Fraunhofer
IMWS

FRAUNHOFER INSTITUTE FOR
MICROSTRUCTURE OF MATERIALS AND SYSTEMS IMWS

HIGHLIGHTS 2017

ANNUAL REPORT

FOREWORD

Dear readers,

The end of the year traditionally provides us with an occasion to look back – and in fact, 2017 was a very successful year for us at the Fraunhofer IMWS. Our annual report is always a welcome opportunity for me to take a step back from the day-to-day business and look at larger developments: what have we achieved over the past twelve months in terms of our strategic further development?

Here, too, the results are very pleasing. In our core competence area of microstructure diagnostics, we outlined a roadmap for further developing our methodological competences until 2025. The main emphases will be on failure diagnostics, as well as 4D and multi-scale analytics, which will be supported by expanding our technical equipment. For instance, the ZEISS Xradia 800 Ultra now allows us to perform extremely high-resolution, non-destructive 3D X-ray imaging. This combination of continuous competence development, the latest equipment, and our development of new analysis techniques will make us perfectly equipped for our customers' future needs.

Naturally, the opportunities offered by digitization played an important role in developing our road map – for instance by automating the defect screening process and sample preparation, and by creating a data structure to act as a "digital twin" of the material on our Materials Data Space platform. In order to digitize the materials, we initiated the position paper "MATERIALizing ideas – the future of materials research" in the Fraunhofer Group for Materials. With this paper, which is supported by numerous companies and associations, we primarily hope to raise awareness among political decision-makers about the importance of materials research when it comes to the competitive strength of German industry and to point out the great potential available here.

Our internal project "IMWS 4.0" also proactively takes advantage of the opportunities that digitization presents for our work, so that we can optimize all of the processes at the Institute – from working in the lab, to internal communication, to further developing our business models – in that direction. It also ensures that we can continue to provide our clients with innovative, efficient solutions in the future.

We continued developing new devices as part of our strategy, for instance with magnet field sensing – an innovative quality control method in the photovoltaic industry. By founding the Center for Economics of Materials CEM, which we support jointly with Martin Luther University Halle-Wittenberg, we will be able to offer our customers technical economics know-how in addition to our material science expertise. Last but not least, the construction work at our locations in Halle, Schkopau and Leuna embodies the dynamic further development of our Institute.

In 2017, we were fortunate enough to celebrate three major anniversaries: 25 years of Fraunhofer at the Halle location and 10 years of the Fraunhofer CSP; Halle also celebrated the 20th anniversary of the Fraunhofer Group for Materials. The specialized program for these events intentionally focused not on past history, but on what lies ahead – with our many important ideas for the future.

I am confident that in 2018 we will continue to be an excellent research and development partner who can strengthen our customers' products and processes in terms of microstructure-based technology development and diagnostics, and I want to thank all of our customers and partners for their collaboration with us so far. I look forward to conducting further exciting research projects with you!

Prof. Dr. Ralf B. Wehrspohn

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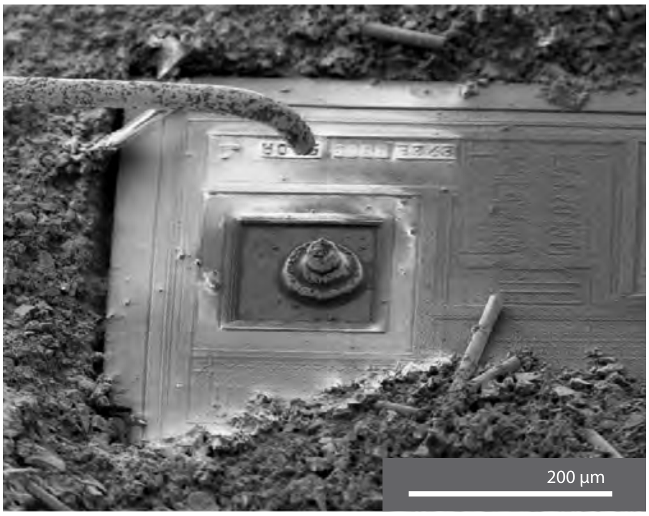
OUR MISSION

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

The main challenge facing humanity in the 21st century is the sustainability of every area of life, especially through efficient handling of limited resources. The Fraunhofer Institute for Microstructure of Materials and Systems IMWS performs applied research in the area of material efficiency, and it is a driving force, innovator and problem-solver for the industry and for public-sector clients in the areas of reliability, safety, lifespan and functionality of materials in components and systems. Our core competences lie in characterizing materials down to the atomic scale and material development.

Example of our core competence in »microstructure design«: Composites optimized on the nanoscale ensure low rolling resistance for tires.

Our skills in the area of device development are showcased, for instance, by the microPREP ™, a device that allows ultra-thin samples to be prepared more quickly and reliably for electron microscopy.

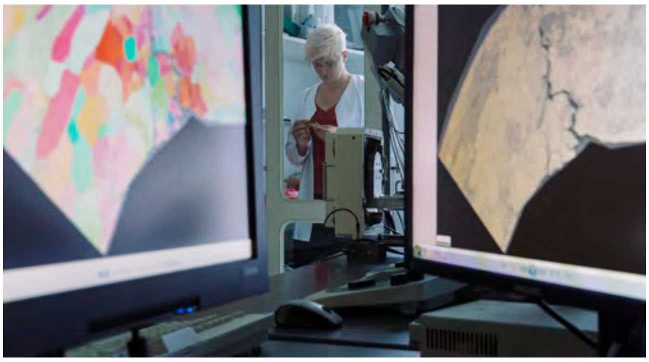


Example of our core competence in »microstructure diagnostics«: some defect causes, such as torn wires in a microchip, are only visible in the resolution from an electron microscope.

CORE COMPETENCES

Microstructure diagnostics – discovered by the Fraunhofer IMWS

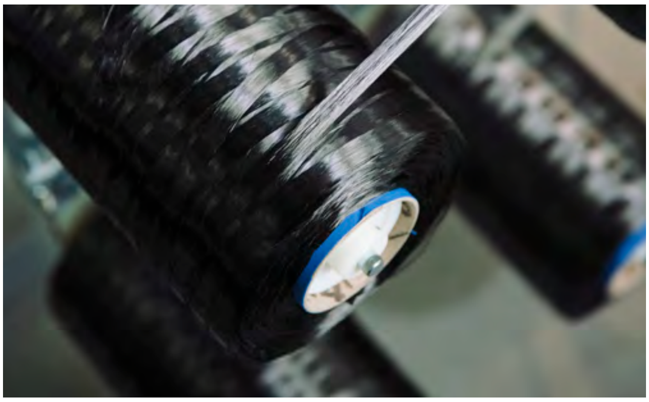
The Fraunhofer IMWS has excellent know-how, and within the Fraunhofer-Gesellschaft it offers the most comprehensive equipment for microstructure diagnostics. This allows us to determine microstructural material and component characteristics down to the atomic level, along with the resulting properties for applications. We use the microstructure, especially of semiconductors, polymers and biological materials, in correlation to local characteristics in order to provide performance reservoirs.



Thanks to the latest technology, we can observe materials down to the level of individual atoms.

Microstructure design – designed by the Fraunhofer IMWS

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



UD tapes made from fiber-reinforced plastics are processed into very lightweight, robust components.

Developing testing equipment – engineered by the Fraunhofer IMWS

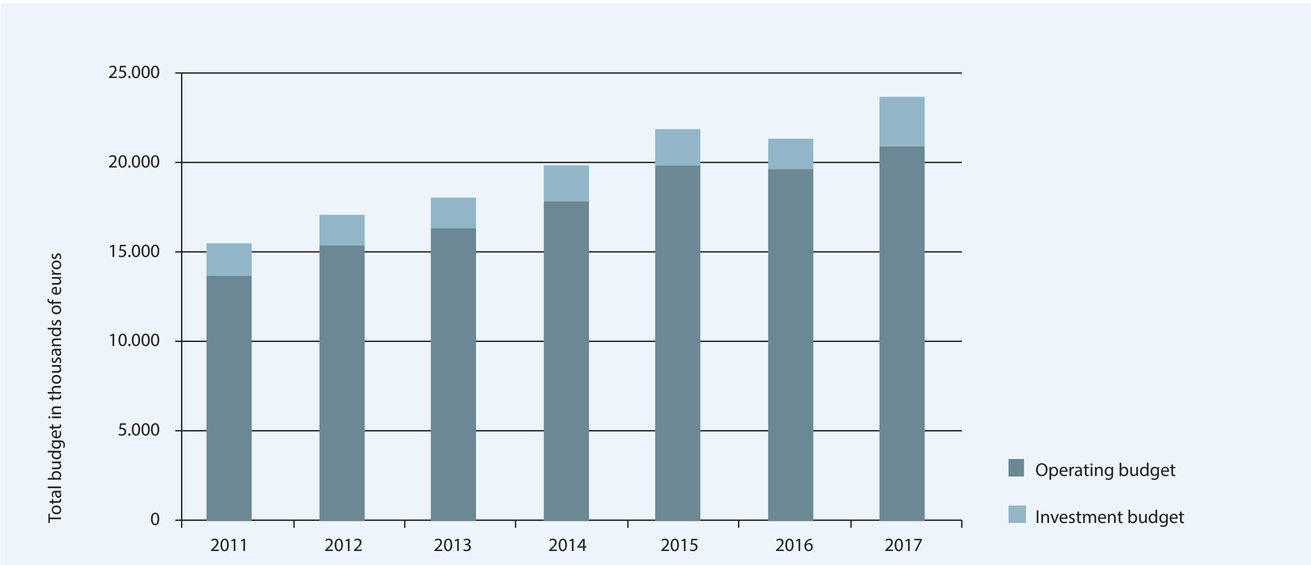
Successful microstructure analytics that meet our customers' needs is made possible through high-quality instrumentation. The complex questions posed in research and development, along with new methods and materials, require perfectly tailored equipment. That is why we are increasingly working on developing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

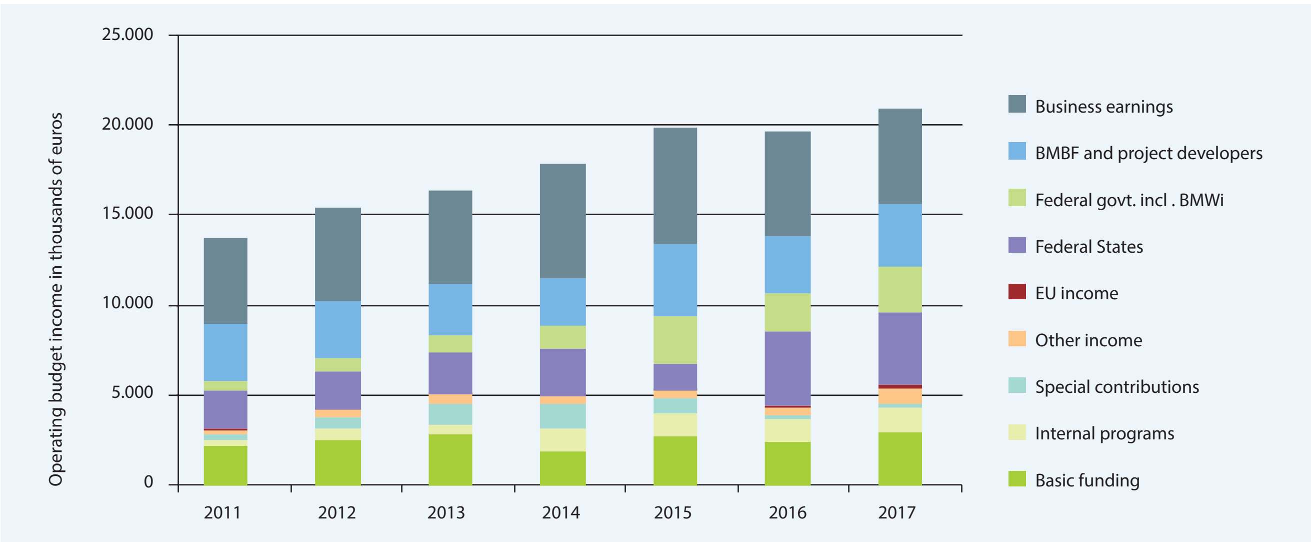
Acoustic microscopy can be used to identify even the smallest cracks in materials without destroying the samples.

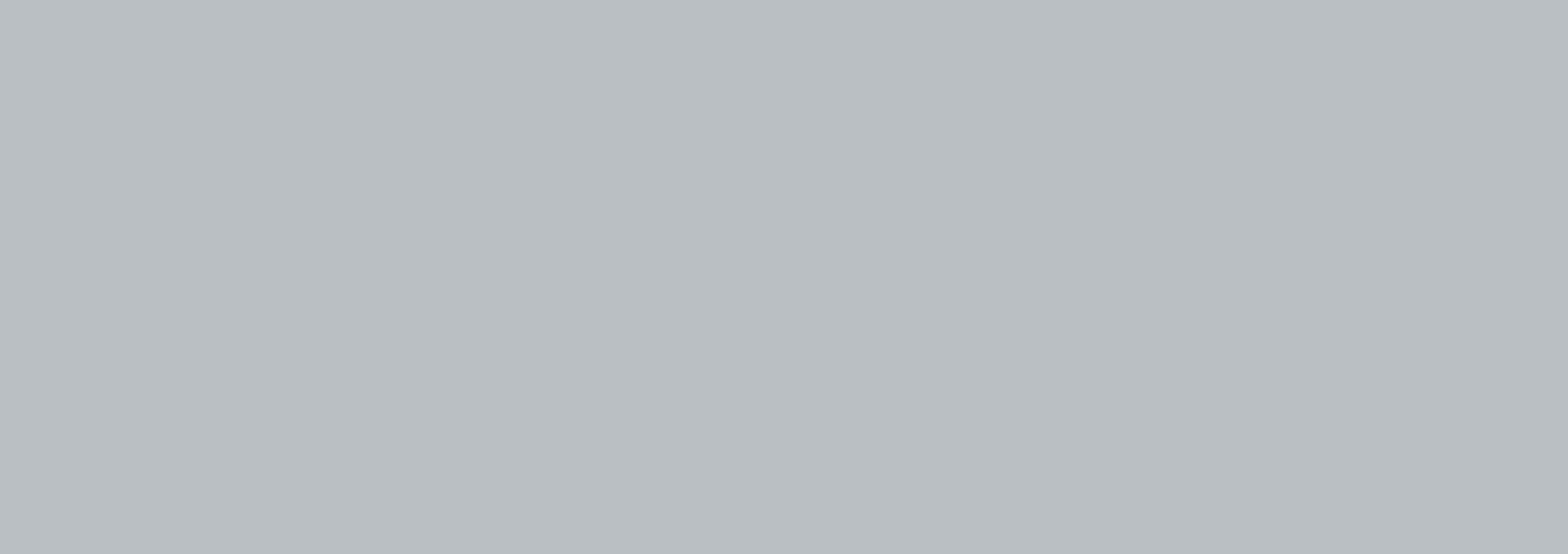
THE INSTITUTE BY THE NUMBERS

Budget

The budget of the Fraunhofer IMWS consists of an operating budget and an investment budget.
The operating budget of the Fraunhofer IMWS is 20.9 million euros. The operating budget includes all personnel and material expenses. It is financed by external income from the industry and the public sector, as well as through institutional support (basic funding).
The percentage of the industry revenues in the operating budget for 2017 was 25.4%. The 2017 investment budget was 2.7 Million Euro.

