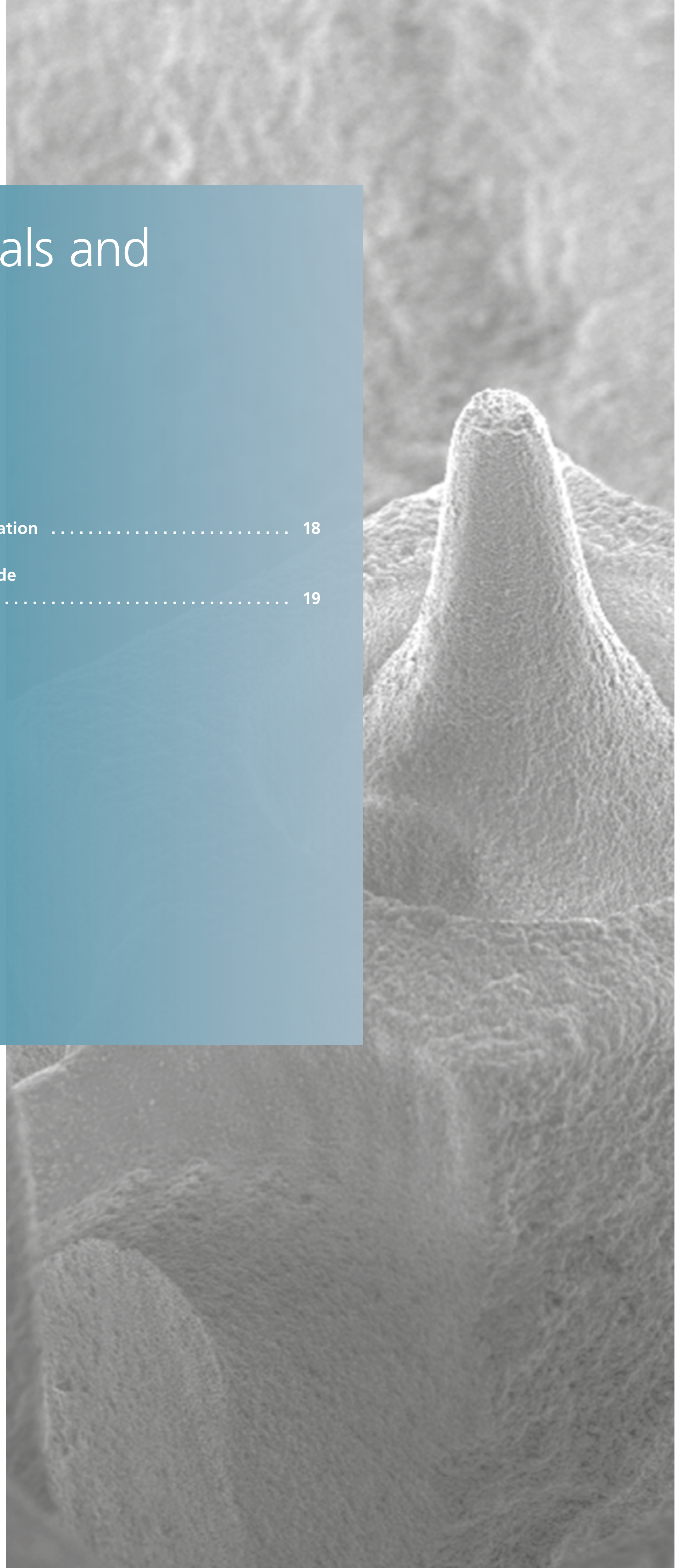

Optical Materials and Technologies

Selected research success stories

“Property-adapted glass and glass ceramics are flagship products of the Business Unit”

Interview with Head of Business Unit Prof. Thomas Höche

What were the highlights of 2022 for your Business Unit?

Besides welcoming our new Director Prof. Erica Lilleodden, we can look back on several notable achievements, together with our customers. Regarding the characterization of optical materials, we significantly expanded our customer base thanks to our high-resolution analytical techniques and also made significant progress in developing our own processes and materials. We are active in the market for vision aids with our project on laser processing of polymer substrates, which is funded by the “Fraunhofer Zukunftsstiftung”. With the “fibNotch” project funded by the State of Saxony-Anhalt, we tapped into new possibilities for the large-scale preparation of samples for transmission electron microscopy. We were also able to complete two important industrial projects focusing on the development of glass and glass ceramics accelerated by microstructure diagnostics, with great success.

In 2022, you restructured your Business Unit in terms of personnel. What are the goals of this restructuring?

By forming the Group “Microstructure-Based Materials Development” headed by Dr. Christian Thieme, we want to acknowledge the fact that the synthesis of property-adapted glass and glass ceramics has become one of the Business Unit’s flagships in recent years. We are seeking to raise the profile of this unit, improve its facilities through investment and, at the same time, reward the commitment of the employees involved.

Which customers can benefit from the offer in your business field?

Our customers are in the optical, paint and special machinery manufacturing industries. We use our microstructure-diagnostic techniques to support them in the development of glass and glass ceramics, optical coatings for lithography, laser technology and ophthalmics, and in the field of effect pigments for paints. We draw on our expertise in diagnostics to develop new materials faster and optimize laser-based material development processes.

What are your expectations for 2023?

On the one hand, we have many ideas about topics that we want to pursue. On the other hand, we are looking forward to working with the other Business Units on a fundamental refurbishment of our analytical equipment in the coming year. This will enable us to further support our partners with excellent analytical equipment and to successfully implement innovative ideas in the future.

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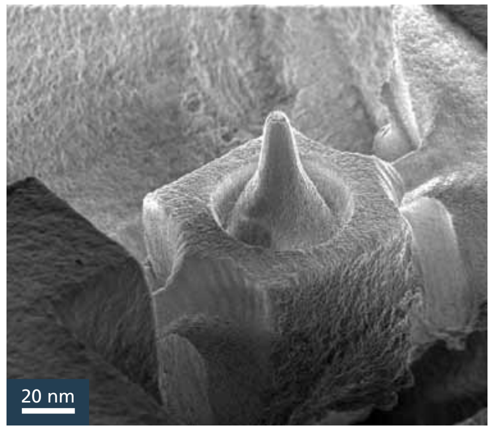
Laser-based sample preparation for high-resolution 3D structure determination

Access to high-resolution, three-dimensional structural data opens up entirely new possibilities not only in terms of design, but also in terms of evaluating the reliability of materials and systems. For this reason, various methods for high-resolution 3D structural analysis are used at Fraunhofer IMWS and new workflows are being developed to implement them in the field of process development or failure analysis. One of the key areas we focus on are high-performance sample preparation methods that are adapted to the requirements of analytical techniques.

Recently, research work in the Business Unit "Optical Materials and Technologies" concerned laser-based preparation of samples for high-resolution X-ray computed tomography (nano-CT) and atom probe tomography (APT). Both techniques share the requirement for minimally invasive, precise and artifact-free production of rotationally symmetric target volumes. In the case of nano-CT, these need to be in the range of less than ten micrometers, depending on the material and diameter, tips with diameters smaller than 100 nm are required for the analysis using APT. To extract these from any given component, various preparation techniques need to be closely dovetailed. The transition between the mechanical preparation methods and the focused ion beam (FIB) technique is particularly challenging. To improve the reproducibility and automation of this process on the one hand, and to also significantly reduce the time required for final thinning by means of FIB, we have developed workflows using ultrashort pulse lasers and have incorporated them into the functional scope of the microPREP™ PRO co-developed at the institute for routine use. As a result, samples can be prepared and analyzed in a highly efficient way without any final FIB preparation, even in the case of very challenging materials, such as glass and glass ceramics (see figure).



Nano-CT sample made of "LEAZit-Glaskeramik" produced by way of laser micromachining.

Furthermore, we have developed an innovative process for sample preparation for APT. Tip arrays can thus be automatically pre-prepared directly from the mechanically pre-tailored material volume. The conventional FIB-based process of transferring samples onto special sample carriers is thus obsolete. At the same time, the time required for final thinning can be kept to a minimum.

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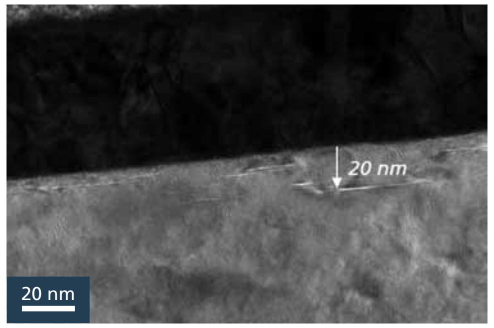
Near-surface damage of calcium fluoride when used in optical components

Calcium fluoride (CaF_2) plays an important role in the optical industry due to its high transparency in the ultraviolet spectral range. However, it must be transformed into a special shape for use in optical components using mechanical processes and ion beam corrective polishing. Near-surface damage and/or chemical contamination can occur during both machining processes. It is possible for a CaF_2 surface to match the desired geometric shape perfectly and exhibit excellent roughness levels, but still have optically absorbing defects caused by areas of near-surface damage that affect service performance.

To prevent such defects from occurring, an analytical evaluation of the damage needs to be performed. To this end, and building on previous studies of optoceramics (spinel, zirconia, and alumina), we carried out a detailed study in the course of an internal Fraunhofer project. Together with Fraunhofer IPT and several industrial partners, we investigated the influence of machining parameters, as reflected in the analytically determined defect structure (structural, near-surface damage and chemical purity). For this purpose, special preparation methods needed to be developed for calcium fluoride, which is brittle and susceptible to high temperature gradients. Using these prepared specimens, damage to the crystal structure could be visualized by means of high-resolution cross-sectional imaging in a transmission electron microscope. Simultaneously, depth profiling based on time-of-flight mass spectrometry was used to characterize the extent of chemical contamination as a function of the distance from the surface. It was evident that a very high surface quality can be achieved with a suitable choice of parameters.



Transmission electron micrograph of a cross-section of an ion-beam-polished CaF_2 surface

The familiar phenomenon of near-surface fluorine depletion was detected analytically. In addition, the study proved that nanoindentation can provide a rapid, inline assessment of subsurface damage.

The analytical toolbox can be used as a basis for further optimization of the machining processes to meet increasing future demands on material integrity and maximum transmission.

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“We take advantage of synergies to make carbon cycles even more efficient”

Interview with Head of Business Unit Prof. Martin Gräbner

What were the highlights of 2022 for your Business Unit?

We were able to add a rotary kiln pyrolysis system with condensate trap to our range of equipment using start-up funding from the Ministry of Science and Culture of the Free State of Saxony. The new rotary kiln will complement the pyrolysis platform currently under construction and is already being used in two projects, including the Fraunhofer lighthouse project “Waste4Future”, which focuses on the chemical recycling of plastic waste. Furthermore, as part of a joint project with the Technical University Bergakademie Freiberg, we were able to expand our expertise in the analysis of liquid products to include synthetic fuels. Of course, the fact that our branch office passed its Fraunhofer evaluation process was a great success and validated the work we have done in the past.

How can companies benefit from collaborating with your Business Unit?

Companies that want to shift their carbon-intensive processes in the direction of a sustainable circular economy can count on our expertise. This applies not only to the chemical industry, the manufacturing sector, mechanical and plant engineering but also to companies in the energy, waste and recycling industries. Thanks to our unique infrastructure, which allows us to test various input materials in different industry-oriented conversion systems, we are able to support companies in the effective and sustainable use of carbon carriers.

You will move to the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden at the beginning of 2023. What changes will this switch bring for you and what are your expectations for 2023?

Since taking office in April 2021, I have focused on strategically gearing our Freiberg branch office more toward the electrification of carbon cycle and hydrogen technologies. While evaluating the start-up funding, the Fraunhofer Gesellschaft and the Free State of Saxony argued in favor of remaining within the Fraunhofer model and integrating it into Fraunhofer IKTS. This merger will result in fascinating synergy effects for us, because the high-temperature electrolysis system developed at Fraunhofer IKTS complements our gasification process extremely well, thereby making carbon cycles even more efficient. In addition, we would like to open up new research fields in 2023 and continue to work on our existing topics together with Fraunhofer IKTS.

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Chemical recycling of carbonaceous waste

Plastic packaging is omnipresent, but it is difficult to dispose of. Some of it is reprocessed into recyclates; non-recyclable plastics are sent to landfills or are incinerated, depending on the region. An alternative to waste incineration is chemical recycling. At Fraunhofer IMWS, scientists are conducting research on new chemical-recycling technologies that contribute to recovering non-recyclable plastics and reduce CO_2 emissions.

According to the German Environment Agency (UBA), each person living in Germany produces around 600 kg of household waste per year. In addition to organic waste, glass and paper, this also includes packaging, most of which is made from plastic. However, though the recycling rate in Germany is increasing, only a small proportion of the plastic produced is reused for new products. Furthermore, some plastics, such as mixed or contaminated plastics, cannot be recycled with current recycling technologies. Thus much of the plastic waste is still being incinerated.

Chemical recycling provides an alternative or supplement to conventional recycling technologies, allowing currently non-recyclable plastics to be reused. Thermochemical processes are used to produce synthesis gases or oils from plastics, which in turn are used by industry or used to replace fossil raw materials in the manufacturing of plastics.

As part of the “SBV-Mono” project, Fraunhofer IMWS is pursuing the goal of generating a synthesis gas consisting of carbon monoxide and hydrogen that can be further processed into various chemical products. To this end, a gasification process using slagging bath technology will be further developed in order to thermochemically transform waste that contains plastics. In addition to this carbonaceous waste, other carbon-containing residues, such as petroleum coke, various pyrolysis cokes or biomass residues, are to be used in this process. The development of this new, adapted gasification process occurs in various stages. The knowledge that has been gained to date with fossil input materials serves as the starting point. Building on this, new approaches and ideas in burner technology, process control and preparation are used to pave the way towards a new technology. By recycling problematic waste, such as mixed plastics, sorting residues or biowaste, the project can help to solve the global waste problem. Moreover, it will support the Central German chemical industry in its transitions towards “Chemistry 4.0”.

The pilot facility of the slagging bath gasifier at the Freiberg site is operated in close cooperation with the Institute of Energy Process Engineering and Chemical Engineering at the Technical University Bergakademie Freiberg. The facility is used for tests involving various solid carbon carriers, such as biomass and plastic-containing waste.

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Polymer Applications

Selected research success stories

"We offer a wide range of methods from a single source"

Interview with Head of Business Unit Prof. Maik Feldmann

What were the highlights of 2022 for your business unit?

Some of the highlights of the year in our Business Unit were the appointment of a new Business Unit Manager in conjunction with the appointment to Professor at the University of Applied Sciences in Merseburg, and the first year in operation of the expansion of the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ. The expansion of the PAZ will create new opportunities in the field of thermoplastics and elastomer processing. By having access to the latest machinery and equipment, we are now able to provide our partners with more tailored support for research and development on an industrial scale and to further develop existing technologies.

We also held our successful Sandwich Conference for the second time last year in cooperation with our industry partner ThermHex. with over 100 participants from 15 countries it was very well attended.

In October, you took up the position as Head of Business Unit. What do you intend to focus on in your new position in the future?

The plastics processing and characterization equipment I have encountered here is both modern and extensive and can be used to serve a wide variety of industry needs along the entire value chain – from microstructure characterization to production-scale processing machines. We are therefore able to offer the industrial sector a wide range of methods from a single source.

In the future, I want to further strengthen our activities in the field of sustainable plastics technology and further improve our visibility in the fields of industry and science. The focus will be on the topics of renewable raw materials, the circular economy and material-efficient lightweight construction solutions. In view of the mobility and energy transition towards zero emissions, there are exciting opportunities for this Business Unit.

What are your expectations for 2023?

The coming year will be particularly important for our entire business unit. Rising energy prices and raw material shortages will pose new challenges for us and our partners, which we intend to tackle together. As part of an internal strategy process, we will refine our profile and align our focus to current political, economic and ecological framework conditions.

In addition to these strategic issues, we will also be holding various events in the coming year. We are particularly looking forward to the "Entwicklung trifft Serie" (Development Meets Series Production) workshop, which will be held for and in collaboration with our industrial partners at the Pilot Plant Center. The workshop will focus on topics from research and development as well as plant technology for large-scale production in real-life operations.

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TS-Moulding: novel manufacturing technology for sandwich components in high-volume applications

Fully automated serial production of continuous fiber-reinforced thermoplastic sandwich structures

New lightweight construction technologies are indispensable when it comes to contemporary mobility and achieving climate protection targets. In vehicles with internal combustion engines, lightweight solutions are already reducing fuel consumption and emissions through reduced vehicle weight.

Sandwich composites with continuous fiber-reinforced plastic cover layers and a honeycomb core in between the layers allow for maximum lightweight performance. Significantly higher weight-specific mechanical properties can be achieved with sandwich composites compared to monolithic materials, especially when used in large-area structural components. Due to costly manufacturing processes, lightweight sandwich structures have so far mainly been used in high-cost applications such as aerospace applications.

The technology, along with a demonstrator, were showcased at the K trade show, the leading business platform for the plastics and rubber industry

In contrast, continuous fiber-reinforced sandwich composites are not yet being used in more complex structural components in large-scale applications. This is mainly due to the lack of manufacturing technologies that would allow such components to be produced fully automatically in short cycle times, or to the fact that these technologies are not yet technically mature.

TS-Moulding® developed by Fraunhofer IMWS provides solutions for this. In essence, the patented technology comprises a novel thermoforming process with which intricately shaped continuous fiber-reinforced sandwich structures can be mass-produced. Thermoforming of continuous fiber-reinforced thermoplastic sandwich composites can be combined with thermoplastic injection molding or impact extrusion. This combination allows ready-to-use sandwich components to be produced in cycle times of about one minute.

Test components produced in the thermoforming injection molding process, each made of different types of continuous fiber-reinforced sandwich composite.

The thermoforming process consists of two main process steps necessary for processing the continuous fiber-reinforced thermoplastic sandwich composite. The first one is the two-dimensional infrared radiation (IR) heating of a sandwich blank with an interposed screening phase.

This is followed immediately by the three-stage forming process itself. The three-stage forming process, which takes only a few seconds, is divided up as follows: Hot forming of the sandwich composite, stabilizing the hot-formed sandwich areas and compressing areas with high sandwich thickness reduction. After forming, the composite is cooled and can be functionalized in the same tool, for example by way of injection molding or impact extrusion.

The new TS-Moulding® technology provides opportunities to utilize essential construction materials efficiently right from the value-creation stage. In this process, waste cuttings from component production are recycled without additional material input when the thermoformed sandwich structures are functionalized during injection molding or impact extrusion. As a result, in addition to the familiar weight advantages of lightweight construction, material consumption can also be significantly reduced during production.

Along with eliminating cutoffs, the TS-Moulding® recycling path, which is based on modern circular economy models, offers the additional advantage of producing the sandwich components from just a single fiber composite. This can be achieved without additional material input when functionalizing the thermoformed sandwich structures during injection molding or impact extrusion. This means that not only can production waste be eliminated during the value-creation process, but the components are also ideally suited to be recycled at the end of their life cycle, having been manufactured from a single material.

In the long term, it will be possible to use TS-Moulding® to produce economical and sustainable lightweight structures for electric vehicles in passenger and freight transport, which are essential for vehicle energy efficiency and the resulting increase in range. The new process also opens up other potential applications in the aerospace industry and in the construction sector.

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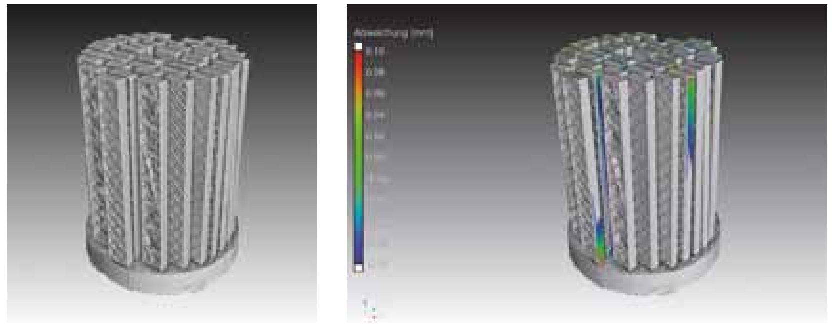
Fewer process interruptions and build errors thanks to semi-automated quality assurance for 3D-printed components

The digitization of production processes enables enormous increases in efficiency in industrial production. Additive manufacturing is a key technology used in this process. For this process to function smoothly in the sense of an industry 4.0, individual steps of the workflow must be adapted. In particular, the requirements for automatic quality assurance play a role that should not be underestimated.

A joint project between Studio.201 Software GmbH and Fraunhofer IMWS focuses on semi-automated quality assurance for 3D-printed components. The central idea behind the approach is to automatically inspect a large number of additively manufactured components simultaneously in order to reduce component distortions and detect defects. To this end, process and geometric data (target data) is linked with measurement data from computed tomography (actual data) on large samples (≈100). The information gained from this process in turn provides a database for machine learning, which is needed for subsequent processes. Combined with automated component tracking it paves the way for the creation of an integrated process-control system. Thus, information from design and pre-development, accompanied by process data, can be correlated with the measurement data on the final component in order to make adjustments to the technology and material selection or to implement steps for post-processing, thus improving reproducibility.