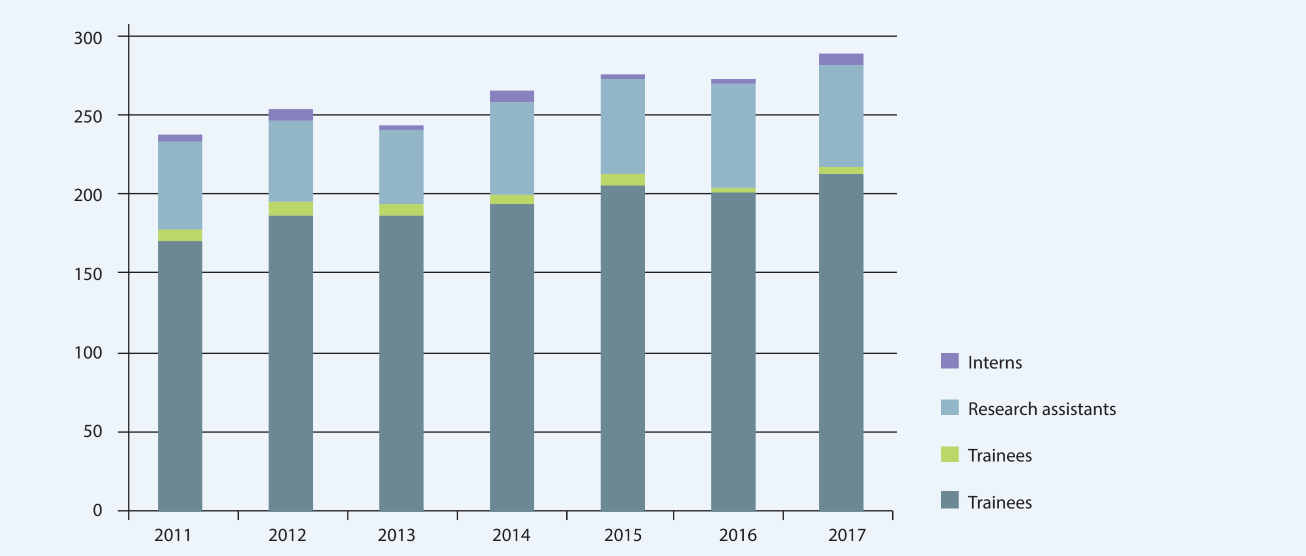


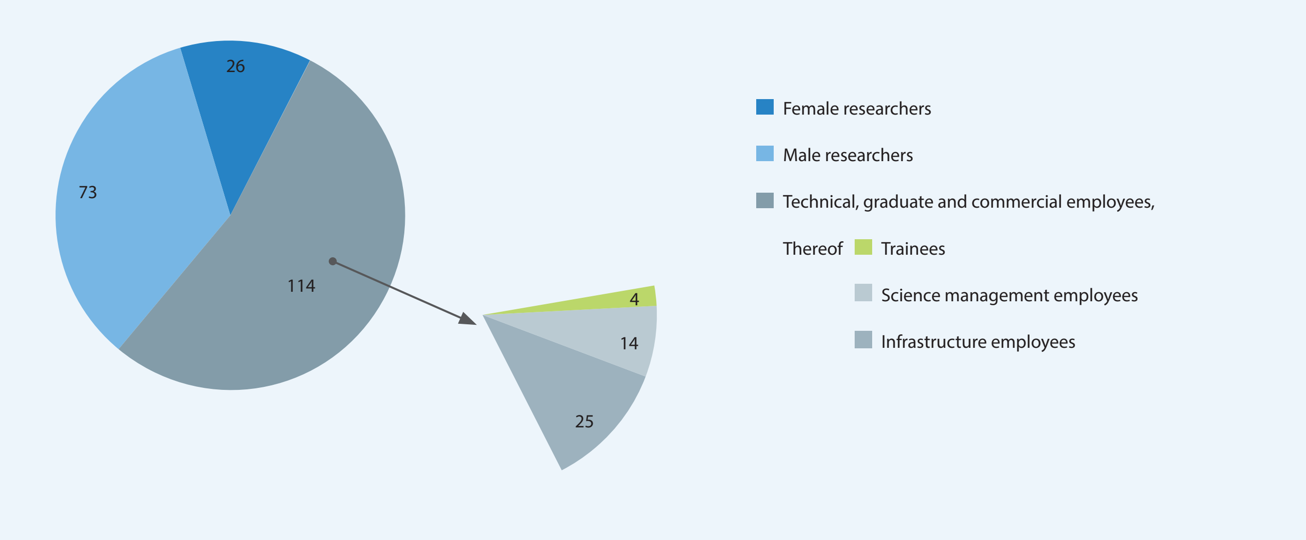




Personnel development

As of the end of 2017, the Fraunhofer IMWS had a total of 213 permanent employees. The number of employees includes: 26 female researchers and 73 male researchers; 114 technical, graduate and commercial employees of whom 25 are employed in infrastructure; 14 science management employees and four trainees. Including the 71 research assistants and the interns, there were a total of 284 people employed at the Fraunhofer IMWS at the end of 2017.





25 YEARS OF THE FRAUNHOFER IMWS – A SUCCESS STORY IN PICTURES

1994: *The Fraunhofer IMWS develops »Help for sensitive teeth«.*

1995: *Construction work on the technology center for the Fraunhofer CAM; today, it houses the lab for the TITAN electron microscope.*

2001: *The Fraunhofer IMWS improves the quality of wire bonding.*

1999: *The Fraunhofer Institute is represented at the June 24 Day of Research at Martin Luther University Halle-Wittenberg, on the market square in Halle.*

2005: *Seven shovels simultaneously break the ground for the new institute building on Walter-Hülse-Straße in Halle.*

2005: *The Pilot Plant Center for Polymer Synthesis and Processing PAZ is dedicated in Schkopau.*

2009: *The Fraunhofer CSP is recognized in the »Land der Ideen« (Country of Ideas) competition.*

2007: *Peter Gumbsch, Ralf Wehrspohn, Jörg Bagdahn and Eicke Weber (from right) raise a glass for the founding of the Fraunhofer CSP.*

2008: *Launch of the BMBF excellence cluster »Solarvalley Deutschland« to make solar power even more competitive.*

2009: *Ribbon-cutting for the new institute building on Walter-Hülse-Straße.*

2013: *Ralf Wehrspohn and Minister President Reiner Haseloff open the Fraunhofer CSP on Otto-Eißfeldt-Straße.*

2013: *Launch of the »HYPOS« project as part of the BMBF funding program »Zwanzig20 – Partnerschaft für Innovation« in which »green« hydrogen is produced on an industrial scale.*

2015: *Guests at the tenth anniversary of the Fraunhofer PAZ included Federal Minister of Education and Research, Johanna Wanka, as well as Sachsen-Anhalt's Minister, President Reiner Haseloff.*

2016: *The Fraunhofer IMWS participates in the »Materials Data Space« initiative.*

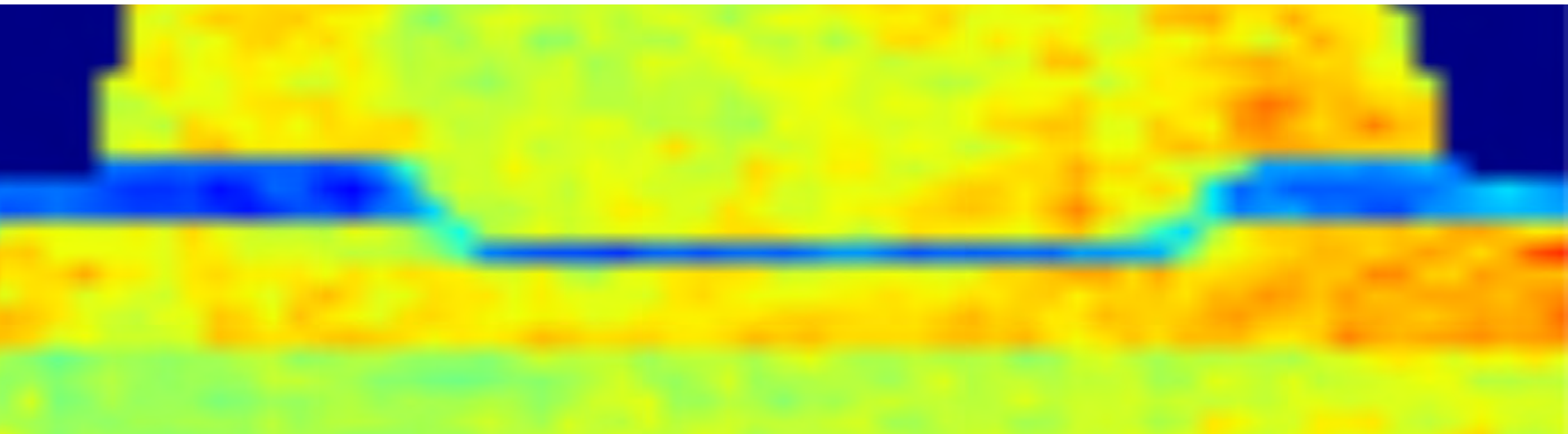
2014: *In June, the Fraunhofer Application Center for Inorganic Phosphors is dedicated at Fachhochschule Südwestfalen in Soest.*

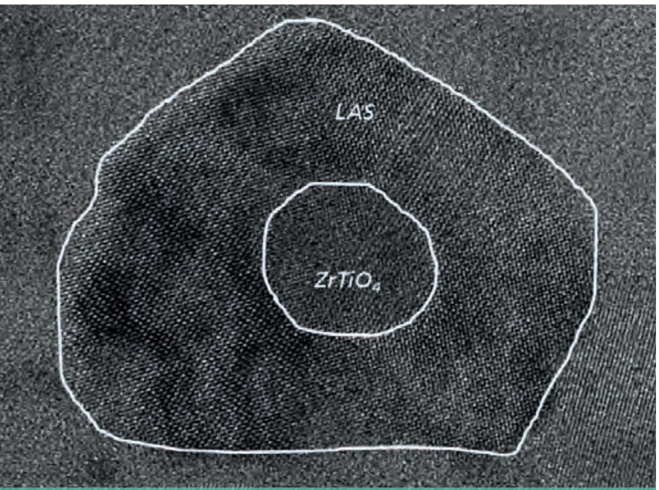
2016: *In January, the independent Fraunhofer IMWS is founded in Halle. German Chancellor Angela Merkel is a guest at the opening ceremony.*

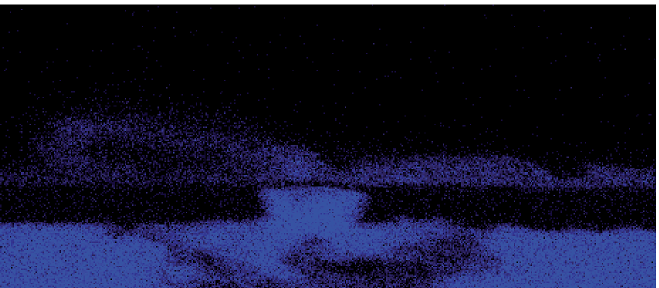
2016: *The Chemical and Biosystems Engineering Center begins its work.*

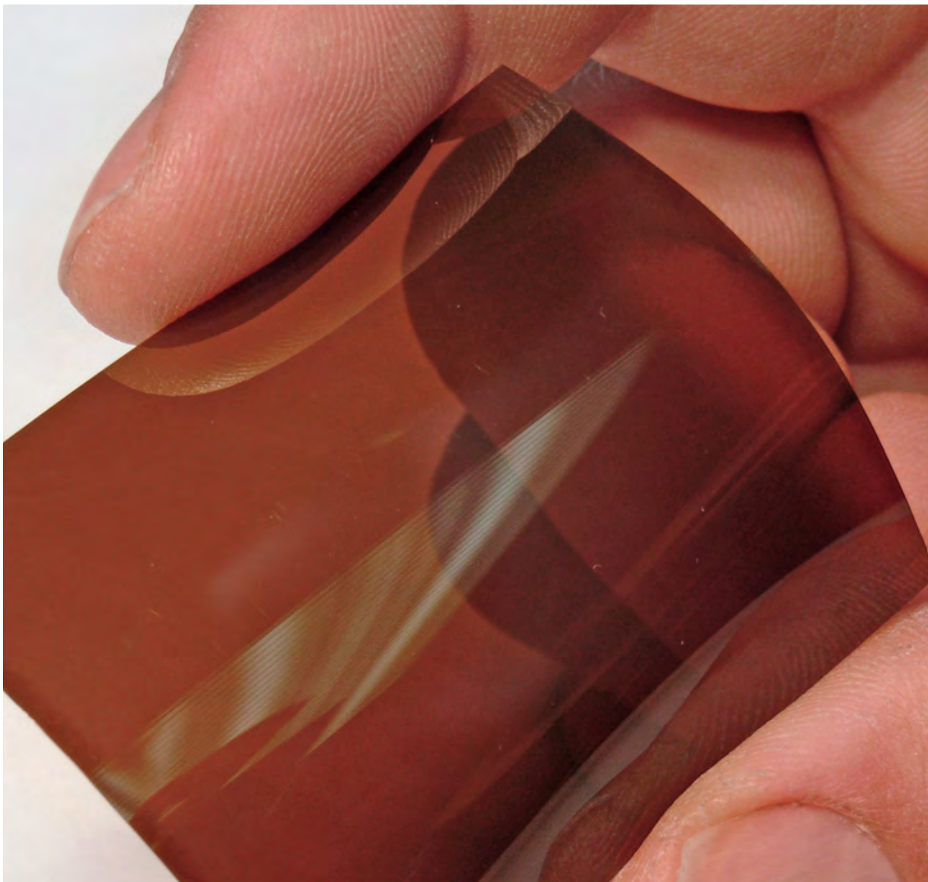
2015: *Front-end carriers made from fiber-reinforced plastics support lightweight construction in the automotive industry.*

SELECTED RESEARCH SUCCESSES









STILL WELL EQUIPPED FOR THE FUTURE

Interview with division head Prof. Dr. Matthias Petzold

What was your personal highlight in 2017 with regard to the division?
Our CAM workshop in April, an international forum that is a fixture in the calendars of industrial electronics fault analysis consumers and diagnostic device manufacturers, was once again very successful in terms of the scientific results that were presented. In addition, we were able to celebrate "25 Years of Fraunhofer Microelectronics Research in Halle" together with our customers and local politicians, while at the same time laying the virtual cornerstone for our CAM expansion at Heideallee. Since the start of construction in February of 2017, a daily highlight for me has been watching the building grow one piece at a time.

What industries and markets interest you?
How could your customers benefit from a collaboration?
The division's customers come from the entire electronics supply chain. They include manufacturers of semiconductors and construction elements, assembly groups and systems as well as nanostructured materials, testing devices and diagnostic devices, all the way to the end customers. Our competences in the areas of material diagnostics and evaluation of electronics components or functional optical materials are particularly effective in sectors that have high standards for process quality and reliability – above all in the automotive industry, but also in the fields of energy and industrial engineering. Our jointly developed results help us accelerate the development of new manufacturing processes and innovative materials; produce high-quality, reliable construction elements and systems; and bring new material diagnostic processes onto the market.

In 2017 we celebrated an anniversary: »25 Years of Fraunhofer in Halle.« What are your thoughts on that?
We can be very proud of our 25 years of successful development, especially in our division, which would not have been possible without our employees' consistently strong commitment to the Fraunhofer model. Personally, I am also very thankful for the long-time support from the Fraunhofer IWM Freiburg. In the future, too, our current research projects and the new opportunities offered by the building expansion will make us very well equipped for new challenges. Without reliable electronics, digitization in industry and society will not be possible.