Due to the greater range of variations in additive manufacturing, these are tested as part of an automated evaluation process using Massive Parallel Testing (MPT).



Determination of the deviation in the geometry of the additively manufactured sample from the target geometry by means of CT analysis. The analysis allows conclusions to be drawn on how to optimize the manufacturing parameters.

Based on the design geometry of a component, a large number of design versions are created automatically, combined with the variants of the manufacturing process and different materials, and then additively manufactured. For this purpose, a tracking and handling system is being developed to prepare the printed components for structural examination using computed tomography and then to examine them microstructurally. This is being documented by a data management system. In the end, a quantitative evaluation, and a statement in the form of a traffic light system are available for each manufactured variant.

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Environmentally friendly and resource-saving plastic substitute products made from flour

Fraunhofer IMWS is collaborating with the companies ceresan Erfurt GmbH and Dornburger Kunststoff-Technik GmbH to develop environmentally friendly and resource-saving plastic-substitute products. The composites being developed consist primarily of flour and cellulose-containing natural fibers and can undergo further processing in the same way as conventional plastics.

Plastics are omnipresent in day-to-day life. Currently, around 330 million tons of plastics are produced worldwide each year, about 95 percent of which are based on petroleum. Packaging accounts for more than 40 percent of total plastic consumption worldwide. Packaging and disposable products that are not disposed of properly and are therefore not recycled place a particularly heavy burden on the environment. To protect the environment, efforts are being made to reduce the use of plastics in disposable products and packaging. But what alternatives to plastics are there for these products?

In the "Flour Composite" project, Fraunhofer IMWS and industry partners have developed a composite material from renewable, non-syn- thetic raw materials that is competitively priced compared to petroleum-based products. The plastics substitute used was primarily starchy flour, which was thermoplastically processed using a twin-screw extruder and can undergo further processing similar to conventional thermoplastics. Only cereal flours of feed quality and readily available on the market were used, thereby adding value to lower-quality flours, and avoiding tying up valuable acreage.

Flour was used instead of pure starch in order to further reduce the CO_2 footprint. The energy intensive and wastewater producing separation of starch from flour is thus eliminated and raw material costs can be considerably reduced. The starch contained in the flour does not possess the processing qualities and usage requirements necessary most applications. To improve the material and processing properties to a level sufficient for a specific application, biowaxes and natural fibers were added to the thermoplastic flour.

The composite material developed during the project consists exclusively of cereal flour, bio-plasticizers, bio-wax, natural fibers and small amounts of bio-additives. The flour composites were used to produce note boxes, and other office supplies. Other consumer goods are to follow.

The composites developed during the joint project were used to make sustainable note boxes.

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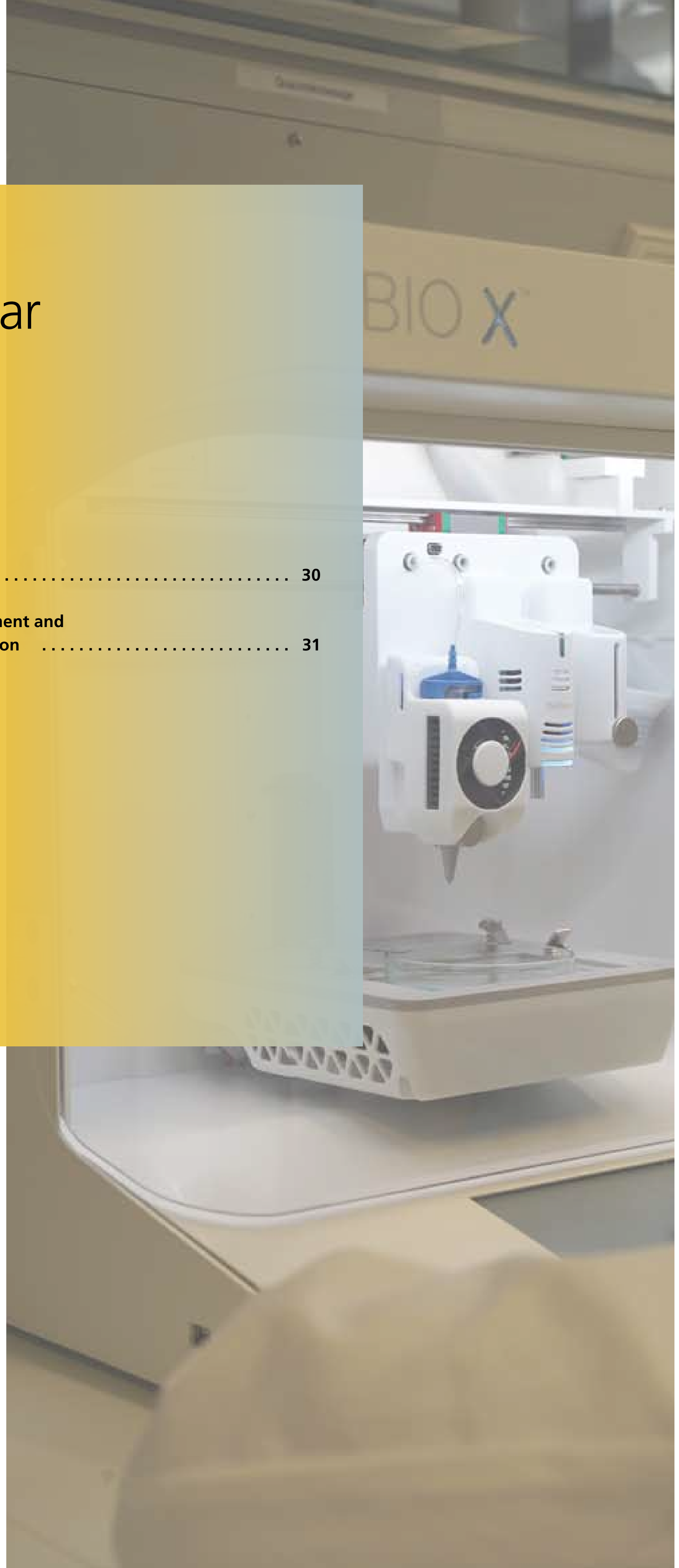

Biological and Macromolecular Materials

Selected research success stories

"We are injecting new momentum into the Business Unit with protein characterization and biological models"

Interview with Head of Business Unit PD Dr. Christian Schmelzer

What were the highlights of 2022 for your Business Unit?

The key highlight of the year in our Business Unit was the founding of "matrihealth GmbH", a spin-off from a Fraunhofer start-up project originally known as "matriheal". We supported the team to the best of our ability in developing their ideas in an application-oriented manner and are pleased that the newly founded company, which specializes in the cost-efficient and scalable production of medical-grade elastin and elastin-based materials, is now based in Halle (Saale).

In 2022, you changed the substantive focus of your Business Unit to some extent. What are the goals of this refocusing?

This primarily concerns the group "Biofunctional Materials for Medical and Environmental Applications", which has acquired additional expertise in the areas of "protein characterization" and "biological models" over the past few years. This enabled us to launch important industrial projects in the past year. We intend to further expand these activities over the medium term. We have also had personnel changes in this regard: Since the beginning of 2022, Dr. Andrea Friedmann has been leading the above-mentioned group and giving it new impetus.

What added value can companies gain from collaborating with your Business Unit?

We support our clients from the medical, personal care and environmental sectors primarily in the development of medical and personal care products. The focus is on the use of innovative materials and quality control. We assess materials and products with regard to their functionality, clarify mechanisms of action and provide support in the screening of new active ingredients, in order to optimize toothpastes or toothbrushes, for example. We are developing new materials with improved structural and surface compatibility in order to improve the biofunctional properties of products such as wound dressings.

What are your expectations for 2023?

We expect that 2023 will be a challenging year. Rising energy prices, inflation and supply bottlenecks are causing difficulties not only for our customers and partners, but also for ourselves. Nevertheless, we are optimistic about the coming year. Our industrial robot, which went into operation in 2022, will allow for a new level of quality in product evaluations in the oral care sector. At the beginning of the year, we will also start on an exciting project that has its roots in the pandemic and that will see us working with several partners to develop improved protective equipment. I am also looking forward to numerous scientific theses being completed, including two PhDs.

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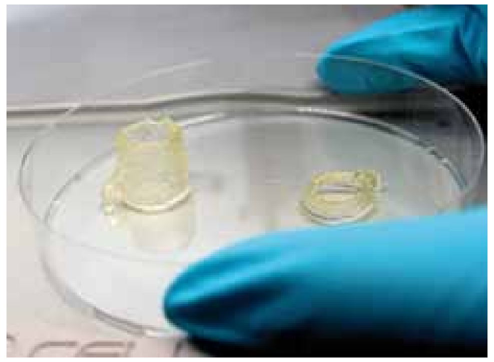
Innovative bioinks for 3D bioprinting

Bioprinting technology is used to produce biological or biologically functional tissues in the laboratory. Using a 3D bioprinter, bioink is printed layer-by-layer to create a complex three-dimensional object. These kinds of bio-based 3D structures are expected to be used in the future, for example as in vitro test systems in pharmaceutical research and in personalized medicine for producing tailor-made vascular and organ components. To turn this vision to reality, researchers at Fraunhofer IMWS are developing new bioinks that are suitable for various applications.

Bioinks must meet a number of requirements: They need to be printable, mechanically stable and biocompatible, must not contain toxic components, and must be capable of being cross-linked to form a hydrogel in order to provide a framework for cell colonization that is similar to the natural matrix found in connective tissue. Various bioinks are used depending on the area of application. These differ depending on the polymer used and in terms of whether cells are printed as part of the process or whether they are subsequently introduced into or onto the printed 3D structure. The bioinks currently available on the market are mostly based on collagen, gelatin and alginate, with other biopolymers currently in development.

This is where our scientists come in who are currently researching new types of bioinks based on proteins, with a focus on elastin. In addition to the actual ink-development process, the mechanical, physicochemical, and biological properties including cell compatibility of the printed objects are being evaluated.

In future, the researchers hope to be able to replicate functional vessel and organ parts using optimized bioinks. For example, computer tomographic data from patients could be used to print custom-fit 3D structures of vessels and implant them in the patient. A maiden research project on new bioinks was completed with great success and a patent was filed for the use of elastin-based bioinks.



Bioinks are printed layer by layer to form a three-dimensional object.

At present, the researchers are looking for collaboration partners from the industrial and clinical sectors to press ahead with further application-oriented development of the inks in terms of features and processability.