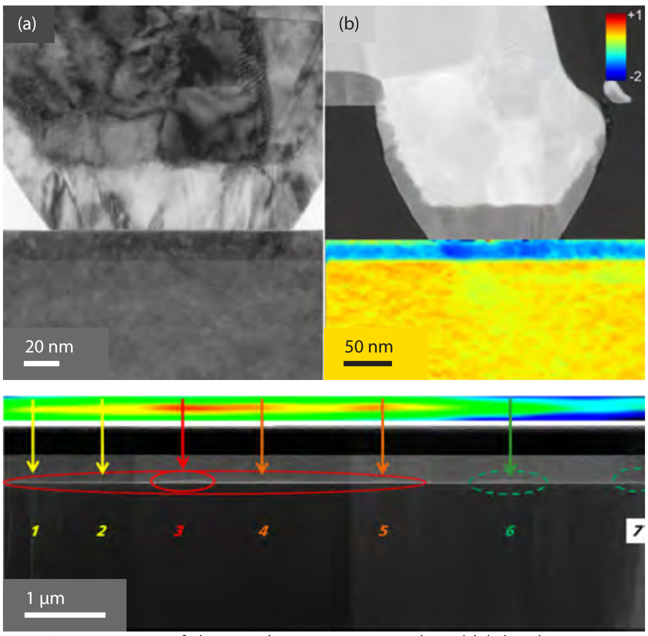
What activities are coming up in 2018?
In 2018, we are looking forward to working with our partners in the context of many new industry partnerships and publicly funded projects, which were successfully acquired in 2017 in all three groups of the division – but especially the dedication and startup of the new CAM building.

Prof. Dr. Matthias Petzold
Doctorate in Physics at the University of Halle-Wittenberg, transferred to the Fraunhofer IMWS in 1992, currently division head and Deputy Institute Director as well as a professor at HS Merseburg
matthias.petzold@imws.fraunhofer.de
+49 345 5589-130

ELECTRICAL BEHAVIOR AND LOCAL RESIDUAL STRESSES IN GAN TRANSISTORS

New analysis methods for residual stress fields in GaN semiconductor structures enable a better understanding of the correlations between transistor structure, electrical properties and aging effects, thereby allowing further improvement in the quality and service life of relevant components.

High electron mobility transistors (HEMT) are electronic components with very high electron mobility and great application potential for high-frequency technology and power electronics. Gallium nitride (GaN) is particularly suitable as a semiconductor for achieving significantly higher clock frequencies, efficiencies and power densities as compared to conventional silicon technology.



Top: *Contact range of the transistor structure under which local stress fields are formed: a) contact of a GaN HEMT component, b): associated local stress fields in the semiconductor material below the contact*
Bottom: *Depiction of areas of increased leakage current in the transistor structure by means of a transmissions electron microscopic image of a HEMT in connection with photoemission images*

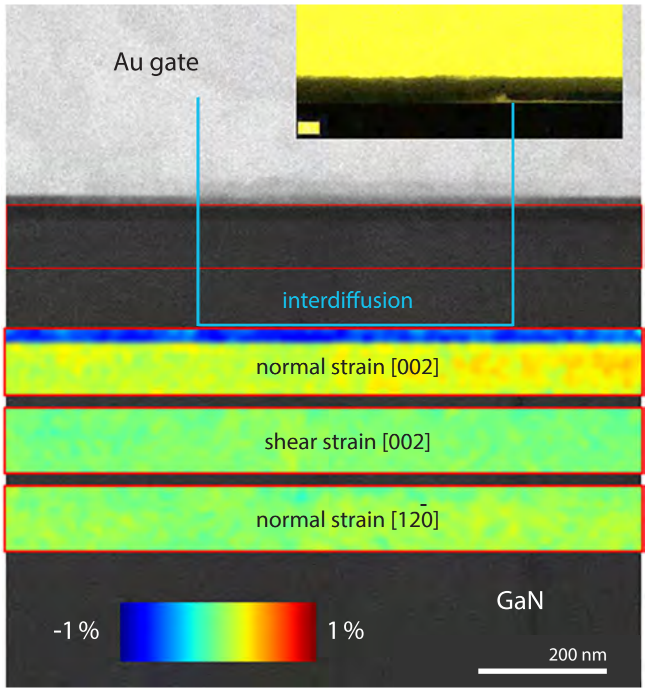
Up to now, carrier substrates such as silicon carbide and sapphire have been used for the production of GaN. To reduce manufacturing costs and thus open up additional fields of application in power electronics, extensive research is currently being conducted on the use of comparatively inexpensive silicon wafers as an alternative substrate material. Due to the different properties of GaN and silicon, buffer layers are applied first during the production, which result in an improved GaN layer quality. These layers must be produced in a way which ensures that as few crystal defects as possible occur and that low residual stress remains in the layer system. The subsequent growth of the active GaN/AlGaN crystal layers and the electrical contacts can potentially lead to further mechanical stresses in the transistor structure. The induced stress fields are suspected to cause, or at least advance, the structural aging of the active structures. This has an overall negative effect on the electrical properties and service life of the components and should therefore be avoided.

Determining relevant stress fields in the HEMT structures poses a major challenge. The stress-induced lattice distortion fields must be precisely measured down to the nanometer, since the functional structures have dimensions in the sub-µm range.
In cooperation with UMS GmbH (based in Ulm, Germany), high-resolution nanobeam diffraction analysis (NBED = nanobeam electron diffraction) was used for the first time to detect such types of lattice distortions on GaN HEMT structures. With this special method, a high-resolution transmission electron microscope is used to scan the sample and record a diffraction pattern that contains information on the local lattice parameters at each measuring point. By comparison with a reference lattice structure, local lattice distortions can be measured with nanometer precision and local stress fields can be identified.

The results for GaN transistors on conventional carrier substrates show local stress fields directly under the electrical contacts of the transistor structure. Over the course of several process steps, the contacts are deposited and thermally treated. Due to the different thermal properties of the semiconductor and metal layer, stress fields arise directly below the contacts.

The active layers that provide the electron conduction are located there. During the electrical operation of the transistor, the component gets heated, which can further increase the lattice distortion. This heating also boosts transport processes in the metal layers, which lead to the disintegration of the transistor structure.

Further analyses showed that local leakage currents at the control port, called the »gate«, can be localized using emission microscopy. These leakage current paths were precisely geometrically associated by previously applying markings and thus an analysis in the transmission electron microscope was performed accurately. The results showed that the positions of the leakage current paths are associated with areas where transport and mixing processes of the metal layers have taken place.



Correlation of lattice distortion measurements (bottom) and areas with transport and mixing processes of the metal layers and local gold diffusion (top) of a GaN HEMT

The lattice distortion distributions in the active layer below were also measured using the new nanobeam diffraction analysis method, and compressive strains could be detected in the process.

Nanobeam electron diffraction analysis was used to measure detailed lattice distortion distributions.

In summary, a new high-resolution analysis method for the nanometer-precise determination of local lattice distortions was tested. For the first time, stress fields in GaN-based HEMT structures could be detected and correlated with the occurrence of leakage currents at the electrical contacts.

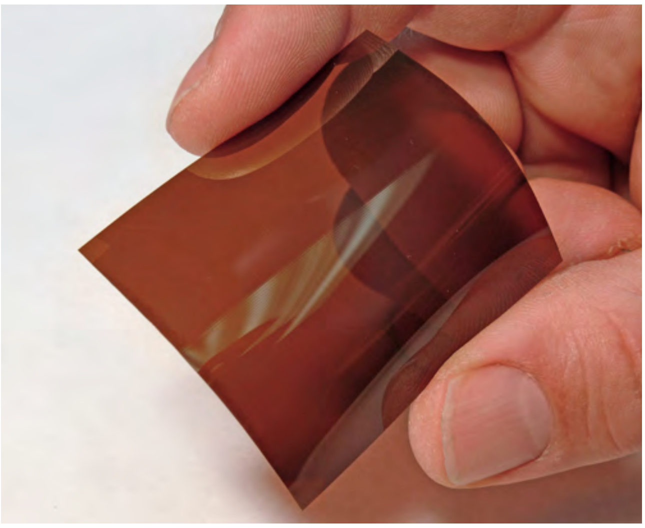
Within the European POWERBASE project, together with project partner Infineon Technologies Austria, the nanobeam electron diffraction method is currently being further evaluated on GaN HEMTs on silicon substrates, with the aim of examining lattice distortions in the grown buffer layers and understanding possible correlations between residual stresses with defects at the edge of the chip.

Dr. David Poppitz
Degree in Chemistry and Materials Science from Leipzig University,
PhD from the Institute of Surface Engineering Leipzig,
at Fraunhofer IMWS since 2015
david.poppitz@imws.fraunhofer.de
+49 345 5589-171

CENTER FOR APPLIED MICROSTRUCTURE DIAGNOSTICS CAM

RELIABILITY OF ULTRATHIN FLEXIBLE ELECTRONIC COMPONENTS

The market acceptance of flexible and transparent electronic components is defined by their reliability. Evaluating this and establishing a correlation to microstructure and process properties is an important research focus at Fraunhofer IMWS.



The reliability of flexible, ultra-thin and transparent glass substrates or ceramics for displays, lighting or switching applications is essential for their successful integration into new electronic products intended for use in everyday life. The interaction between various process properties and the microstructure of the material and their effect on reliability play a key role here.

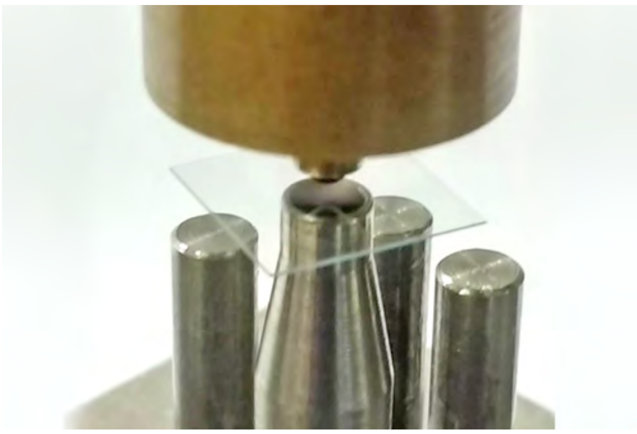
In order to evaluate these under realistic conditions and understand the interaction within the manufacturing processes, test procedures have to be adapted. That is the only way to reliably characterize the wafer-thin substrate materials, which are only a few micrometers thick.

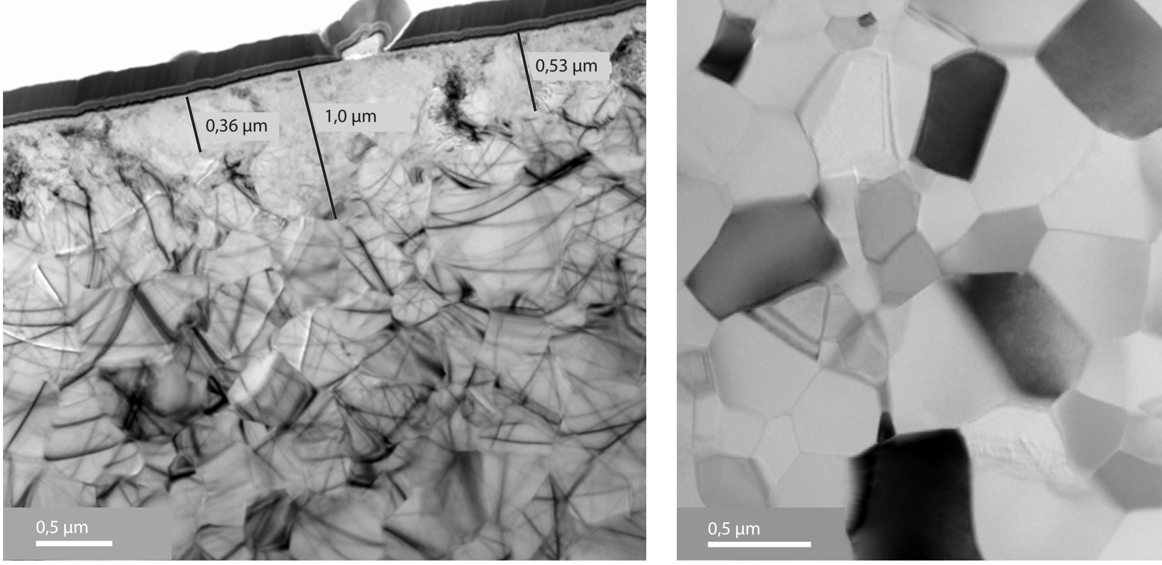
Top: Ultrathin glass substrate after functional coating
Right: Test arrangement for characterizing the surface strength

In the »Zug4Flex« project, Fraunhofer IMWS, in close cooperation with the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, based in Dresden, therefore examined the interaction of functional coating processes and the resultant mechanical properties of ultra-thin glass materials.

For the electrical functionality, for example as a lighting element or display, coating systems made from conductive oxides are applied. Due to the thin substrate thickness of less than 50 µm, they already have a significant impact on the breaking strength and thus on the processability of the coated glass in the subsequent process steps. Therefore, methods for evaluating the effect of the coating on surface strength and substrate distortion of the ultrathin substrates were developed in the project. This was also the prerequisite for optimizing the coating technologies, in order to achieve the highest possible strength and low failure probability due to defects or external influences on the substrate surface.

Deformation tests suitable for the thinnest brittle materials were adapted to the requirements of coated ultrathin glass in combination with numerical simulations. The strength was evaluated as a function of the process parameters of the coating. In addition, the coating-related residual stresses were characterized using optical deformation measurements.





TEM analysis for evaluating the microstructural process influence in transparent ceramic

Left: *Processing area*
Right: *Reference area (transparent ceramic sample, provided by Fraunhofer Institute for Ceramic Technologies and Systems IKTS)*

The FEP then analyzed the results to derive suitable process optimizations for the coating technology.

Moreover, the effect of potential post-processing or finishing steps – for example thermally-induced curing processes – on the mechanical and microstructural properties could be evaluated, thus further increasing the material reliability.

These findings provide essential information for cost-effective automated production and further processing of functionalized material systems.
Furthermore, the knowledge gained about the process-related changes in strength properties facilitates adapting subsequent technologies and mechanical engineering to the processing chain accordingly and helps avoid equipment downtime caused by breakage of the substrate materials.

Reducing edge defects and residual stresses is the most important approach for increasing reliability.

As a result of the project, it was ensured that the surface strength following the coating is reduced as little as possible and is greater than the edge strength. The latter is determined by unavoidable damage caused by separation processes during the assembly of the materials and during the separation for the end application.

Together with four other Fraunhofer institutes, Fraunhofer IMWS is examining the issue of edge strength as part of the new Fraunhofer internal research project »CeGlaFlex«. The focus is on minimizing the risk of failure by using new, material-friendly separation and cutting processes for large glass substrates in electronic applications. To this end, the partners are developing and testing innovative mechanical and laser-based separation and cutting processes. Additional goals of the project include the production of thin, moldable and transparent ceramics and glass, as well as the resultant material composites.

For example, as new scratch-resistant, stable and individually molded switches and display elements, these new materials can be integrated into mobile phones, automobiles and industrial products.

On the basis of the previous results, Fraunhofer IMWS is also contributing to the materials testing and characterization of the separating/cutting processes and the new materials.

The separating/cutting processes influence the defect structure, which is evaluated by means of high-resolution material analysis. Destructive methods are also used for the reliability assessment. This allows a detailed understanding of the relationship between process parameters, microstructure and state of damage as well as the resultant strength properties and processing behavior. Using the technologies developed in the joint project, innovative flexible and break-resistant displays and interface elements for the electronics of tomorrow will be developed in the future.

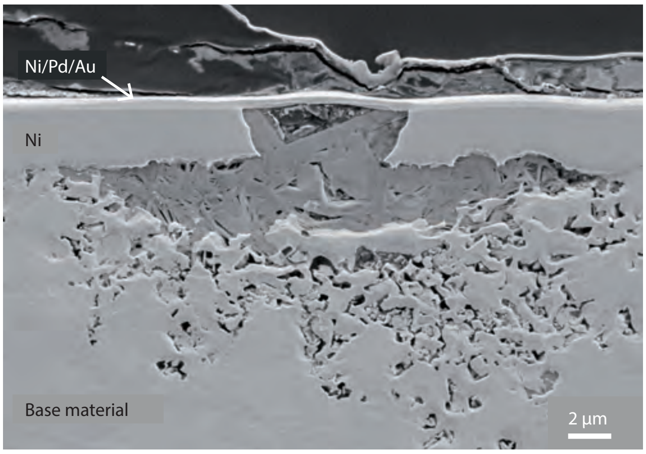
Falk Naumann
Mechanical Engineering degree from TU Dresden with a major in Applied Mechanics, at Fraunhofer IMWS since 2007, Head of the »Mechanics and Simulation« team in the »Assessment of Electronic System Integration« group.
falk.naumann@imws.fraunhofer.de
+49 345 5589-225

Georg Lorenz
Mechanical Engineering degree from Leipzig University of Applied Sciences, at Fraunhofer IMWS since 2008, staff member in the »Mechanics and Simulation« team in the »Assessment of Electronic System Integration« group
georg.lorenz@imws.fraunhofer.de
+49 345 5589-188

CORROSION IN AUTOMOTIVE ELECTRONIC MATERIALS

Materials in electronic components are exposed to corrosive processes due to environmental conditions such as dampness, temperature and pollution. Corrosion – also the materials reaction to its environment – usually occurs locally and results in components and systems being significantly affected; this increasingly is the cause of failure of electronic components.

The proportion of faults due to corrosive processes has clearly increased in the past five years. The reason for this is the progressive miniaturisation and broad use of control electronics in automobile and performance electronics.
Standard tests to examine corrosion have hitherto been very lengthy, expensive and could not deliver sound evidence on the corrosion behaviour of actual assembly modules. Plug connectors or circuit boards – components, which are difficult to access for chemical analysis – pose particular problems. Fraunhofer IMWS is working in order to establish a more efficient and environmentally-friendly test method. The research project aims to develop a faster and more cost effective test method in order to explore local electrochemical processes on automobile and performance electronics components and contacts when they are exposed to corrosive media agents.



Scanning electron microscopy (REM) analysis of defect formation on the cross-section of a corroded layer system Bronze-Ni-NiPd-Au

This method can be used in the area of safety-related applications such as, for example, in technological qualification for autonomous driving in order to explore chemical corrosion mechanisms. The test method is based on standardised electrochemical measurements. A locally usable, miniaturised corrosion-measuring cell must be developed for this. The new test method is to be used for monitoring industrial processes. In the first instance, the main emphasis is focused on the development of a local micro test method for typical coating

We want to understand locally occurring electrochemical reactions scientifically and characterise them under the specifically required test conditions.

systems in the electronics industry, with thin metallised top layers in gold, which are a few nanometres thick. Here, questions on monitoring of coatings, density and failure phenomena such as the Black Pad Effect – the corrosion of deposited nickel/gold layers without current – will be examined. The newly developed measuring method and the relevant ECH GmbH measuring instruments are tested at Fraunhofer IMWS using comparison measurements and associated high resolution physical methods (scanning electron microscopy, energy dispersive x-ray analysis, transmission electron microscopy). The new miniaturised testing device allows, for the first time, the characterisation of corrosive processes in the smallest of electronic components without having to rely on the costly preparation of model samples or reference test specimens. This allows the much accelerated and more efficient evaluation of new materials and material combinations regarding their corrosion behaviour.

Sandy Klengel
Degree in Precision and microtechnology at TU Dresden,
since 2014 Goup Manager at Fraunhofer IMWS,
Research in the field »Microstructure of construction and joining materials«
sandy.klengel@imws.fraunhofer.de
+49 345 5589-125

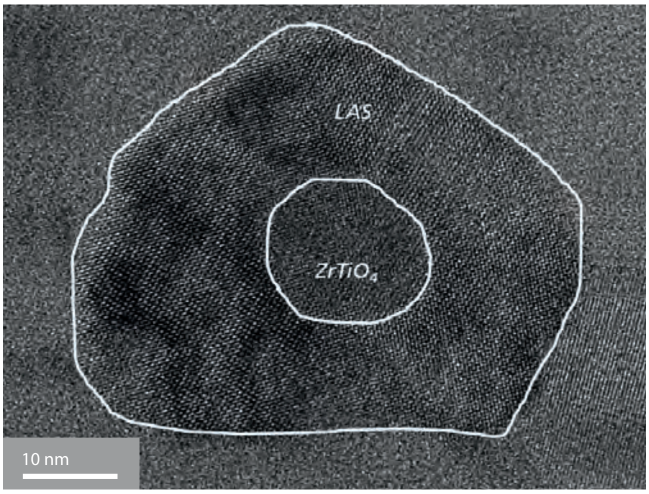
NANOSTRUCTURE-BASED DEVELOPMENT OF GLASS-CERAMIC

In a joint project with the Otto Schott Institute of the University of Jena, Fraunhofer IMWS investigates the complex, running on the nanoscale Nucleation processes in the synthesis of zero-expansion glass ceramics.

Glass ceramics are often used as material without significant thermal expansion. They are particularly resistant to thermal shock and do not change their shape when temperatures fluctuate. For example, they are used particularly often for ceramic glass hobs or for telescopic mirrors. Researchers at the Fraunhofer IMWS discovered new negatively expanding silicates and integrated them into innovative glass ceramics with low thermal expansion. This innovative material facilitates better manufacturing processes and new uses for high-tech products or the mass market. Finely distributed crystals with negative thermal expansion are produced in a glass that has positive thermal expansion so that in the end this results in a zero-expansion material. Suitable crystals with negative thermal expansion are extremely rare, however, as they are based on high-melting lithium-aluminum silicates. Other crystalline phases with negative thermal expansion, which can be crystallized from conventional silicate glasses, are not hitherto known.

Scientists at the Fraunhofer IMWS have found a new crystalline material with the composition $Ba_{1-x}Sr_xZn_2Si_2O_7$ and with just this rare property. This is the first new negative-expanding silicate for 50 years with the great advantage that the manufacturing costs of glass ceramics with these new crystal phases is significantly below that of the conventional zero expansion glass ceramics. A further advantage is that the expansion conduct of individual components can be set variably to wide ranges of temperature. The crystallization conduct of this new glass ceramic had to be completely re-explored in recent years. It turned out that the new glasses, when converted into glass ceramics, tend to form micro-cracks, which cause inferior mechanical properties.

To prevent this, microscopically small crystals distributed finely in the volume must be produced. This needs nucleating agents, which cause the separation of the tiniest crystals in the volume through heat treatment of the glass. The actually required crystals can then grow on these extremely small seed crystals. Conventionally common nucleating agents such as ZrO_2 or TiO_2 do not work in the new glass systems at all. The glass ceramics, wich the Fraunhofer IMWS discovered, show different crystallization behavior and significantly lower synthesis temperatures than those commercially available. Due to the significant lowering of the melting temperatures, the new glass-ceramic material can certainly replace conventional materials in certain fields of application, such as perhaps in



High-resolution imaged nanostructure of a LAS glass-ceramic: Growing a LAS crystal on a $ZrTiO_4$ seed crystal

Dr. Christian Patzig
Physics studies at the University of Jena, PhD at the Leibniz Institute for Surface Modification Leipzig, Staff Layertec GmbH Mellingen, since 2010 in the group »Nanomaterials and Nanoanalytics« at the Fraunhofer IMWS
christian.patzig@imws.fraunhofer.de
+49 345 5589-192

Prof. Dr. Thomas Höche
Physics studies at the University of Halle-Wittenberg, PhD at the MPI for Metals Research Stuttgart, Habilitation in Experimental Physics at the University of Leipzig, since 2010 team leader »Nanomaterials and Nanoanalytics« at the Fraunhofer IMWS and Professor at the University of Leipzig
thomas.hoeche@imws.fraunhofer.de
+49 345 5589-197

CENTER FOR SILICON PHOTOVOLTAICS CSP

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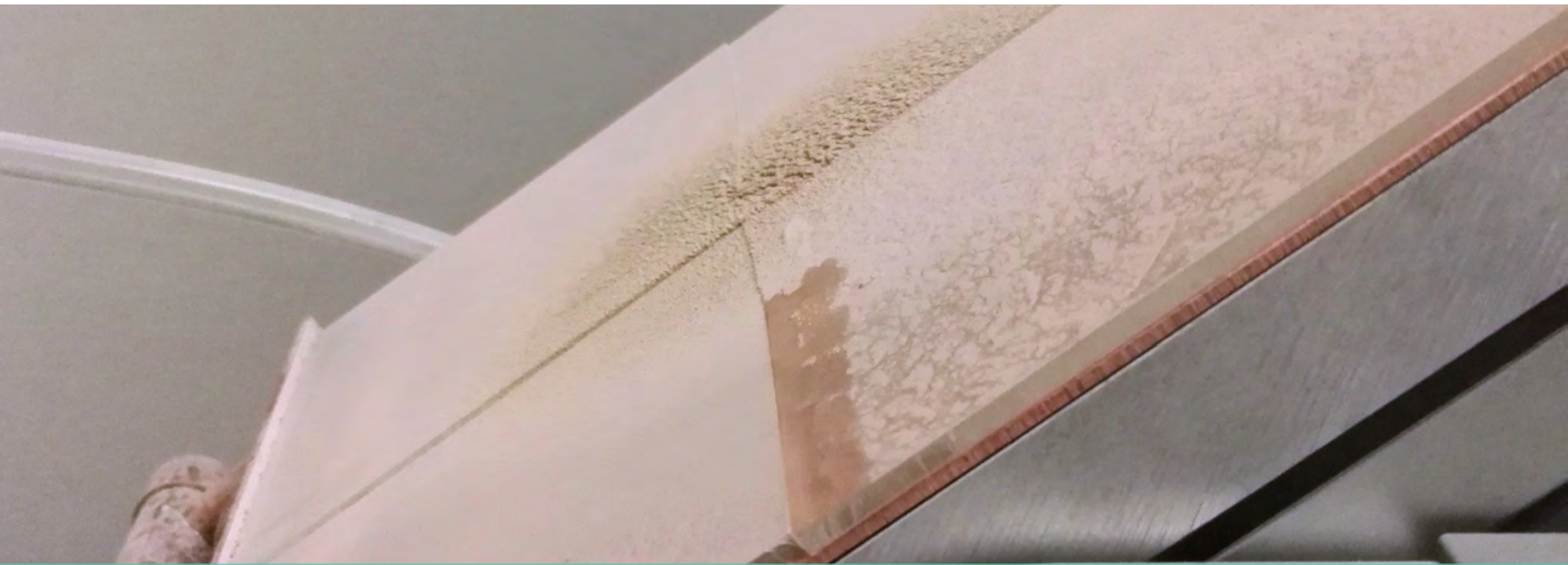
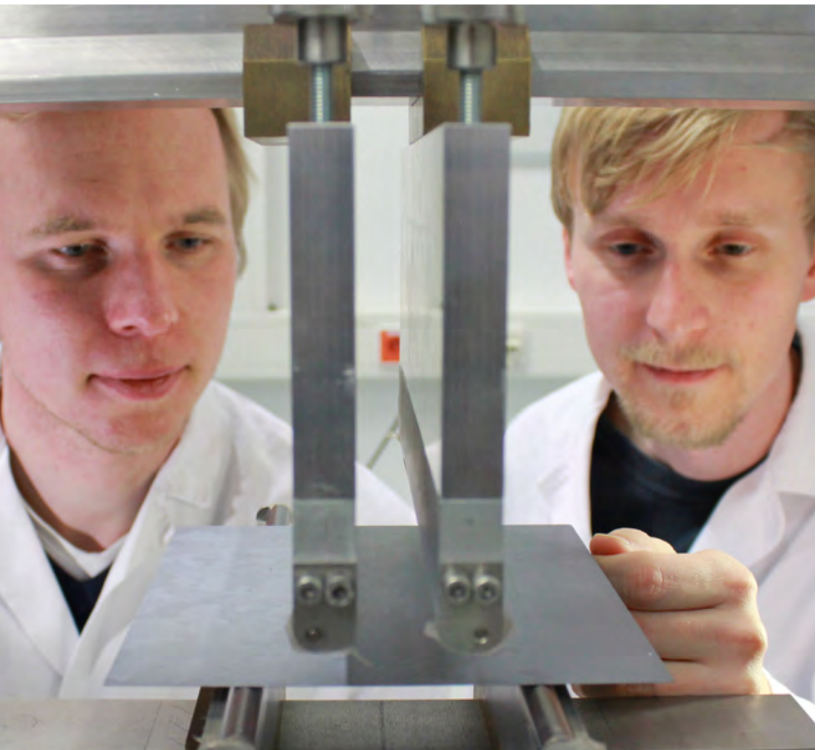
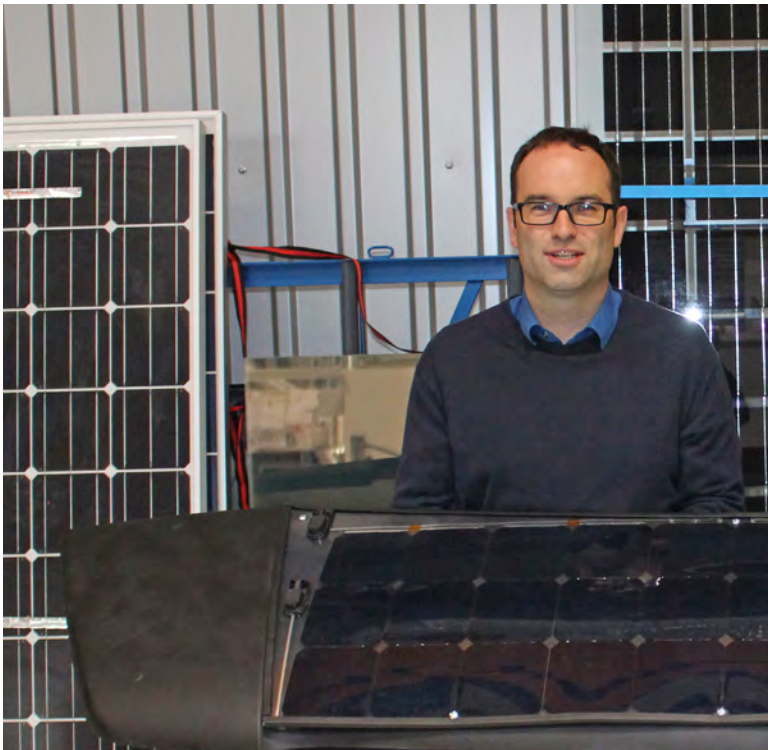






SOLAR TECHNOLOGIES ARE ESSENTIAL

Interview with Dr. Karl Heinz Kuesters, Head of Business Unit

What was your personal highlight in 2017 in terms of the business unit?
The highlight in 2017 was the tenth anniversary of Fraunhofer CSP, when we welcomed the Prime Minister of the state of Saxony-Anhalt, Dr. Reiner Haseloff, as a guest. Together with 130 guests, including longstanding partners, we looked back on our accomplishments and discussed the future of photovoltaics. Ten years is a turning point, especially in view of the highs and lows that the solar industry has experienced in Germany. This means we have to keep reinventing ourselves to a certain extent. The awards for the PID test standard and the anti-soiling test bench, as well as the Smart Magnetic Field start-up selected by Fraunhofer-Gesellschaft from among many applicants seeking funding, show that we set benchmarks with our innovations and are on the right track.