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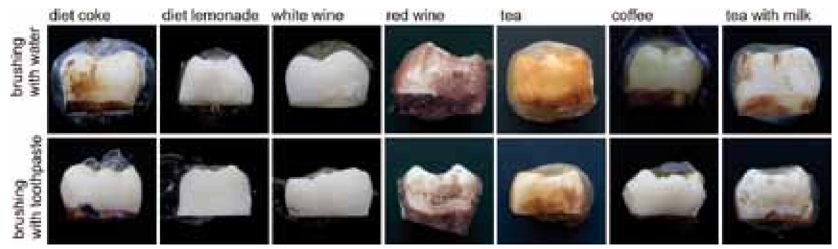
The link between chlorhexidine treatment and the choice of beverage in tooth discoloration

Chlorhexidine is currently the most applied antimicrobial active substance, especially in dentistry. Due to its proven track record of clinically alleviating gingivitis, this active substance has established itself as the gold standard in infection treatment and prevention over the past few decades.

The cationic chlorhexidine adheres to the negatively charged surfaces in the oral environment, i.e., saliva, skin or membrane layers. As a result, the active ingredient remains in the mouth for several hours. Due to its surface-active properties, it prevents proteins from adhering to the tooth surface, thereby destroying the foundations on which dental plaque forms. However, mouth rinses containing chlorhexidine have the potential to lead to discolorations when combined with colorants from food and beverages An in vitro study at Fraunhofer IMWS investigated the formation and removal of this discoloration from a materials science perspective. The study was commissioned by project partner GSK Consumer Health Care (now Haleon).

The aim of the study was to investigate the discoloration potential of different beverages when combined with chlorhexidine in an in vitro test model in order to obtain a data basis that allows for simple recommendations of alternative beverages to avoid discoloration during chlorhexidine treatment. The developed test model simulated a period of 14 days application of the mouth rinse. For this purpose, half dental crowns were subjected to cyclic exposure of artificial saliva and mouthwash in combination with a series of beverages. In addition to the exposure only treatment, the samples were brushed in a brushing simulator to evaluate the effect of mechanical cleaning.



The study concluded that the risk of tooth discoloration when using chlorhexidine-containing products is reduced if highly staining beverages are not consumed during treatment. Black tea and red wine caused the most severe discoloration. Significant discoloration was also observed when ginger-lemon tea, coffee (both with and without milk), tea with milk, and lager beer were used. After the teeth were exposed to highly staining beverages, the scanning electron microscopy evaluation showed the formation of a surface layer. The mechanical resistance of the discoloration varied depending on the beverage, with that of black tea being the most resilient. Adding milk to tea and coffee changed the discoloration layer and significantly reduced the adhesion to the tooth surface.

Consumption of highly staining beverages prior to chlorhexidine treatment increases the risk of tooth discoloration.

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"New ways to ensure tamper-proof traceability of components and materials"

Interview with Head of Business Unit Prof. Stefan Schweizer

The lighting industry is the primary focus of your work. Which related fields did you continue to develop in 2022?

Building on our expertise in the lighting industry, we expanded our competencies in the area of infrared thermography methods for evaluating power semiconductor modules and in the optical simulation of optical assemblies, especially luminescent light rods. We intend to continue on this path in the future.

One area that we will also continue to expand on is product marking with luminescent glass. The enormous range of variations offered by the combination of different dopants with elements from the rare earths group means that components and materials can be traced in a tamper-proof manner throughout the entire life cycle of a product so as to optimize further use or reuse.

What specific expertise does your Business Unit offer clients?

We now have established ourselves, in close cooperation with the South Westphalia University of Applied Sciences, as a competent research partner for the regional lighting industry and companies from related sectors throughout Germany. Our expertise covers the qualitative and quantitative study of thermal paths, the development of glass-based luminescent materials (phosphors), and the optical characterization and evaluation of optical materials, especially phosphors.

Our studies are based on comprehensive optical and spectroscopic analyses, thermal measuring methods and laboratory-based performance testing for the assessment and development of phosphors, phosphor systems and materials.

What are your expectations for 2023?

We will continue to intensify our long-standing cooperation with HELLA (FORVIA Group). Furthermore, we intend to expand our expertise in thermography on power semiconductor modules. In the area of luminescent glass, we are currently planning joint projects with the German Federal Institute for Materials Testing and the company SCHOTT AG. In cooperation with S&I Spectroscopy & Imaging in Warstein we will also continue to drive forward measurement techniques for Raman spectroscopy, a combination of time-resolved Raman and photoluminescence spectroscopy.

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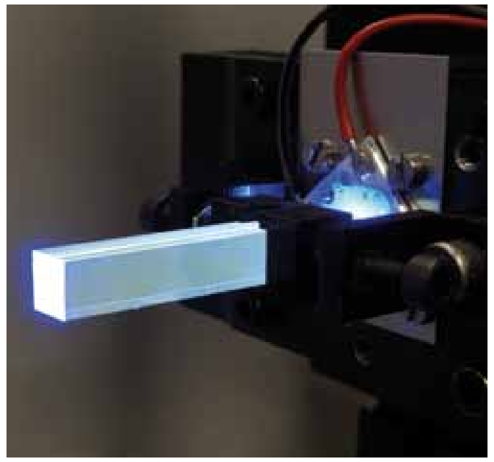
Application Center for Inorganic Phosphors

Luminescent light rods – greater luminance for projectors

Phosphor-converted ultraviolet or blue laser diodes are an intriguing source of green light due to their high luminance.

Digital projectors, such as those used in cinemas or meeting rooms, need to be very bright so that even large-format images can still be clearly seen. The high-intensity discharge lamps previously used for these purposes are increasingly being replaced by laser diode-based light sources. The brightness of the projector depends heavily on the power of the laser diodes used. The efficiency of green-yellow laser diodes is far lower than that of blue or red emitting diodes. This is referred to as the "green gap", and it remains a challenge for the production of modern light sources such as LEDs and laser diodes. Glass phosphors containing metal ions from the rare earth group combined with a source of ultraviolet (UV) or blue light provide an alternative for achieving a bright light impression in the green-yellow spectral range.

Borate glass offers very good chemical and thermal stability, high transparency, and good solubility for rare-earth ions. The latter is particularly important for the optical activation of glass with dysprosium (Dy^{3+}) or terbium (Tb^{3+}). Both ions produce intense yellow-green to green luminescence when excited in the ultraviolet to blue spectral range. However, they differ in terms of the percentage of the absorbed ultraviolet blue light that is converted into yellow-green luminescent light. Despite the high conversion values in borate glass of about 40 percent for Dy^{3+} and 80 percent for Tb^{3+}, the light yield is low. This is mainly due to the weak absorption capacity of rare-earth ions. Light rods can offer a solution. They extend the absorption path and at the same time accumulate the generated light so that the light yield is significantly higher.



Dy^{3+}-doped light rod which conducts the light generated under blue excitation.

The length of the light rod determines the luminous flux and thus the luminance at the exit face. Generally speaking, the longer the light rod, the greater the amount of excitation light absorbed. Above a certain length, however, the light yield at the end of the rod decreases due to self-absorption, meaning that the optimum length must be determined in each case. To date, the best simulation results have been achieved with a Tb^{3+}-doped light rod measuring about 40 mm in length: When excited in the UV spectral range (378 nm) with an optical input power of 1 watt, a luminous flux of more than 300 lumens is achieved. Comparable green LEDs offer a luminous flux of 100 lumens with an electrical output of 1 watt.

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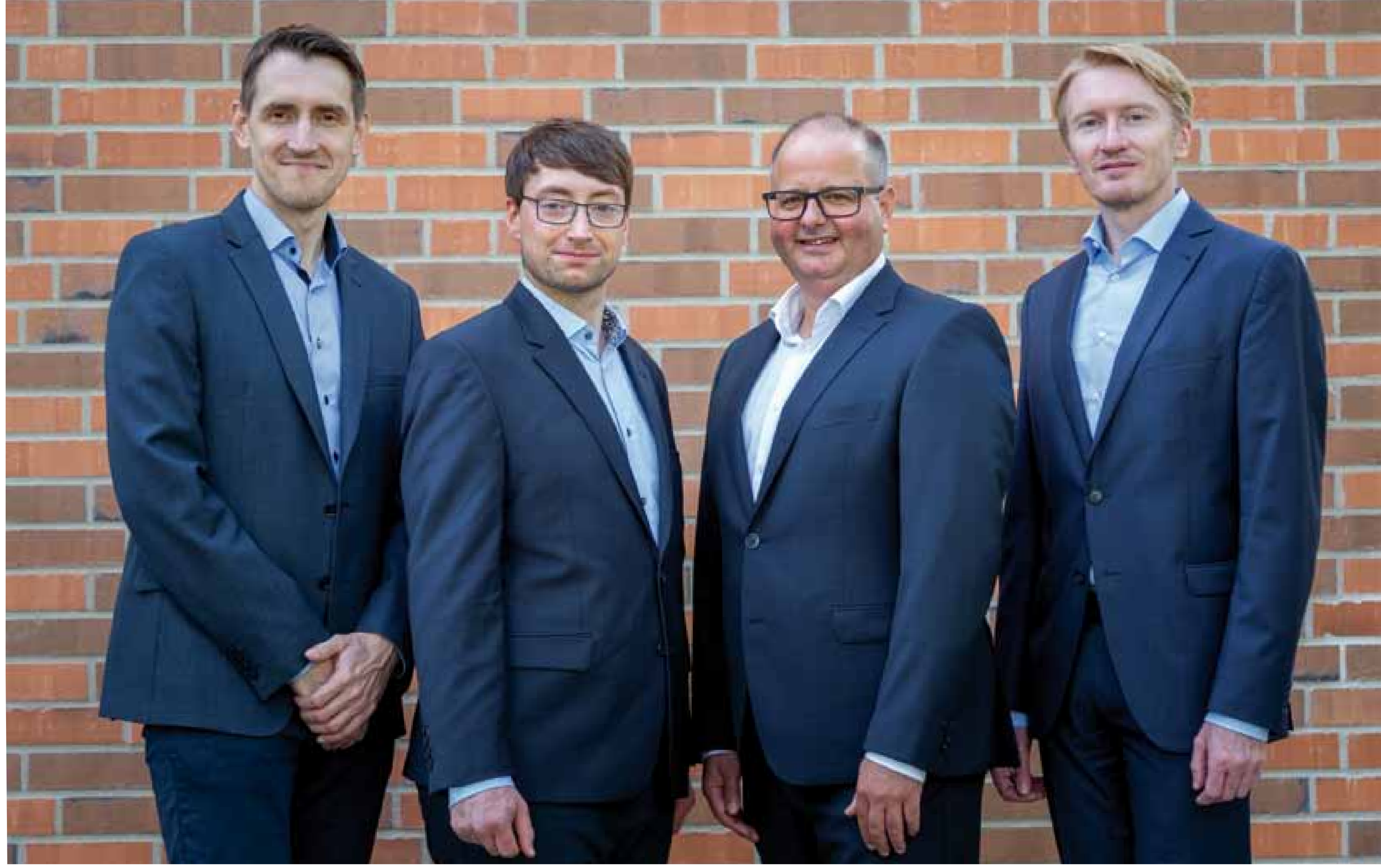
High-quality elastin for various market segments

Fraunhofer IMWS spin-off takes off as “matrihealth GmbH”



The “matrihealth” founding team: Dr. Marco Götze, Tobias Hedtke, Dirk Schuster and PD Dr. Christian Schmelzer (from left to right).

Producing high-purity, medical grade elastin is the core business concept of “matrihealth GmbH”. The spin-off of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS has been known by the name “matriheal” as a start-up project since 2020 and is now an independent company based in Halle (Saale).

The main product offered by “matrihealth GmbH” is soluble elastin, the properties of which can be adapted to the intended use.

The four founders Dr. Marco Götze, Tobias Hedtke, PD Dr. Christian Schmelzer and Dirk Schuster intend to produce elastin quickly, cost-effectively and in a scalable manner, enabling them to offer market-specific elastin solutions for medical products, food, cosmetics and for research purposes, among others.

The “matrihealth” founding team conducted research on the structure and properties of elastin at the Fraunhofer IMWS for more than six years. The result of their research is a method for extracting natural elastin and converting it into a water-soluble derivative that can be used in a variety of ways. In the growing market for elastin-based medical and cosmetic products, the founders trust they have excellent opportunities to establish themselves with their innovative and sustainable products.

Elastin is an important structural protein that, together with collagen, provides stability and elasticity to the skin, blood vessels and other organs and tissues. Unlike collagen, however, it is not renewed by the body, which can lead to problems in wound healing, and also causes wrinkles in old age. One idea is therefore to compensate for the loss of elastin in the skin with elastin-containing products.

In contrast to previous manufacturing processes, the technology used by “matrihealth” to isolate and purify elastin is less expensive, can be scaled up to an industrial scale, and offers the possibility of obtaining elastin in varying qualities and modifications for different applications. This highly pure, water-soluble elastin can then be used as a raw material for further processing in various markets. Prof. Erica Lilleodden praised the spin-off idea for a technology developed at the institute and the great transfer achievement.

Currently the team aims to produce and market elastin primarily for the medical, food, and cosmetics sectors. Later, the company also plans to develop its own semi-finished products and products for wound care. In this area, “matrihealth” already has extensive experience thanks to its many years of research at Fraunhofer IMWS, for which it was awarded the IQ Innovation Prize of the city of Halle (Saale) as well as the Hugo-Junkers Award.

The spin-off started off as part of a project that received funding under the Fraunhofer “Attract” program. Fraunhofer supported the subsequent spin-off process through the “AHEAD” funding program. Those responsible received further support from the “Weinberg Campus Accelerator” program at Halle’s Technology and Incubator Center (Technologie- und Grunderzentrum Halle GmbH, TGZ Halle).

Currently, the founders are looking for investors to set up their first production facility, alongside other activities.

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New Fraunhofer Innovation Platform for hydrogen in South Korea

Fraunhofer IMWS takes on a leading role in expanding German-South Korean cooperation in the field of hydrogen research and development

> " In the energy system of the future, hydrogen can play a key role as a raw material and energy carrier.

Fraunhofer IMWS has been conducting research jointly with Korean scientists on issues related to the import of green hydrogen since 2020. Now, the establishment of the "Fraunhofer Innovation Platform for Hydrogen Energy at the Korea Institute of Energy Technology FIP-H2EN-ERGY@KENTECH" will provide the foundation for a more enhanced cooperation with partners in South Korea.

The availability of green hydrogen will be an essential part of the journey toward defossilization. Fossil fuels are to be increasingly replaced by climate-neutral green hydrogen which most commonly is produced through electrolysis. Demand for hydrogen is expected to rise sharply worldwide. In countries like Germany and South Korea, where demand for hydrogen exceeds the country's own production capacity, reliance on imports will rise. Both countries will thus face similar technical challenges.

As a result, the German Fraunhofer-Gesellschaft and the KENTECH research institute in Korea have joined forces to create the "FIP-H2ENERGY@KENTECH (FIP)" platform. During an initial five-year term, the Fraunhofer IMWS and five other Fraunhofer institutes are cooperating with Korean scientists at KENTECH to

Prof. Euijoon Yoon, President of KENTECH (left), and Prof. Axel Muller-Groeling, Executive Vice President of the Fraunhofer-Gesellschaft e. V. – Research Infrastructures and Digital Transformation (right), at the signing ceremony in Berlin.

develop technologies along the entire hydrogen value chain.

In the energy system of the future, hydrogen can play a key role as a raw material and energy carrier. To actively shape this system, we need to optimize existing technologies,

After the signing ceremony in Berlin (from left): Dr. Klemens Ilse (Deputy Director of "FIP" and Group Manager of "Material Diagnostics for H2 Technologies" at Fraunhofer IMWS), Prof. Erica Lilleodden (Institute Director of Fraunhofer IMWS), Prof. Euijoon Yoon (President of KENTECH), Prof. Axel Müller-Groeling (Executive Vice President of the Fraunhofer-Gesellschaft e. V. – Research Infrastructures and Digital Transformation), Prof. Chinho Park (Vice President of Research and Dean of the KENTECH Institute), Prof. Jihyun Hwang (Managing Director of FIP, KENTECH)

develop new solutions, set standards and build the infrastructure required for this.

Jointly, the scientists will conduct research in the field of hydrogen logistics focusing on the different aspects of the production, conversion, or liquefaction, the transport and the use of green hydrogen. Fraunhofer IMWS will contribute its expertise in the areas of material characterization and developments for "Proton Exchange Membrane" (PEM) electrolysis and in photovoltaic-driven hydrogen production.

The signing ceremony for the "Fraunhofer Innovation Platform for Hydrogen Energy" took place during the 3rd Germany-Korea Hydrogen Conference (H2DeKo'22) on September 27 in Berlin. Guests from multinational companies based in Korea and Germany, policymakers and experts from the world of hydrogen attended the launching ceremony.

Fraunhofer Innovation Platforms (FIPs) are temporary research units that are based at universities or research institutions outside of Germany but are set up in close collaboration with Fraunhofer institutes within Germany.

A FIP is a temporary research unit at a university or research institution abroad, which is set up in close cooperation with Fraunhofer Institutes in Germany. In addition to the FIP-H2ENERGY@KENTECH, there are currently 15 Fraunhofer Innovation Platforms worldwide. Their purpose is to promote a collaborative approach to the valorization, transfer and commercialization of scientific research results and to utilize synergies to develop new business models and create competitive advantages. The positive impact of research on the economy and society is thereby always paramount.

Author

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“Bringing dynamism into everyday research”

Interview with Institute Director Prof. Erica Lilleodden

You have been the institute director of Fraunhofer IMWS since February 1, 2022. Please tell us a little about yourself.

Originally from Minnesota in the USA, I studied Materials Science at the University of Minnesota – Twin Cities and received my PhD from Stanford University, Department of Materials Science & Engineering. After completing a postdoc at the Lawrence Berkeley Laboratory, I moved to Germany in 2004 to become a Humboldt Fellow at the Institute for Materials Research at the Karlsruhe Research Center, now known as the KIT. Before I moved to Fraunhofer IMWS, I worked at the Helmholtz Center Hereon in Geesthacht for 15 years, where I headed up the department of Experimental Materials Mechanics. In my previous research activities, I focused on the interaction between the microstructural properties and the micromechanical response of material systems.

What motivated you to take up the position of Director of the Institute at Fraunhofer IMWS?

The Fraunhofer Gesellschaft’s idea of merging research and industry in the field of applied research was an incentive for me. This approach brings dynamism to everyday research and opens up entirely new horizons.

Of course, the position of Director ia great challenge — after all, it involves managing more than 300 employees. At the same time, it gives me the opportunity to build on my materials science background, learn about the broader aspects of materials science, and gain new perspectives as a result.

Also, the opportunity to enhance the profile of the institute by establishing and maintaining relationships with the economic, political, and business communities was part of the reason I decided to apply for the position. It was the fact that the position was multifaceted that appealed to me.

What goals have you set for your tenure?

Fraunhofer IMWS has been successful since its inception as an independent institute. I would like the institute to continue down this path. Up to this point, a lot of emphasis has been placed on growth and the expansion of new research fields. Looking back, this was very important in terms of positioning the institute in the German scientific landscape. That said, I think we have now reached a point where we need to go back to our roots and shift our focus back to our core competence, namely microstructures. This will provide us with many opportunities to enter new markets and further expand existing ones.

As such, we can play a major role in the transportation and storage of green hydrogen. With our comprehensive failure-analysis expertise in detecting weak points in microchips, and in lightweight structures, new types of coatings and rubber, we are a valuable research partner for the automotive industry. We are also very pleased that the semiconductor manufacturer Intel has set up shop in Magdeburg, as this will allow us to strengthen our long-standing cooperation with the company. Furthermore, the imminent “renaissance” of the photovoltaic industry in Germany will present additional opportunities, in particular for Fraunhofer CSP

Board of Trustees

Duties 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. Together with the Fraunhofer Executive Board, the members of the Board of Trustees advise the institute with their expertise on strategic issues, setting the course for the institute and developing future perspectives. They are appointed by the Fraunhofer Executive Board in agreement with the institute’s management and work on an honorary basis.