Which industries and markets do you work with?
How can your customers benefit from a cooperation?
We work together with machinery and material manufacturers, as well as photovoltaic module manufacturers and field operators. Our areas of focus include the development of measuring instruments, optimization of service life, quality control of solar modules and the mobile characterization of PV systems. We also work on standards, for example to determine the breaking strength of silicon wafers.

With our focus areas, we can give our customers a technological edge over the competition, which relies on low prices. Our projects help identify potential for improvements in photovoltaics. If you look at how – thanks to applied research – the efficiency and reliability of PV modules have continued to improve while prices have dropped, it becomes clear that solar technologies are essential in order to realize a successful energy transition.

In 2017, we celebrated the 25th anniversary of Fraunhofer in Halle. What do you associate with it?
For our business unit, this anniversary is particularly associated with the tenth anniversary of Fraunhofer CSP. Founded in the wake of the economic euphoria of the Solar Valley, the agonizing decline in the PV industry has also had a noticeable impact on our work. However, the slump in the industry in Saxony-Anhalt was less pronounced than in Germany as a whole. With our work, we are striving to give companies in the region a technological advantage.

What activities are planned for 2018?
The new head of the "Reliability and Technologies for Grid Parity" department will be appointed this year, which will give new impetus to the unit. We will also further intensify our partnerships with Morocco and South Korea.

Dr. Karl Heinz Kuesters
PhD in Physics, held posts in the Microelectronics division of Siemens/Infineon as well as leading positions at Conergy and Hanwha QCells, Interim Manager of Fraunhofer CSP since 2016
karl.heinz.kuesters@csp.fraunhofer.de
+49 345 5589-5001

PHOTOVOLTAIC TEST BENCH BRINGS THE DESERT INTO THE LABORATORY

Numerous solar modules are currently being installed in desert regions. We meet our customers' challenges by developing laboratory-compatible methods for the efficient simulation of desert conditions and analyze the behavior of the modules in extreme climates.

The use of photovoltaics in desert areas in the solar belt of the earth offers numerous advantages: on average, the solar radiation is more than twice as high as in our latitudes and large areas are readily available for use.

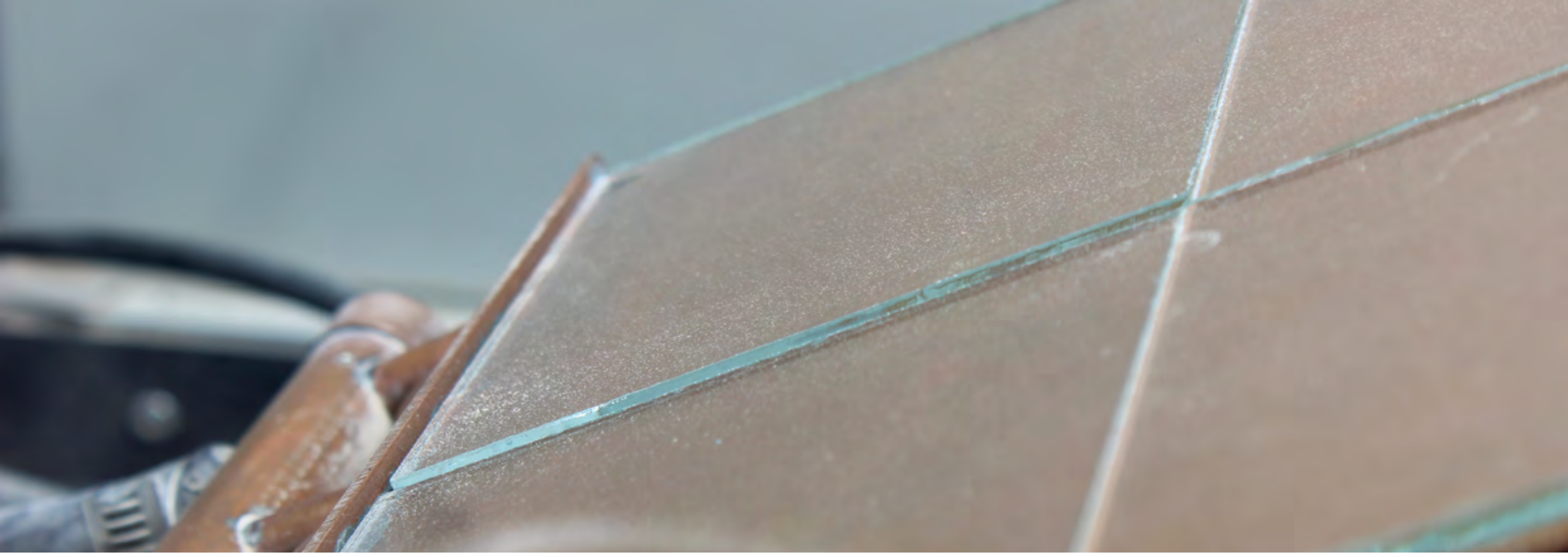
However, solar modules must also meet special requirements when used in desert regions. In addition to the strong UV radiation and the large temperature differences between day and night, the muddying of the modules by dust and sand, referred to as »soiling« by specialists, is another issue. If the wind blows particles onto the surfaces of the solar modules and these are then »caked on« when dew forms on the module's surface, less light reaches the solar cells and thus less electricity is produced. The aim is to prevent this soiling to the greatest extent possible in the future.

Our research enables an understanding of the soiling processes and faciliates a better assessment of yield losses.

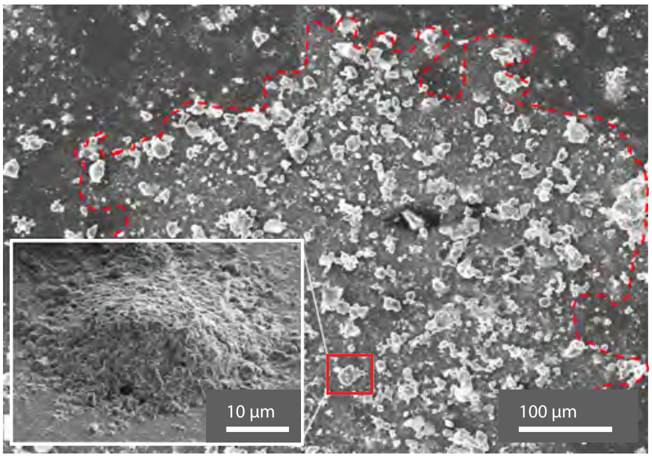
At present, solar modules are primarily cleaned mechanically, depending on the location and dust exposure and buildup. A better solution would be to have optimized surface properties on the glass panes of the modules which ensure that dust cannot adhere in the first place and that natural cleaning mechanisms such as the wind can be more effective.
To work on developing such an »anti-soiling coating«, a soiling test bench was built at the Fraunhofer Center for Silicon Photovoltaics in cooperation with Anhalt University of Applied Sciences. This allows the researchers to realistically simulate both the dusting behavior of coated glass samples and the dewing processes in the laboratory.

With this approach, a precise understanding of the processes underlying the soiling behavior can be developed. Extensive series of tests show that the data from the soiling tests conducted in the laboratory correspond very well with the data measured during a five-month comparison test in the Atacama Desert in Chile. The key advantage of the soiling test bench is that just a few hours are needed to obtain the desired results on soiling patterns or thickness of the dust layers. The soiling test bed is currently being further developed in cooperation with a company in the region in preparation for a market launch.
Microstructural investigations on dusty glass samples from Chile have shown that the adhesion of particles on glass surfaces is induced by different processes. In the case of the samples from Chile, it is not the cementation (i.e. the »caking on« of the particles caused by precipitation of salts previously dissolved in water drops) but rather »particle caking«. This term is used to describe a process that causes larger particles to »cake« by the rearrangement and compaction of very small particles (smaller than 4 micrometers) during the condensation processes. During the process, platelet-shaped clay minerals such as kaolinite fill gaps between larger particles and the glass surface. This results in a larger contact area and thus also greater adhesion forces for the large particles – the dirt therefore adheres even more strongly to the glass surface. These findings are extremely helpful in terms of the development of adapted anti-soiling coatings. Fraunhofer CSP has thus taken a decisive step in making solar modules used in desert environments more resistant to soiling.

In parallel with the accelerated process on the soiling test bench, reliability and yield studies on photovoltaic modules are being conducted under real conditions in desert regions. In these projects, Fraunhofer CSP is cooperating with partners



View into the dust chamber of the soiling test bench:
Four dusty glass samples are bedewed here by cooling the sample table (detailed photo above).



Electron microscopy image of the glass surface following exposure in the Atacama Desert. »Caking« occurred in the area of a dewdrop (red bordered area).

in Morocco and Qatar. The test platforms operated there for individual modules and systems offer great opportunities for scientific investigations. In Morocco, Fraunhofer CSP has been working together with IRESEN, a research institute for renewable energies, since 2012. In Ben Guerir, near Marrakech, Fraunhofer has provided technical and scientific support for the construction of the »Green Energy Park«. There, modules can be precisely observed by means of high-resolution measurements at ten-second intervals in conjunction with climate data, and the »anti-soiling coatings« are also examined over longer periods of time. The soiling behavior and its effect on the energy yield at the site can thus be verified on this basis. These investigations enable an understanding of how soiling processes occur depending on the weather conditions and how they can be predicted for the upcoming days. This in turn facilitates a better assessment of yield losses.

Another important cooperation partner for Fraunhofer CSP is QEERI in Doha, Qatar. At the solar test field located there, investigations are conducted in a similar way using highly innovative equipment.

Here, the latest bifacial modules – modules that capture sunlight from both sides – are also analyzed with regard to their yield and soiling behavior.

Klemens Ilse
Degree in Physics from MLU Halle, PhD student at Fraunhofer CSP since 2015 in the »Diagnostics of Solar Cells« group in cooperation with Anhalt University of Applied Sciences
klemens.ilse@csp.fraunhofer.de
+49 345 5589-5264

David Daßler
Degree in Applied Mathematics from Leipzig University, PhD student at Fraunhofer CSP since 2015 in the »Reliability of Solar Modules and Systems« group in cooperation with Anhalt University of Applied Sciences
david.dassler@csp.fraunhofer.de
+49 345 5589-5214

CENTER FOR SILICON PHOTOVOLTAICS CSP

LEIGHTWEIGHT SOLAR MODULES FOR VEHICLE INTEGRATION

Photovoltaic modules are integrated into the roof and wind deflectors of the Conti Innovation Truck.

In cooperation with Continental Automotive GmbH, the Fraunhofer CSP has developed a flexible solar module for the towing vehicle of the Continental Innovation Truck and presented it at the »IAA Commercial Vehicles 2016« trade fair. Since then, the Innovation Truck with solar modules is traveling through Europe.

The development of mobile photovoltaics supports three major trends in the mobility industry: Electrification, digitalization and autonomous driving. All three claims require environmentally friendly electrical energy. The integration of solar modules in vehicles enables the energy supply even without motor operation. This reduces consumption while driving and reduces or avoids engine runtimes during legal breaks, especially in freight traffic on the road.

The photovoltaic integration in the semi-trailers of trucks is relatively easy to implement due to the flat and rectangular geometry. Many devices that consume power are in the truck tractor. In their collaboration, Fraunhofer CSP and Continental Automotive GmbH have integrated a 3000 WP photovoltaic module into the towing vehicle of the Continental Innovation Truck. The Fraunhofer CSP has developed solar modules that combine several advantages: They are light and do not add much weight. The flexible material can be adapted to the arched shape of the body. They are highly efficient and generate maximum yields in a small area. In addition, they are connected in such way that inhomogeneous solar radiation does not reduce the yield excessively.

> *Vehicle-integrated Photovoltaic (ViPV) is a great opprtunity for innovation Made in Germany.*

Continental has developed electrical integration using a DC-DC converter, which enables utilization of the variable solar yields for direct use or battery charging. Althoug the space available for photovoltaics on vehicles is actually too small to provide signifcantly more than 10 percent of the required drive energy even in the most favorable scenarios and applications. However, the generation of power from solar modules in the body has the potential to become one of the most favorable forms of energy supply in the vehicle.

Prof. Dr. Jens Schneider
Studied electrical engineering at the University of Duisburg and TU Berlin, PhD in electrical engineering at the Hahn-Meitner-Institut Berlin and TU Berlin, since 2011 at the Fraunhofer CSP, Group Manager »Module Technology«, Professor at the HTWK Leipzig
jens.schneider@csp.fraunhofer.de
+49 345 5589-5500

Sebastian Schindler
Studied electrical engineering at the TU Dresden, since 2008 at the Fraunhofer CSP
sebastian.schindler@csp.fraunhofer.de
+49 345 5589-5523

STANDARD FOR STRENGTH TESTING OF PHOTOVOLTAIC WAFERS

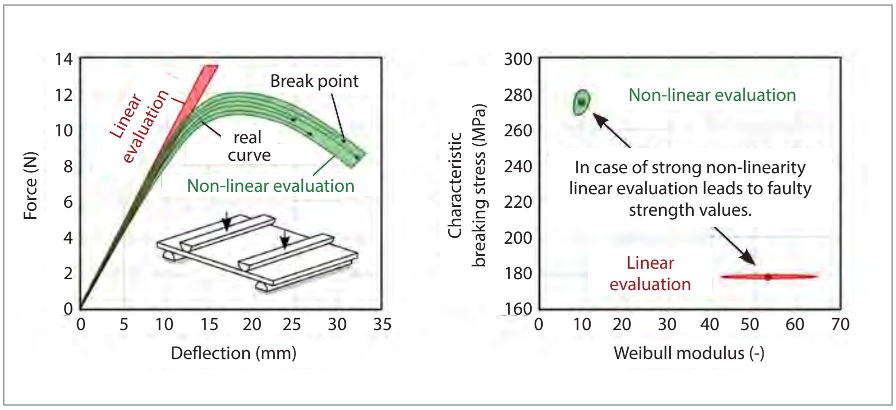
The Fraunhofer Center for Silicon Photovoltaics CSP has developed a DIN SPEC together with Leipzig University of Applied Sciences (HTWK Leipzig), regional industrial partners, and the German Institute for Standardization DIN for strength tests on photovoltaic wafers. The standardized procedure facilitates quality control in the solar industry.

With DIN SPEC 91351:2017-04 »Strength Testing for Photovoltaic Wafers«, a standardized strength test can be performed on silicon panels from 120 to 220 µm thin, called wafers, for photovoltaic cells and modules. As part of this, a standardized bend test identifies at what force a wafer made from crystalline silicon breaks. The test is necessary because the brittle material is very fragile and thus cannot be exposed to high mechanical strain during the production process. DIN SPEC defines how this bend test must be arranged, performed and assessed. It is the world's first standard specification in this field. For users of the standard, complex nonlinear problems are provided in illustrated charts and tables, which significantly facilitates communication throughout the value creation chain in solar cell production.

The working group on the DIN SPEC was led by Felix Kaule at Fraunhofer CSP and cooperated closely with Stephan Schönfelder, Professor for Simulation Methods in Energy and Mechanics at HTWK Leipzig. Both research institutions have already been working together in the fields of mechanics and finite element simulation for many years, thus gaining new knowledge about the theoretical and material-mechanical connections for brittle materials along with valuable skills relating to strength measurements for brittle silicon wafers.

Until now, it had always been necessary to put a great deal of work into simulating the deformation behavior of the wafer. This is because wafers become deformed in a nonlinear manner under a load. Thanks to conversion tables in the DIN SPEC, anyone can now reliably assess the strength of silicon wafers, even without simulation models.

The DIN SPEC is used to publish international standards and can form the basis for a DIN standard.

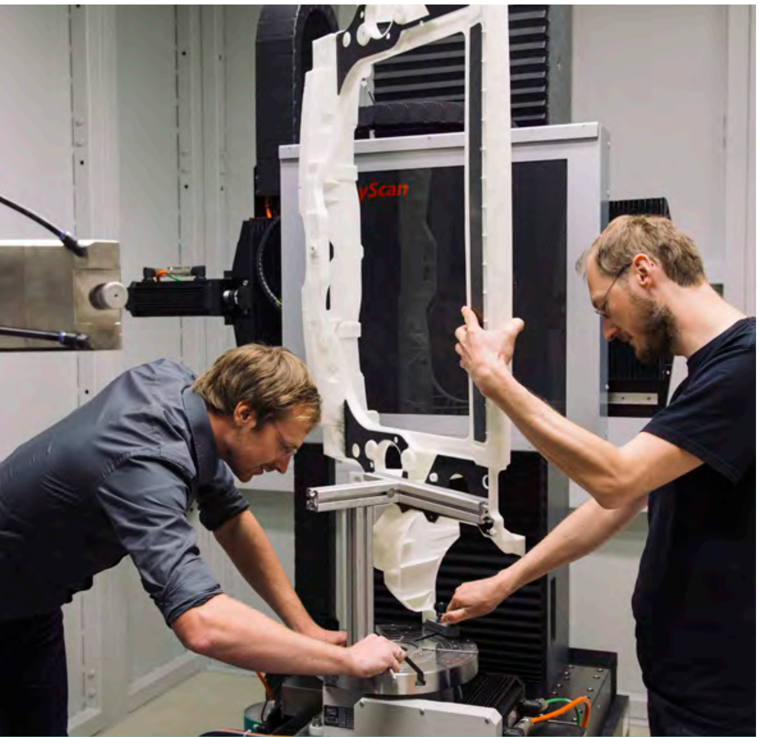


Left: *Force-displacement curve in a 4-point bending test*
Right: *Strength parameters with 90% confidence intervals*

Felix Kaule
Mechanical engineering studies at the HTWK Leipzig,
since 2012 Employee in the mechanics team of the group »Silicon Wafers« at the Fraunhofer IMWS
felix.kaule@csp.fraunhofer.de
+49 345 5589-5312

Prof. Dr. Stephan Schönfelder
Mechanical engineering studies at the HTWK Leipzig,
Doctorate in the field of mechanics of semiconductor materials,
since 2004 at the Fraunhofer IMWS, Team Leader Mechanics in the Group »Silicon Wafers«, since 2014 professor at the HTWK Leipzig
stephan.schoenfelder@csp.fraunhofer.de
+49 345 5589-5310

SELECTED RESEARCH RESULTS



OUR UD TAPE LINE IS AN IMPORTANT UNIQUE SELLING POINT

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

What was your personal highlight in 2017 in terms of the business unit?

It was the commissioning of the unidirectional (UD) tape line at the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau. With this technology for the production of fiber-reinforced plastics, we see enormous potential for lightweight construction applications. In starting up the line, we have implemented a key technical component of the business unit's strategy and created an important scale-up instrument for this technology. We are now able to produce UD tapes on a pilot scale, and at the same time, a laboratory facility was put into operation at Merseburg University of Applied Sciences. This creates a valuable unique selling point for us.

The ceremonial opening of the plant is planned for spring 2018. In addition to mobility applications, ballistic composites played a major role in 2017. We succeeded in achieving very good initial results in this area, which were appreciated by the industry.

Which industries and markets do you work with?
How can your customers benefit from a cooperation?

We are the specialists for materials and processes in the field of fiber-reinforced high-performance thermoplastics and innovative rubber composites for use in high-volume production. Our fields of application include, for example, lightweight materials for the automotive and aviation industries, as well as security technology as a new market. We consider the entire value-adding chain along with the diagnostics and technology axis.This ranges from the selection of raw materials, to the processing technology and resultant processing structure and structure-property relationships through to the desired component properties.

In 2017, we celebrated the 25th anniversary of Fraunhofer in Halle. What do you associate with it?

I am particularly impressed by the rapid development of the technology. In 1992, I had just started my job as a department head for application developments in an industrial company. Back then, nobody would have guessed what opportunities and challenges we would be talking about in 2017. I'm thinking here about topics such as the digitization of material properties or sensor-equipped components, which we are working on in a use case as part of the Materials Data Space. This demonstrates that in Halle and at many other locations, Fraunhofer has not only succeeded in keeping up with this pace, but has also helped to drive development forward.

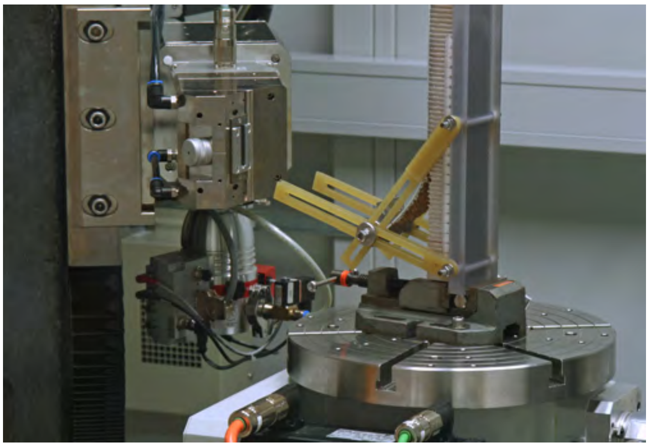
What activities are planned for 2018?

2018 will be marked by the expansion of Fraunhofer PAZ. We want to push ahead with our successfully initiated strategic realignment process, for example by expanding microstructure assessment using non-destructive testing techniques and online testing methods. Purchases of the necessary equipment are already scheduled as part of the PAZ expansion. And last but not least, we have planned exciting new projects in the field of crystallization management.

Prof. Dr. Peter Michel
Degree in Mechanical Engineering and Plastics Engineering, Head of Business Unit at Fraunhofer IMWS since 2013, professor at Merseburg University of Applied Sciences since 2014
peter.michel@imws.fraunhofer.de
+49 345 5589-203

IN-SITU X-RAY COMPUTED TOMOGRAPHY ON COMPOSITE STRUCTURES

In-situ x-ray computed tomography is a particularly efficient method for analyzing internal material structures. Under mechanical stress, failure processes in high-performance composite materials could be visualized.



Loaded sandwich sample with partially detached facesheet in the SCB test within the x-ray CT system

Modern sandwich components made of high-performance composite materials are used in all areas of mobility due to their enormous potential for lightweight construction. Sandwich materials are advantageous because of their high degree of bending stiffness and stability, especially for flat and large-surface components. Thin and stiff facesheets are firmly bonded to each other via a supporting sandwich core. For highly stressed components in the aviation industry that are subject to very heavy loads, extremely lightweight, rigid and fracture-resistant carbon fiber-reinforced plastics (CFRP) are used in the outer facesheets.

In recent years, flexible manufacturing and shaping processes have been developed for these types of fiber-reinforced components; these processes can also be used to cost-efficiently manufacture complex sandwich components. In such components, the sandwich core is subjected to greater mechanical stress. If additional reinforcing elements, such as CFRP pins for example, are integrated into a polymer foam sandwich core, performance, stability and reliability can be further increased. Sandwich materials offer material and component

The fracture processes in honeycomb core sandwich components can be better predicted

developers a wide variety of design options, since they consist of very different material components and with their internal structure can already be regarded as a complex mechanical construction in themselves. To fully utilize the lightweight construction potential of such components, the core reinforcement structures must be optimally aligned to the operating loads. Deformations of sandwich components can be accurately predicted using numerical calculation methods, if the internal material structure of the facesheets, core material and reinforcement structure is thoroughly taken into account. The damage and failure behavior, however, is much more complex. Even very slight deformations and load redistributions in the inner reinforcement structure can lead to quite different failure processes and ultimately influence component reliability. A better understanding of such correlations can be achieved using non-destructive imaging techniques.

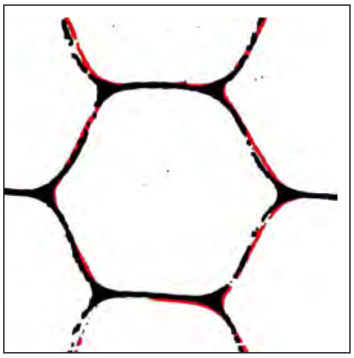
In-situ x-ray computed tomography allows the internal structures of a component to be made visible at various load levels – directly in the mechanical deformation device under load. The result is an exact spatial image of the internal material structure and the movements and deformations of the smallest structural details inside the component during the entire loading process can be visualized. In a working group initiated by the Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA) and other partners, Fraunhofer IMWS is working on an international test standard to determine the strength of the facesheet-core compound in high-performance sandwich materials.

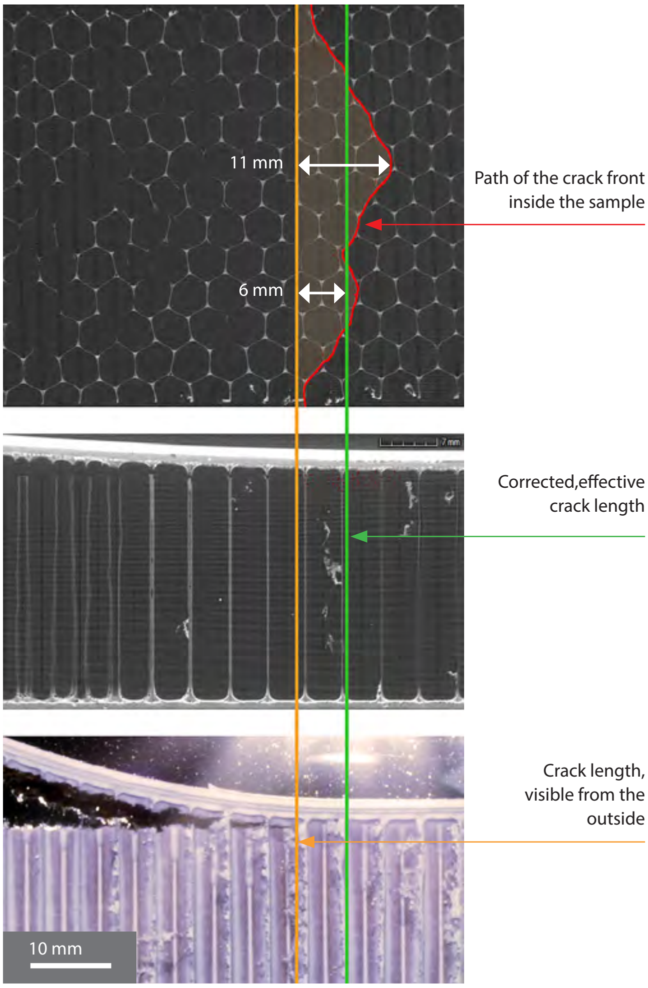
While such a standard later will subsequently provide a simple test specification and calculation rule for engineers, it must be ensured in advance that it can be applied to a broad selection

Sandwich sample in the single cantilever beam test: Facesheet depending at very high loads due to tearing of the aramid paper honeycomb core below the facesheet

of sandwich materials, even with a very complicated internal structure. For the analytical calculation of the fracture mechanics material properties, the actual sandwich core structure must be greatly simplified, but at the same time the material characteristic must be recorded.

A crucial question concerned the extent to which the honeycomb structure in the inside deforms immediately before crack propagation occurs. Within the scope of this project, a special procedure (SCB test) was set up and performed in the x-ray CT system at Fraunhofer IMWS, accompanied by numerical simulations. To avoid inaccurate images, the test apparatus was specially constructed without metallic components in the beam path. The sandwich sample consisted of CFRP facesheets and a NOMEX® honeycomb core. The cell walls are formed from only a 51-µm-thick, coated aramid paper and would be easily deformed without the stable honeycomb geometry and the strong bond to the CFRP facesheets and could only transfer small loads. If the facesheet is partially debonded from the core due to punctiform overloading of the component, there is a risk of tearing/cracking and destruction of the sandwich component.
The in-situ x-ray examinations showed that slight buckling deformations of the cell walls can occur in the area of the highest material loads near the crack front. At the same time, the honeycomb shape remains intact and stabilizes the core structure. The end of the crack in the SCB sample visible from the outside does not correspond to the actual crack length in the middle of the sample. However, the effective crack length can be corrected on the basis of the test results and thus leads to a much more accurate representation in the calculation rules of the test standard.





Loaded SCB sample with corrected crack length. Top: View through the upper facesheet. Middle and bottom: Side view as CT scan and camera image. Left: Honeycomb cell at the crack front (black). Slight deformation in the sandwich plane with the facesheet applied immediately before the crack propagation (red).

Dr.-Ing. Ralf Schäuble
Degree in Electrical Engineering from Chemnitz University of Technology, PhD from University of Halle-Wittenberg, at Fraunhofer IMWS since 1996
ralf.schaeuble@imws.fraunhofer.de
+49 345 55 89-151

STRAIN-INDUCED CRYSTALLIZATION IN ISOPRENE RUBBERS

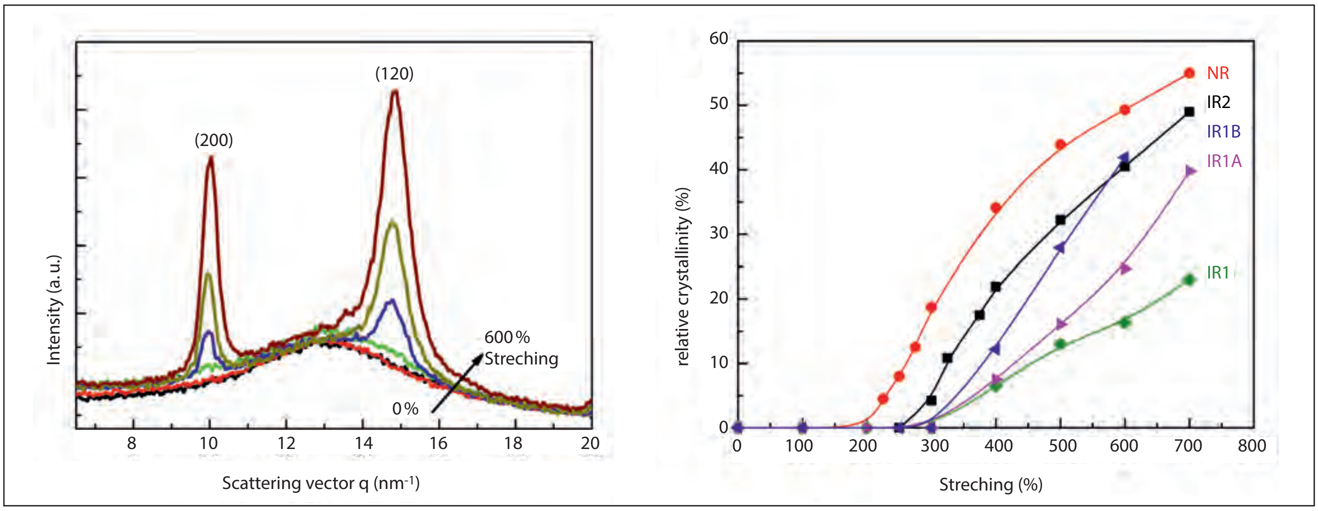
Isoprene-based natural and synthetic rubbers have different properties. To optimize the application properties of synthetic isoprene rubbers, this project examined the influence of microstructural aspects and special additives on strain-induced crystallization in various rubbers.

Rubbers are elastic polymer materials in which linear macromolecules are chemically crosslinked. They are characterized by the property that they deform reversibly under external loads. It is particularly significant that they can withstand large elongations and return to their original form again and again, even under repeated strain. The excellent properties of natural rubber, such as high tensile strength, elasticity as well as chemical and thermal stability, combined with outstanding resistance to further tearing after initial tears are still unrivalled in many respects.