Members of the Board of Trustees

Prizes and awards

Named one of the "Most Innovative Companies in Germany" by "Capital"-magazine and market research service provider "Statista"
Fraunhofer IMWS
March 2, 2022, Hamburg

2nd prize at the Conference of Mathematics Disciplines (KMATHF)
Antonia Kaufmann
Antonia Kaufmann was awarded 2nd prize by the Conference of Mathematics Disciplines (KMATHF) for her paper on "Numerical Parameter Identification in Models of Fatigue Stress of Lightweight Materials." She carried out her research at the Martin Luther University in Halle-Wittenberg in collaboration with the Business Unit "Polymer Applications".
September 9, 2022, Cottbus

Best Poster Award CIPS 2022
Bianca Böttge, Sandy Klengel, Falk Naumann
Falk Naumann, Bianca Böttge and Sandy Klengel received the Best Poster Award at the Conference on Integrated Power Electronics Systems (CIPS) 2022 for their poster entitled "Potential failure modes of cement-based encapsulation concepts for reliable power electronics".
March 18, 2022, Berlin

Research award for students at the Merseburg University of Applied Sciences
Paul Beckert
Paul Beckert received the student research award from the Merseburg University of Applied for his final thesis entitled "Comparative life cycle assessment of a light electric vehicle", which he prepared at the university in cooperation with the Business Unit "Polymer Applications".
February 17, 2022, Merseburg

Fraunhofer Medal
Prof. Dr. Matthias Petzold
Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft (left), presented the Fraunhofer Medal to the Institute's former Acting Director Prof. Matthias Petzold for his services within the Fraunhofer Gesellschaft and the Institute. Prof. Matthias Petzold was one of the first employees of the Institute in Halle (Saale) 30 years ago.
November 2, 2022, Halle (Saale)

Badge of Honor of the State of Saxony-Anhalt
Prof. Dr. Dieter Katzer
For his extraordinary services in setting up the Institute and related activities as Director of the Institute of the then Fraunhofer IWM branch office in Halle (Saale) and for his work on behalf of the Heinz Bethge Foundation, Prof. Dieter Katzer (right) was awarded the Badge of Honor of the State of Saxony-Anhalt by Prof. Armin Willingmann, Minister for Science, Energy, Climate Protection and the Environment and Deputy Minister-President of Saxony-Anhalt (left).
November 2, 2022, Halle (Saale)

Patents and theses

Patents granted in 2022

Michael Busch
Polymers modified by means of a modifying reagent and method for producing those polymers
EP 3 224 286 A1

Thomas Höche / Michael Krause / Georg Schusser
Method for preparing a sample for microstructure diagnosis and sample for microstructure diagnosis
EP 3 101 406 A1

Thomas Gläßer / Peter Michel
Device for additively manufacturing a component
US 2018/0250876 A1

Richard Busch /Thomas Höche / Michael Krause / Georg Schusser
Method for preparing a sample for the microstructure diagnosis and sample for microstructure diagnosis
EP 3 153 838 A1

Ivonne Jahn / Stephan Lehmann / Peter Michel
Impregnating tool for the production of thermoplastic fiber composites
DE 10 2016 201 153 A1

Thomas Höche / Michael Krause
Method for the production of a micromachined workpiece by means of laser ablation
JP 2018-47503 A

Stephan Großer / Christian Hagendorf / Marko Turek
Method and equipment for inspecting buried structures in solar cells and solar cell precursors
10 2018 201 723 A1

Ulrich Wendler / Marlen Malke / Lowis-Gerrit-Boje Müller / Christian Schulze Gronover / Dirk Prüfer / Jacqueline Wötzel / Mario Beiner / Gaurav Kumar Gupta
Biomimetic synthetic rubber
2021105880 / P2021-536513A

Andreas Kiesow / Mirko Buchholz / Sandra Sarembe / Karsten Mäder / Martin Kirchberg / Sigrun Eick
Tetracycline complexes with sustained activity
3873432 A1

Marko Turek / Christian Hagendorf / Kai Sporleder
Method and device to test solar cells and solar modules for material degradation
3 748 843

Marko Turek / Christian Hagendorf / Stephan Großer / Hongming Zhao / Stefan Stöckel / Eve Krassowski / Eckehard Hofmüller
Method for improving the ohmic contact behavior between a contact grid and an emitter layer of a silicon solar cell
10 2020 002 335 A1

Kai Sporleder / Marko Turek / Volker Naumann / Jan Bauer / Christian Hagendorf
Method for testing solar modules or solar cells for potential-induced degradation
10 2020 203 747 A1

Thomas Höche / Michael Krause
Method for the production of a micromachined workpiece by means of laser ablation
10-2017-0119463

Theses

Nils Jonas Ziegeler
University of Siegen
Thermal equivalence networks for analysis of transient thermography

Stefan Söhl
Martin Luther University in Halle-Wittenberg
Development and characterization of deformation-matched composite base plates for reducing the pump-out effect of power electronic assemblies

Stefan Behrendt
Martin Luther University in Halle-Wittenberg
Analysis of thermal performance of novel module concepts using inorganic encapsulation materials

Kai Sporleder
Martin Luther University in Halle-Wittenberg
Root cause analysis of potential-induced degradation on the rear surface of bifacial silicon solar cells with passivated emitter and passivated rear surface

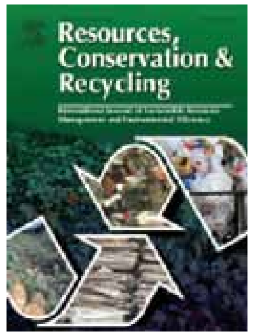
Publications

Highlights

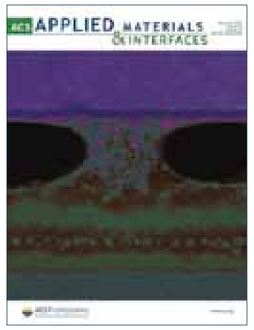
F. Alobaid, N. Almohammed, M. Massoudi Farid, J. May, P. Rößger, A. Richter (IMWS), and B. Epple
Progress in CFD Simulations of Fluidized Beds for Chemical and Energy Process engineering
Progress in Energy and Combustion Science
Volume 91, 2022

A. Bieniek, M. Reinmöller, F. Küster, M. Gräbner, W. Jerzak, A. Magdziarz
Investigation and modelling of the pyrolysis kinetics of industrial biomass wastes
Journal of Environmental Management
Volume 319, 2022

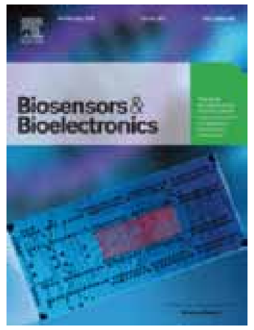
W. Eschen, L. Loetgering, V Schuster, R. Klas, A. Kirsche, L. Berthold, M. Steinert, T. Pertsch, H. Gross, M. Krause, J. Limpert, J. Rothhardt
Material-specific high-resolution table-top extreme ultraviolet microscopy
Light: Science & Applications
Article number: 117 (2022)



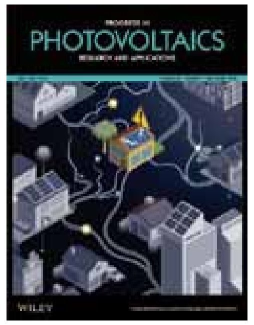
R. Voss / R. Lee
Life cycle assessment of global warming potential of feedstock recycling technologies: Case study of waste gasification and pyrolysis in an integrated inventory model for waste treatment and chemical production in Germany
Resources, conservation and recycling
Volume 179, 2022



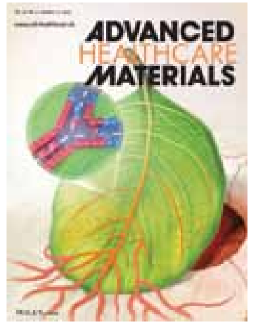
Ph. Storm, K. Karimova, M. Bar, S. Selle, H. von Wenckstern, M. Grundmann, M. Lorenz.
Suppression of rotational domains of cul employing sodium halide buffer layers
ACS Applied Materials & Interfaces
2022



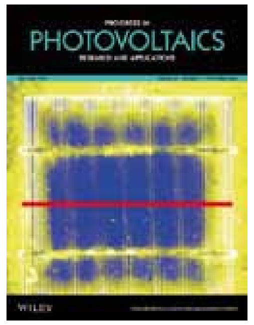
L. Jianfeng, A. Reimers, K. Dang, M. Brunk, J. Drewes, U. Hirsch, Ch. Willems, Ch. Schmelzer, Th. Groth, A. Nia, X. Feng, R. Adelung, W. Sacher, F. Schütt, J. Poon
3D printed neural tissues with in situ optical dopamine sensors
Biosensors and Bioelectronics
2022



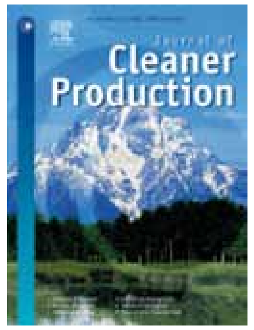
N. Kyranaki; A. Smith.; K. Yendall; D.A. Hutt; D.C. Whalley; R. Gottschalg; T.R. Betts
Damp-heat induced degradation in photovoltaic modules manufactured with passivated emitter and rear contact solar cells
Progress in Photovoltaics
Volume 30, Issue 9, 2022



C. Husteden, Y. Brito Barrera, S. Tegtmeyer, J. Borges, J. Giselbrecht, M. Menzel, A. Langner, J. F. Mano, Ch. Schmelzer, Ch. Wolk, T. Groth
Lipoplex-Functionalized Thin-Film Surface Coating Based on Extracellular Matrix Components as Local Gene Delivery System to Control Osteogenic Stem Cell Differentiation
Advanced Healthcare Materials
2022

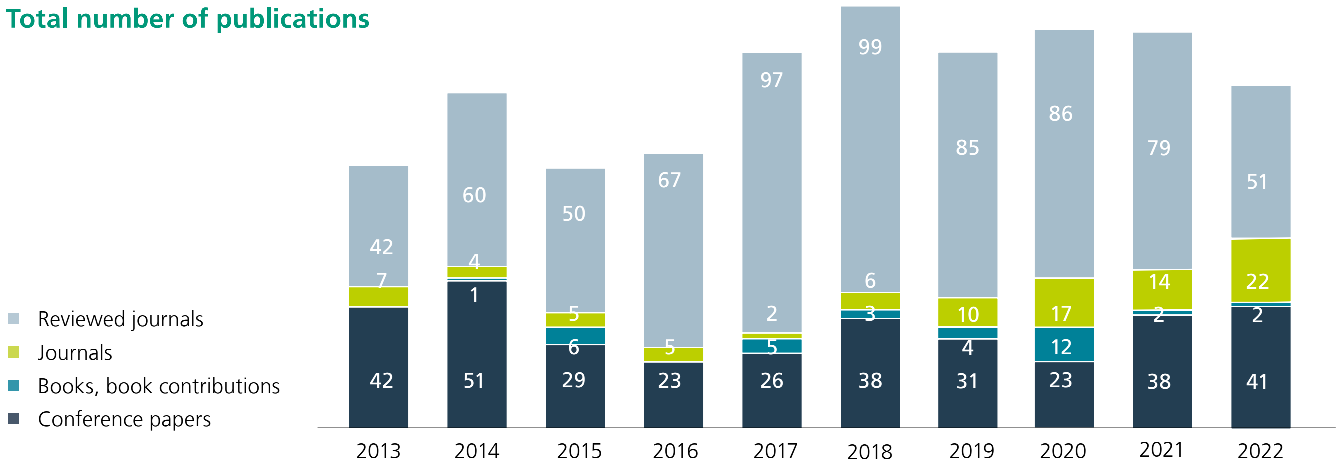


J. Karas, I. Repins, K. Berger, B. Kubicek, F. Jiang, D.Zhang, J. Jaubert, A. Cueli, T. Sample, B. Jaeckel, M. Pander, E. Fokuhl, M. Koentopp, F. Kersten, J. Choi, B. Bora, C. Banerjee, S. Wendlandt, T. Erion-Lorico, K. Sauer, J. Tsan, M. Pravettoni, M. Caccivio, G. Bellenda, Ch. Monokroussos, H. Maaroufi
Results from an international interlaboratory study on light- and elevated temperature-induced degradation in solar modules
Progress in Photovoltaics
Volume 30, Issue 11, 2022



P. Rößger, L. Seidl, F. Compart, J. Hußler, M. Gräbner, A. Richter
Integrating biomass and waste into high-pressure partial oxidation processes: Thermochemical and economic multi-objective optimization
Journal of Cleaner Production
Volume 358, 2022

Total number of publications



Events

Events (co-)organized by Fraunhofer IMWS

or to which it actively contributed (poster, lecture, etc.)