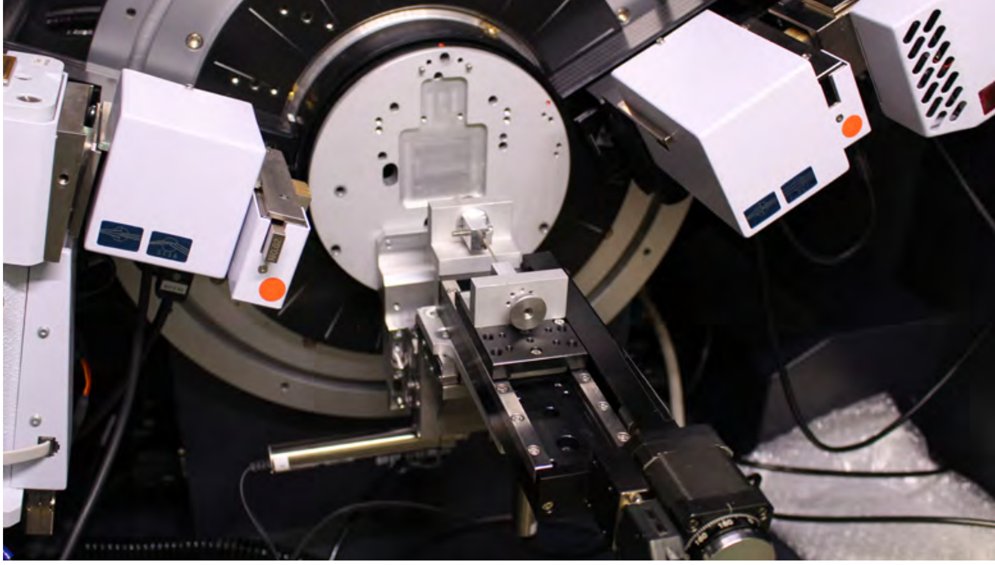
Therefore, natural rubber is still today the main component of many products in vehicle construction and mechanical engineering as well as in consumer goods and medical technology and equipment. In chemical terms, natural rubber is primarily comprised of high-purity cis-1,4 polyisoprene (with more than 99.9 percent cis-1,4 structural units). However, it also contains other components, called additives, such as proteins, phospholipids and resins.

If rubber is stretched, crystallization processes occur in the material that lead to a spontaneous, reversible stiffening of the material. This strain-induced crystallization is one of the fundamental sources of the excellent mechanical properties of natural rubber. This phenomenon is unique and occurs due to a very specific arrangement of side chains in the polymer, the almost perfect stereoregularity (cis-1,4 content of nearly 100 percent).

Isoprene rubbers are polymerized from isoprene (2-methyl-1,3-butadiene). The properties of synthetic isoprene rubbers (IR) are inferior to those of natural rubber due to their lower degree of stereoregularity and the absence of certain additives. The strain-induced crystallization is hindered.
To specifically improve the properties of synthetic isoprene rubbers, it is important to understand the influence that the microstructure of the polyisoprene chains



Left: *X-ray diffraction patterns for natural rubber at different degrees of strain:*
Right: *Relative crystallinity for various isoprene-based rubbers*



Measurement setup for in-situ diffraction measurements with motorized linear stage on a BRUKER D8 ADVANCE X-ray Diffractometer

and the additional components have on strain-induced crystallization. The application-oriented optimization of synthetic isoprene rubbers is a key goal of the »Biomimetic Synthetic Rubber in Innovative Elastomer Composites« research project being conducted by Fraunhofer-Gesellschaft; five Fraunhofer Institutes with different focuses and expertise are collaborating together on the project.

Additive-enhanced isoprene rubbers show pronounced strain crystallisation and improved mechanical properties.

In this research project, comparative analyses of various natural rubbers and many specific additive-enhanced isoprene rubbers are being conducted. Fraunhofer IMWS has developed a special laboratory measurement setup to evaluate the strain-induced crystallization in different isoprene-based rubber systems.
For the project, a motorized linear stage was integrated into a D8 ADVANCE Diffractometer in order to be able to determine diffraction images in situ, i.e. directly at strains (stretching) of up to 750 percent. This allows comparable crystallinities to be determined for stretched samples on the basis of a special analysis called a peak area analysis. Highly regular isoprene rubbers (cis-1,4 content >97 percent) were synthesized at the Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau. The Fraunhofer Institute for Molecular Biology and Applied Ecology IME analyzed natural rubbers and extracted various additives. The synthesized isoprene rubbers and various additive-enhanced synthetic isoprene rubbers were then extensively analyzed by Fraunhofer IMWS.

A comparison of the results from the analyses of various isoprene-based rubbers using x-ray diffraction shows clear differences with regard to strain-induced crystallization. In natural rubber (NR), this crystallization already starts at low strains (~225 percent). The relative degree of crystallization is generally higher compared to synthetic isoprene rubbers. The strain-induced crystallization in synthetic isoprene rubber apparently only starts with greater deformations (~300 percent). The advantageous crystallization behavior of natural rubber is probably not only due to the almost perfect microstructure (100 percent cis-1,4) of the polyisoprene chains, but can also be attributed to the natural additives it contains. Isoprene rubber samples (IR1A, IR1B) containing special bioanalogous additives show a significant increase in the relative crystallinity (factor 1.5 to 2.5) at high strains compared with non-additive-enhanced samples. Even higher crystallinities can be achieved in special systems (IR2). This is a promising result: it suggests that isoprene rubbers with mechanical properties similar to those of natural rubber can be produced in the future using specific customized additives and synthesis. Further work to optimize the microstructure of the isoprene rubber and the additives used is a current research focus of the project.

Dr. Gaurav Kumar Gupta
PhD from the Institute of Physics at University of Halle-Wittenberg, research associate at Fraunhofer IMWS since 2015, promotion at the Institut for Physics at the University of Halle-Wittenberg,
gaurav.kumar.gupta@imws-extern.fraunhofer.de
+49 345 5589-201

Prof. Dr. Mario Beiner
Degree in Polymer Physics at Merseburg University of Applied Sciences, PhD and postdoctoral qualification at University of Halle-Wittenberg, at Fraunhofer IMWS since 2011, Scientific Director of the Polymer Applications business unit, Group Manager »Polymer-Based Material Design«, Professor at Merseburg University of Applied Sciences
mario.beiner@imws.fraunhofer.de
+49 345 5589-247

SUSTAINABLE REINFORCEMENT ELEMENTS WITH POTENTIAL FOR CONSTRUCTION APPLICATIONS

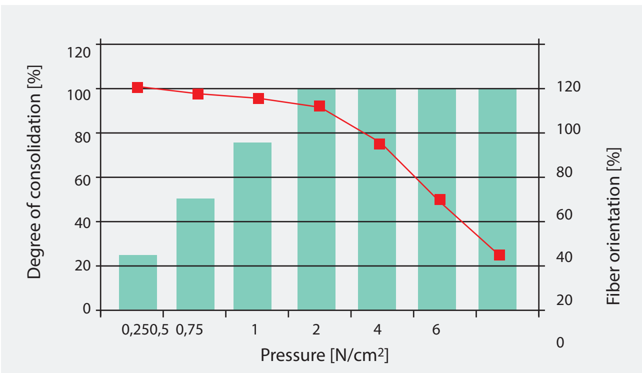
For the production of reinforcement elements for use in the construction industry, the manufacturing process of a material mix of thermoplastic and natural fibers could be optimized.

Natural fiber-based composites are increasingly being used in the construction industry. At the Fraunhofer IMWS, the development of special, sustainable, fiber-reinforced continuous laminates was tested, which are intended to serve as reinforcing elements in extruded plastic profiles that are pressed by molding nozzles.

First, different natural fibers were combined with polyethylene terephthalate (PET) to form endless or quasi-continuous fiber reinforced tapes. The challenge in the tape production process lay in the best possible wetting of the fibers with the matrix material. It was found that a flax fiber fabric made of directionally deposited long fibers is suitable. The tapes produced were processed on a continuous double belt press to form endless laminates.

A material system made of PET and the highest possible proportion of flax fibers was identified as being effective in terms of the desired material properties. The layer structure of seven layers of PET and six layers of flax fiber (200 g/m²) came closest to the objectives of high rigidity with simultaneous limitation of the laminate thickness to approx. 1.8 mm. By optimizing residence time and pressure in the processing process, the stiffness of this laminate structure could be increased from 23.5 GPa to 26.5 GPa in the fiber direction. The requirements in the later extrusion process, in which the continuous reinforcing laminates must be fed continuously, are very high in terms of the dimensional stability of the laminates. They allow only very low geometric tolerances. Intensive development work was necessary here because a natural material is also subject to natural property fluctuations, such as local weight fluctuations in the flax fiber layers, errors in their structure or residual moisture content. The manufacturing process and the cutting were optimized so that a laminate was present, which could be integrated continuously and without disturbances in the extrusion process for profile production.

Manufacting process of a flax fiber reinforced PET tape



Influence of the pressing pressure on the degree of wetting of the fibers with matrix material and fiber displacements in the laminate (100 percent = fiber orientation in process direction)

Ivonne Jahn
Studied materials science at the University of Halle-Wittenberg, Specialization in plastics technology, since 2007 at the Fraunhofer IMWS, Group Manager »Thermoplastic Semi-Finished Fiber Composites«
ivonne.jahn@imws.fraunhofer.de
+49 345 5589-474

Frank Nagel
Studied physical engineering at HS Merseburg, since 2001 at the Fraunhofer IMWS, Group »Thermoplastic Semi-Finished Fiber Composites«
frank.nagel@imws.fraunhofer.de
+49 0345 5589-260

SUSTAINABLE INJECTION MOLDED PARTS MADE FROM TECHNICAL BIOPOLYMERS

In the future, high-quality and resilient injection molded parts can be produced from plastics based on renewable raw materials, thus allowing the creation of ecologically sustainable products.

At present, injection molded parts are primarily made from petrochemical plastics and then are recycled and ultimately thermally recycled at the end of their service life. The consequence is a negative carbon footprint with corresponding negative effects on the climate. One approach to improving the sustainability of injection molded parts is to use technical biopolymers based on renewable raw materials, such as sugar cane or Ricinus (castor oil plant). This approach results in a significantly more positive carbon footprint, since CO_2 is also consumed during the growth phase of the renewable raw materials via the photosynthesis process.
However, the prerequisite for the widespread implementation of this approach is that the technical biopolymers used must have comparable or even better properties than petrochemical plastics and also be competitive in terms of cost-effectiveness. In cooperation with industrial research partners, Fraunhofer IMWS is developing new formulations, and preparation and processing methods in this field – for example for thermoplastic composites based on bio-based polyamides or polylactides. These can be used for sustainable injection molded parts in the automotive, construction and furniture industries, among others. One focus of the research project is the gentle processing and injection molding of natural fiber-reinforced biopolymers. These are technical biopolymers which, due to their natural fiber reinforcement, have an improved level of mechanical properties, but nevertheless are comprised entirely of renewable raw materials. In the analyses conducted up to now, chemically modified beechwood fibers in particular have proven to be an effective reinforcing material. These fibers significantly improve the mechanical properties of the biopolymers and maintain good flowability of the composite melt even at higher fill levels. In demonstrator tests, high-quality and sustainable injection molded parts with a wall thickness of 2 mm and a fill level of up to 50 percent beechwood fibers could be produced.

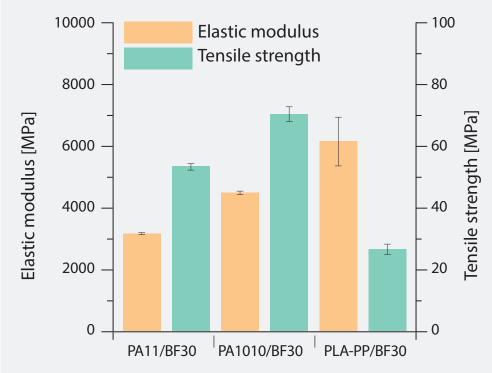
Injection molded parts made from technical biopolymers with a fill level of 30 percent beechwood fibers (PA11/BF30)

PA11: *Polyamid 11*

PA1010: *Polyamid 1010,*

PLA-PP: *Blend of polylactide and polypropylene*

BF: *Beechwood-fibers*



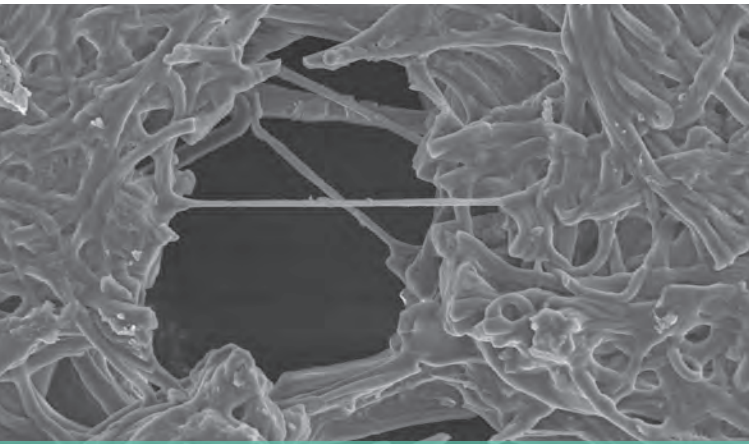
Mechanical characteristics of injection molded test specimens made from various technical biopolymers with a fill level of 30 percent beechwood fibers

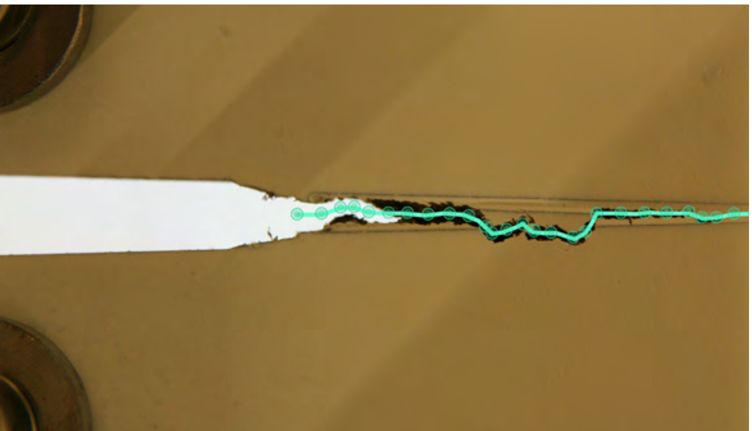
Dr.-Ing. Patrick Hirsch
Degree in Industrial Engineering and PhD in Plastics Engineering from University of Halle-Wittenberg, research associate at Fraunhofer IMWS since 2008
patrick.hirsch@imws.fraunhofer.de
+49 345 5589-264

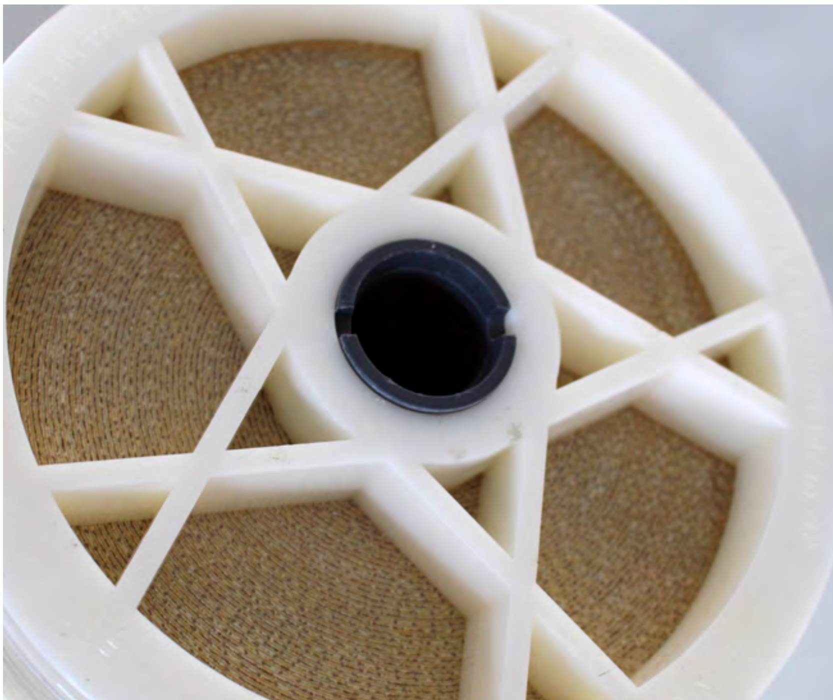
Stefanie Meyer
Degree in Polymer Materials Science from University of Halle-Wittenberg, research associate at Fraunhofer IMWS since 2017
stefanie.meyer@imws.fraunhofer.de
+49 345 5589-390

BIOLOGICAL AND MACROMOLECULAR MATERIALS

SELECTED RESEARCH RESULTS







»IT IS HIGHLY MOTIVATIONAL TO PRODUCE EXCELLENT PRODUCTS FOR THE MARKET«

Interview with Dr.-Ing. Andreas Kiesow, Deputy Head of Business Unit

What was your personal highlight in the year 2017 with regards to the business unit?
I temporarily took over the leadership of the Business Unit in 2017 and held it until October. For me personally, it was very exciting to follow the work of other groups as well as working as Manager of the Group »Characterization of Medical and Cosmetic Care Products«, supporting them as well as strengthening collaboration and synergies. It was most gratifying to realize how much in demand the achievements of this business segment are. This is reflected in small and medium-sized companies as well as in large corporations at international level and in the state of Saxony-Anhalt, which – in my opinion – engages in applied research in an exemplary manner.