Online workshop with the German Rubber Association (DKG) on “Technologies and Materials for Sustainable Rubber Compounds”
March 9-10, 2022, virtual event

NK2 Workshop in Freiberg
March 22, 2022, virtual event

Silicon PV – 12th International Conference on Crystalline Silicon Photovoltaics
March 28-30, 2022, Constance, hybrid

Rousselot Innovation & Inspiration Days
April 13-14, 2022, Gent

BioZ Alliance Conference
May 12, 2022, Zeitz

BioEconomy Conference
May 18-19, 2022, Halle (Saale)

GRAVOmer Project Workshop
May 18, 2022, Chemnitz

European Wound Management Association EWMA 2022
May 23-25, 2022, Paris, hybrid

Composite Sandwich Conference 2022
May 24-25, 2022, Halle (Saale)

ECTC 2022 – IEEE 72nd Electronic Components and Technology Conference
May 31-June 3, 2022, San Diego

16. Themed Days on Interface and Surface Technology ThGOT and 13th Biomaterials Colloquium
June 13-15, 2022, Zeulenroda

CAM workshop
June 14-15, 2022, Halle (Saale)

The international CAM Workshop organized by Fraunhofer IMWS brings together experts from the electronics industry and manufacturers of material diagnostic equipment to discuss challenges, new solutions and future needs related to failure analysis and material characterization of electronic devices, sensors and systems.

PV Symposium
June 21-23, 2022, Bad Staffelstein

German Rubber Conference
June 27-30, 2022, Nuremberg

Annual Conference of the German Society for Biomaterials DGBM
September 15-17, 2022, Essen

2022 PER-IADR Oral Health Research Congress
September 15-17, 2022, Marseille

2022 International Conference on Waste Gasification
September 19-21, 2022, Freiberg

Smart Textiles International Conference “InMotion 2022”
September 21-23, 2022, Weimar

German Materials Society (DGM): Materials Science and Engineering MSE Congress 2022
September 22-29, 2022, Darmstadt, hybrid

ESREF – European Symposium on Reliability of Electron Devices Failure Physics and Analysis
September 26-29, 2022, Berlin

WCPEC-8 – 8th World Conference on Photovoltaic Energy Conversion (EUPVSEC)
September 26-30, 2022, Milan

The TS-Moulding® process developed by Fraunhofer IMWS and the joint project “RUBIO” were showcased at the Fraunhofer stand at the K trade show by David Hartung from the Group “Thermoplastic-Based Fiber Composite Semi-Finished Products”, among others.

TS-Moulding® demonstator: Reformed organo-sandwich structures with thermoplastic honeycomb core and cover layers made of UD tape laminates.

Velektronik Workshop “Analysis 4 Trusted Electronics”
September 27, 2022, Berlin

3rd Germany-Korea Hydrogen Conference
September 27-28, 2022, Berlin, hybrid

Matrix Biology Europe 2022
September 28-30, 2022, Florence

PV Days
October 19-20, 2022, Halle (Saale)

Proteina’22
November 3-4, 2022, Magdeburg

Electron and X-ray Microscopy User Meeting 2022
November 29-December 1, 2022, Oberkochen

Trade shows

SMT Connect 2022
May 10-12, 2022, Nuremberg

Intersolar
May 11-13, 2022, Munich

Transfer Trade Show Magdeburg
September 14, 2022, Magdeburg

K trade show
October 19-26, 2022, Düsseldorf

Other high-profile events

Night of Science and Industry
June 18, 2022, Freiberg

Long Night of the Sciences
July 1, 2022, Halle (Saale)

“30 years of Fraunhofer in Halle (Saale)” anniversary event
November 2, 2022, Halle (Saale)

Dr. Patrick Hirsch from the Group “Thermoplastic-Based Fiber Composite Components” provided interested visitors with information about the “RUBIO” joint project.

Networking

Fraunhofer IMWS forms part of numerous networks with partners from industry, science and civil society, both within Fraunhofer and with external institutions.

Networking within the Fraunhofer Gesellschaft

- Fraunhofer Group for Materials and Components – MATERIALS
- Fraunhofer Group for Microelectronics (guest membership)
- Fraunhofer Energy Alliance
- Fraunhofer flagship project MaNiTU
- Fraunhofer flagship project Waste4Future
- Fraunhofer Academy
- Mining Network working group (working group on structural transformation)
- The Fraunhofer Innovation Platform for Hydrogen Energy at Korea Institute of Energy Technology FIP-H2ENERGY@ KENTECH

Networking with external partners

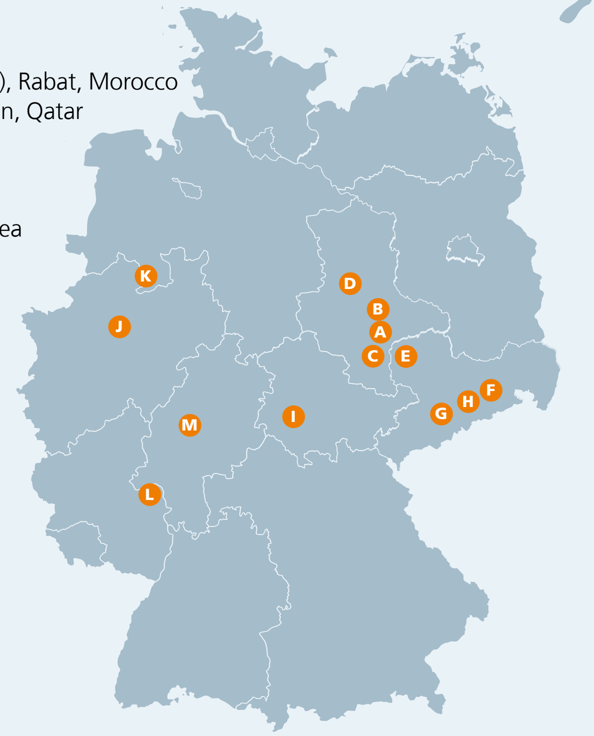
- High-Performance Center:
  Chemical and Biosystems Technology
  www.chemie-bio-systemtechnik.de

- High-Performance Center for Transdisciplinary Systems Research and Transfer (TransTech)
  https://s.fhg.de/transtech

- German Research Foundation (DFG)
  Collaborative Research Center for Polymers under Multiple Constraints
  www.natfak2.uni-halle.de/sfbtrr102

Partnerships with universities of applied science

1 Rensselaer Polytechnic Institute RPI, Troy, New York, USA
2 Indiana University, Indianapolis, USA
3 University of Connecticut, USA
4 University of British Columbia, Vancouver, Canada
5 CIC nanoGUNE Nanoscience Cooperative Research Center, San Sebastian, Spain
6 Institute for Nanomaterials, Advanced Technologies and Innovation Technical University of Liberec, Czech Republic
7 Institute of Scientific Instruments of the Academy of Sciences of the Czech Republic (ISI), Brno, Czech Republic
8 University of Reims Champagne-Ardenne, Reims, France
9 College of France, Paris, France
10 Institute for Research into Solar Energy and New Energies (IRESEN), Rabat, Morocco
11 Qatar Environment and Energy Research Institute QEERI, Ar-Rayyan, Qatar
12 Hanyang University, Seoul, South Korea
13 Korea Institute of Energy Research KIER, Daejeon, South Korea
14 Yeungnam University, Gyeongsan, South Korea
15 Korea Institute of Energy Technology (KENTECH), Naju, South Korea



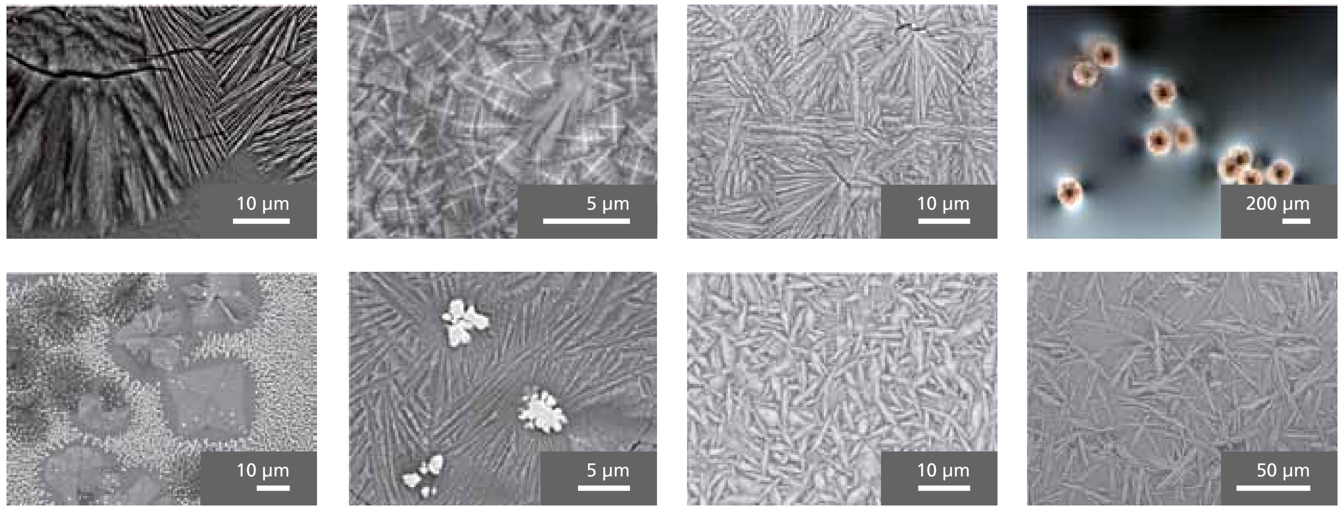
A Martin Luther University Halle-Wittenberg, Burg Giebichenstein University of Art and Design Halle (Saale)
B Anhalt University of Applied Sciences (Köthen)
C Merseburg University of Applied Sciences
D Otto von Guericke University, Magdeburg
E Leipzig University, Leipzig University of Applied Sciences
F Technical University of Dresden
G Technical University of Chemnitz
H Technical University Bergakademie Freiberg
I Technical University of Ilmenau
J South Westphalia University of Applied Sciences (Soest)
K University of Osnabrück
L Johannes Gutenberg University Mainz
M Philipps University Marburg

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 institute's scientific team conducts research on 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, 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.

"Microstructure diagnostics" – our core competence: With state-of-the- art technology, it is possible to gain in-depth insights into materials and their behavior in use.

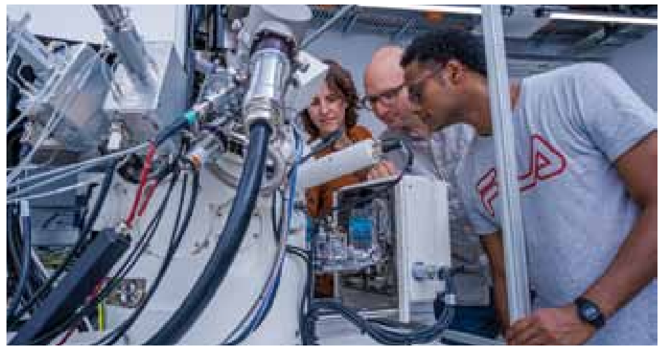


"Microstructure design" – our core competence: Homogeneous volume nucleation enabled the development of the low-expansion ceramic LEAZit™.

Core competencies

Microstructure diagnostics – discovered by Fraunhofer IMWS

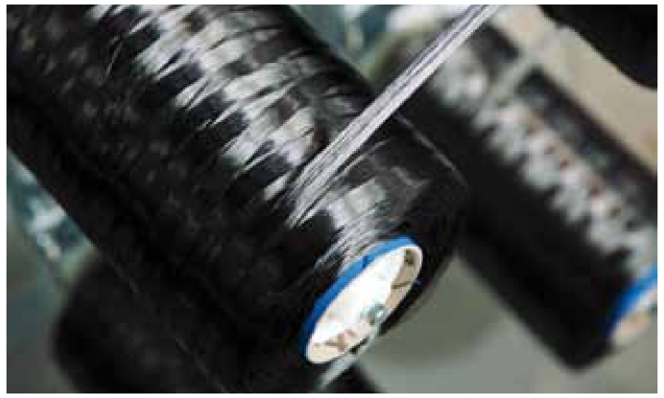
Fraunhofer IMWS possesses outstanding know-how, and within the Fraunhofer-Gesellschaft it is able to offer the most comprehensive range of equipment for microstructure diagnostics. This allows us to determine the microstructural characteristics of materials and components down to the atomic level together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



State-of-the-art equipment can be used to gain insights into the microstructure of materials.

Microstructure design – designed by 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 customers at the start of the value chain with materials that are perfectly designed for each application. In doing so, Fraunhofer IMWS makes an important contribution to resource efficiency and competitive strength of its customers, allowing for more high-performance materials and opening up new fields of application.



UD tapes made of fiber-reinforced plastics are processed into particularly lightweight and robust components.

Developing testing equipment – engineered by Fraunhofer IMWS

Successful microstructure investigation that meets our customers' 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.

Ultra-thin samples for nanoanalytics can be produced faster and more reliably using the microPREP™ device developed by Fraunhofer IMWS.

Sustainability Report

Over recent years, we have steadily and consistently tried to improve our sustainability performance. We were able to continue on this course in 2022, both by continuously improving our own use of resources in the research process and through projects whose subject matter is aligned with some of the UN Sustainable Development Goals.

With the help of intelligent systems for controlling and monitoring the building's technical systems and through energy measurement, we successfully optimized the cooling supply and made adjustments to the ventilation systems. These measures have already led to significant energy savings in recent years. This year, the focus was on preparing an energy-optimized compressed air supply. Notably, the first group of existing compressors were replaced by models with modern variable-speed drives. We expect to see the first reference values in 2023.

In light of the energy crisis, we have continued to exploit our energy-saving opportunities. Jointly with our Heads of Business Units and the technical services team, the Institute Management has taken an in-depth look at the issues of energy management and security of supply. Additional organizational and technical measures will increase the energy saving potential at the institute and accelerate the transition to a more sustainable and climate-friendly research facility.

For example, further energy-saving measures were adopted in line with the German federal government's directive on securing the energy supply. The standard room temperatures were lowered to 20 °C, and the room temperature in technical rooms and laboratories was also lowered to 20 °C and only raised at certain times to the standard temperature required by testing standards. Our employees also made proactive use of individual savings opportunities to help achieve a more positive energy balance for the institute.

In the longer term, three further measures will also help to reduce electricity consumption and, in turn, reduce our CO_2 emissions: the installation of a PV system on the roof of the building on Walter-Huelse-Strasse, the expansion of the energy management system, and the ongoing optimization of the building's technical systems. These measures include lowering the main system pressure for air pressure and converting the lighting in all the technical centers of the Fraunhofer IMWS to LED.

Our research projects address topics such as clean energy, sustainable production, and health, which are included in the 17 UN Sustainable Development Goals. We are exploring ideal degrees of cross-linking in solar modules to increase the productivity of photovoltaic systems, are improving energy efficiency and conserving resources through research into gallium nitride power semiconductors and are addressing issues relating to the import of green hydrogen. With efficient lightweight sandwich technology, we can provide climate-friendly logistics systems or develop innovative nonwovens for improved protective textiles. These are just a few of the research topics that Fraunhofer IMWS has addressed over the past year.

Together with partners from industry and science as well as other Fraunhofer Institutes, we address topics that are aligned with the six global challenges identified by the UN Sustainable Development Goals and that the Fraunhofer Gesellschaft has identified for itself based on its expertise. These include health, water, clean energy, sustainable industrialization, sustainable cities, and sustainable production.

To reinforce the social aspects of the sustainability concept, we are continuing with the works council agreement on flexplace and flextime work that was signed at the end of 2021. This initiative helps employees to strike a better balance between work and family life and to save resources by avoiding unnecessary travel. It also forms part of the Fraunhofer Gesellschaft's New Work Initiative. This project aims to promote participation, trust, collaboration and cooperation among employees, give more responsibility to employees and strengthen customer-focused forms of organization and cooperation. The aim is not only to boost our appeal as an employer, but also to improve our innovative strength and increase customer satisfaction.

Outlook

This year, we celebrated 30 years of Fraunhofer activities in Halle (Saale) and looked back on exciting projects, outstanding research achievements and rewarding collaborations. Since 1992, Fraunhofer IMWS, initially a branch office of the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg, has been a sought-after and reliable point of contact for industry and society in all matters relating to the microstructure of materials and systems.

In 2023, we intend to continue this success story and play a key role in shaping future issues of sustainability, the circular economy and climate protection through our research projects. This will go hand in hand with a drive to refine our profile over the next year. We are now taking a close look at the strategic orientation of the institute. The goal is to strengthen our focus on our core competencies in the field of microstructure analysis and to further develop them and to identify new markets. This will enable us to better support the region and industry as a reliable partner.

Our activities in relation to hydrogen will also play an important role. In future, we will be focusing on material analytics and failure diagnostics for H2 technologies with an emphasis on electrolysis and fuel cells. In addition, the potential renaissance of the photovoltaic industry in Central Germany and Germany as a whole will be one of the defining issues for us in 2023. We intend to further expand our role as a reliable research and development partner for the photovoltaic industry and to strengthen our quality assurance expertise at Fraunhofer CSP along the entire value chain, especially in the areas of material, solar cell and module reliability and system diagnostics.

Our Freiberg branch office and thus our Business Unit "Carbon-cycle Technologies" will move to Fraunhofer IKTS at the beginning of 2023. We will stay connected through various projects and continue to work on the carbon circular economy issues. In the Fraunhofer flagship project "Waste4Future" for example, we are conducting research on new ways to recycle plastics. To further intensify our transfer activities, we will reassume the leadership role at the High-Performance Center Chemical and Biosystems Technology (CBS) in 2023.

The high-performance center sees itself as a transfer network of research institutions and companies in the Central German region whose aim is transferring knowledge and technologies from Fraunhofer institutes and universities to small and medium-sized enterprises in the region, by way of targeted measures and cooperation projects.

Next year's event highlight will be the international CAM Workshop. Intel's decision to invest in Magdeburg also emphasizes the relevance of this workshop on failure diagnostics in microelectronics. During the Long Night of the Sciences in July, we will once again open our doors to interested members of the public. The well-established PV Days event will take place in the fall.

We look forward to meeting you in person at one or the other event and to working with you in the future. Together, we will continue to successfully rise to any new challenges that the future may bring.

Organizational chart

INSTITUTE MANAGEMENT: Erica Lilleodden, Thomas Höche (Deputy), Thomas Merkel (Head of Administration)

BUSINESS UNITS

Electronic materials and components Frank Altmann*	Fraunhofer Center for Silicon Photovoltaics CSP Ralph Gottschalg	Optical Materials and Technologies Thomas Höche	Carbon-cycle Technologies (Freiberg) Martin Gräbner	Polymer Applications Maik Feldmann	Application Center for Inorganic Phosphors (Soest) Stefan Schweizer	Biological and Macromolecular Materials Christian Schmelzer
Assessment of Electronic System integration Sandy Klengel	Solar Cell Diagnostics and Metrology Christian Hagendorf	Microstructure-Based Material Processing Michael Krause	Thermochemical Conversion** Jörg Kleeberg	Thermoplastic-Based Fiber Composite Semi-Finished Products Ivonne Jahn		Characterization of Medical and Cosmetic Care Products Andreas Kiesow
Diagnostics of Semiconductor Technologies Frank Altmann	PV Systems and Integration Matthias Ebert	Microstructure of Optical Materials Christian Patzig	System Analysis and Technology Transfer** Martin Gräbner	Evaluation of Fiber Composite Systems Ralf Schlimper		Biofunctional Materials for Medicine and the Environment Andrea Friedmann
	Material Analytics Sylke Meyer		Process Modeling and Optimization** Martin Gräbner	Polymer-Based Material Design Mario Beiner		
	PV Modules, Components and Manufacturing Bengt Jäckel		Chemical Processes and Catalysis** Sven Kureti	Fiber Composite Components Matthias Zscheyge		
	Material Diagnostics for H2 Technologies Klemens Ilse			Equipment Engineering and Construction Andreas Krombholz		

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