Which industrial sectors and markets do you address? How do your customers benefit by collaborating?
Colleagues in the business sector »Biological and macromolecular materials« work in the field of applied research above all for businesses engaged in medical technology and the plastics processing industry. Customers benefit from our research work particularly when we are directly integrated into the development and optimization of production processes through collaboration based on trust. It is highly motivational to develop good products for the market together with our clients.

In 2017 we celebrated the anniversary »25 years of Fraunhofer in Halle«. What do you associate with this?
I did not witness the founding year in Halle, but have been at the institute since 1999 and know many colleagues, who were there during the first years – also those who started here as diploma students and then contributed in various positions up to business unit leader to the institute's success story. What particularly impresses me about the anniversary – apart from the personal achievements – is the balance of continuity and innovation, which has been managed in Halle and continues to work. Meanwhile we have built relationships with many customers and partners for many years. As before, we also actively address important and challenging cutting-edge fields with great creative drive in the year of the anniversary such as digitalization or Big Data. This is surely one of the reasons why Fraunhofer in Halle can celebrate this happy jubilee.

Which activities are planned for 2018?
We are looking forward to the return of Andreas Heilmann as Head of our Business Unit. We are well prepared for the future. I also think that we will develop the transfer of research to companies in the performance centre »Chemical and Bio-system Technology«, resulting in many innovative projects.

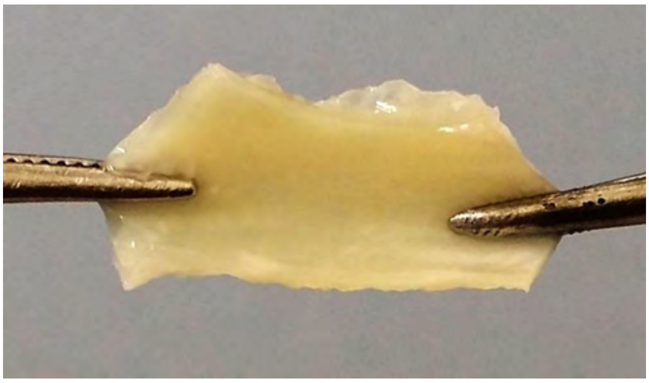
Dr.-Ing. Andreas Kiesow
Studies in Micro-System Technology at TU Chemnitz, since 1999 at Fraunhofer IMWS, since 2009 Group Manager »Characterization of medical and cosmetic care products«
andreas.kiesow@imws.fraunhofer.de
+49 345 5589-118

BIO-INSPIRED MATERIALS FOR SPECIFIC USE ON SKIN

We utilize the unique properties of natural structural proteins for developing innovative biomaterials. These have great potential for many applications in the medical field such as enhancing tissue repair following burn injuries.

In view of demographic development and increasing pressure on costs in healthcare, modern tissue repair plays an ever-increasing role. Poorly healing wounds present a particular medical challenge, for example in the case of chronic or large surface wounds. Also for the more than six million serious burns recorded yearly worldwide, appropriate bandages are needed for comprehensive closure of wounds. This could counteract infections, loss of fluids and electrolytes, ease pain or even prevent amputations. Apart from human and animal skin grafts, which are only available to a limited extent and pose increased risk of infection, above all frame structures of synthetic polymers are applied to cover wounds. However, these materials can stay on the wound only temporarily.

They are not as elastic as healthy skin, which can result in contractions and tension. This is not just uncomfortable for the patient, but also increases the risk of compromising the healing of a wound.



Example from nature: stretched elastin from the aorta – blood vessels must be extremely elastic and long lasting for over 3.5 billion beats of the heart in the life of a human being.

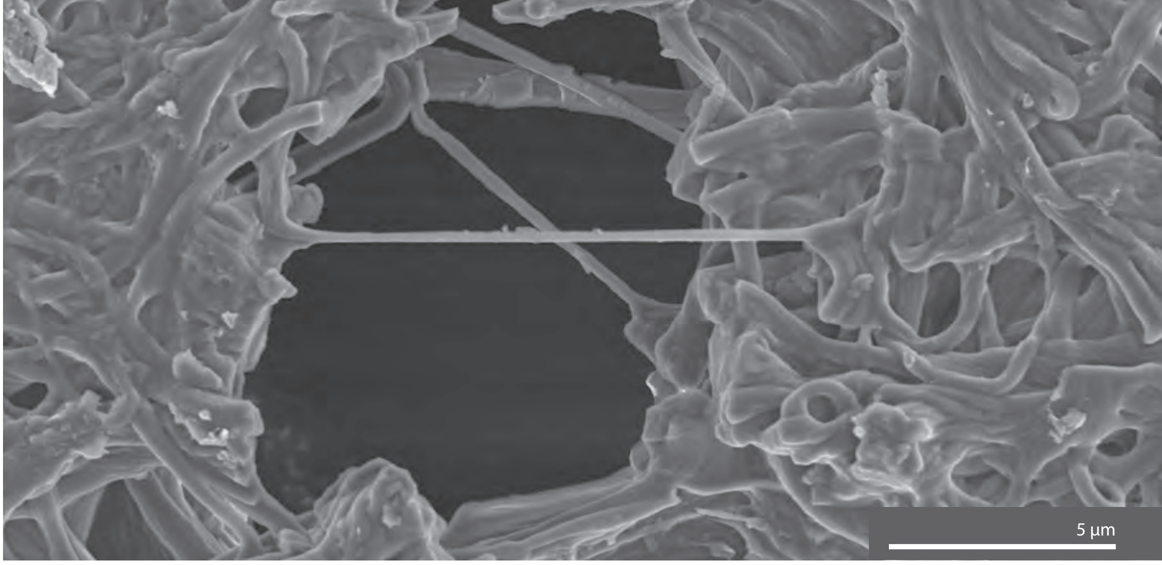
This is where the project »SkinNext« positions itself, planned for five years and sponsored by the Fraunhofer society as part of the »Attract« program. Our team develops and researches innovative biomaterials at the Fraunhofer IMWS for dermal application. The materials have to be developed in such a way that they are biologically compatible, immunologically tolerable and have the appropriate biological and mechanical stability depending on the field of application.

Our artificial elastin fibres show elasticity of more than 150 per cent.

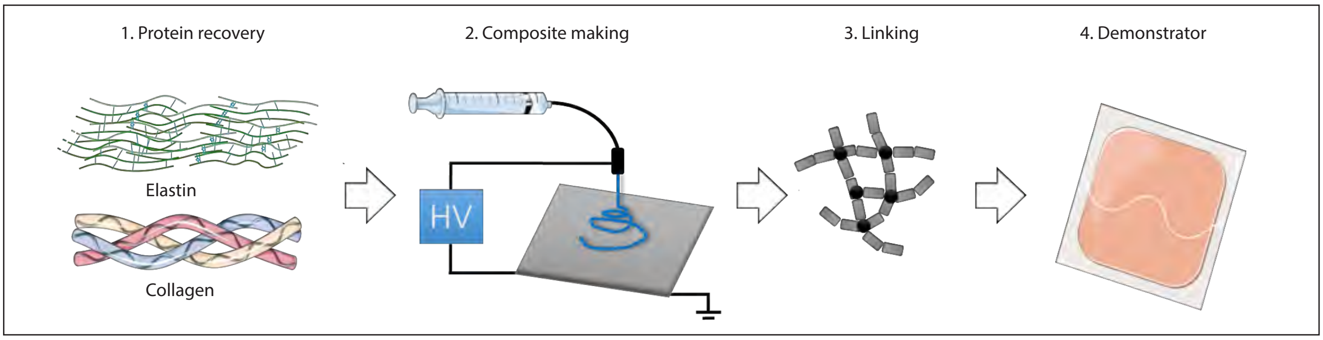
Components of the matrix, which surround our cells, provide the inspiration for our materials. In particular these include the fiber protein elastin and collagen. The fact that skin, lungs, blood vessels or cartilage are elastic, robust and resilient and manage stresses over the entire lifespan is primarily due to the interaction of these two proteins: Collagen fibers show extremely high tensile strength and thus give tissue mechanical stability.

Elastin has the complementary properties for this, and is a main component of elastic fibers responsible for the elasticity and tensile strength of many tissue types. Apart from its good mechanical properties, elastin fibers have additional advantages as materials for the healing of wounds: they can thus serve as »victim substrates«. This means, that they bind surplus proteases in the wound secretions, namely enzymes, which break down the proteins of newly growing tissues and thus can counteract the healing of wounds. Furthermore, they allow the establishment of the building cells essential in the healing process, the fibroblasts, at the seat of the wound. They can also absorb exudates with appropriate porosity and capillary activity, therefore most inflammatory excretions and cell debris.

As source materials for biomaterials, we isolate proteins from animal tissue or produce them biotechnologically



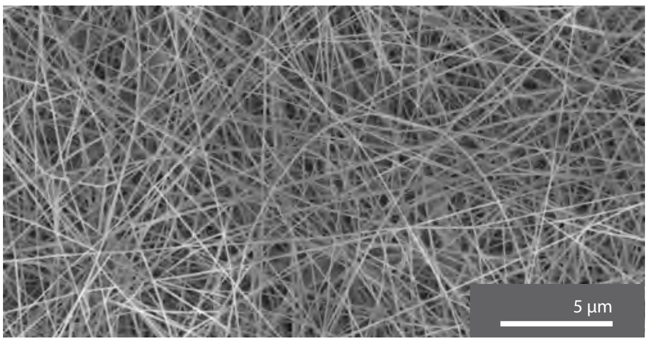
Electron microscopic photograph of elastic fibres of human skin



Process chain for producing elastin and collagen based biomaterials

together with colleagues from the Martin-Luther-University Halle-Wittenberg. Alternatively, we use synthesized peptides, namely short chain proteins, which we polymerize later. Following that, these macromolecules have to be »shaped« first. Here, we process collagen and elastin to make hydrogels, for example, and afterwards – having extracted the water – turn them into open pore, porous sponges. As a further suitable process, which can also easily be scaled, we deploy electro-spinning. Treatment in an electric field allows the production of composites in the form of nano-fiber fleeces.

Independent of the production process used, stabilization of these protein layers is an important step. As, on one hand, these should later be fully absorbable by the body, and thus be biologically degradable, on the other hand they must also withstand enzymes and physical stresses for a considerable time. We cross-link the materials to achieve these properties. For this, we use for example enzymes of the lysyl oxidase family, which are also responsible for cross-linking collagen and elastin in the body. The use of different chemical cross-linking agents also allows affecting material properties with regard to their later application purpose. Experimental research of biomaterials produced by us till now shows promising results. Thus, we were able to verify the forming of typical natural cross-linking such as in desmosine, a special amino acid, by means of high resolution mass spectrometry and extend the stability of the materials with respect to enzymes from a few seconds to several days. The mechanical properties are also similar to natural structures. The current research focus aims at optimizing interaction capability with various cell types relevant to the healing of wounds.



Scanning electron microscopic photograph of electro spun nano-fibers consisting of elastin and collagen with a mean diameter of 82 nm

Dr. Christian Schmelzer
Studies in Physical Technology at HS Merseburg, doctorate at the University of Halle-Wittenberg, Postdoc at Technion (Israel), since 2016 Manager of the Attract-Group »SkinNext« at Fraunhofer IMWS
christian.schmelzer@imws.fraunhofer.de
+49 345 5589-116

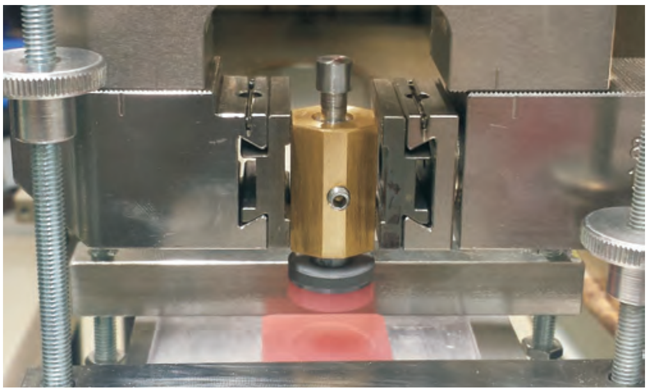
HELP FOR A DRY MOUTH

A dry mouth is not only unpleasant, but also harmful to health: The persons affected feel burning and pain, which can be accompanied by taste, eating and sleep disorders and halitosis. The mucous membrane of the mouth (oral mucosa), gums and teeth can also become inflamed. Skinomics GmbH and researchers of Fraunhofer IMWS are together searching for solutions to prevent and treat dryness of the mouth (xerostomia).

If the dry mouth becomes chronic, the mucous membranes concerned waste away, the oral flora become unbalanced and last but not least the teeth are damaged: Natural redeposition of minerals in the hard tooth tissue and repair of the smallest damage in the dental enamel no longer functions properly and tooth decay and ultimately tooth loss occurs. Older people in particular are exposed to this risk. Around one third of all persons in Germany over the age of 65 do not produce saliva in sufficient quantity or with the correct composition. This is problematic, because saliva has a central function for oral health: It is composed of more than 95 percent of water, but important minerals, hormones and antimicrobial constituents are also dissolved in it. The body itself does not reduce its saliva production with increasing age. But if, for example, several medicines are taken at the same time, as is frequently the case with older people, a dry mouth can be a side effect. Typical age-related diseases such as diabetes mellitus also impair saliva formation, as does smoking and caffeine.

The aim is the development of formulations for the dry mouth that mainly occurs in old age.

Skinomics is working on a gel, which is intended to merge an innovative combination of active ingredients with high water-binding capacity and stability. It is based on water-binding amino acids and water-binding plant extracts. In order for the active ingredients to effectively end up on and in the mucous membrane of the mouth, this mixture is combined with different microemulsions, which perform a »transporter function« for the active ingredients. The behavior of the gel is then tested by Fraunhofer IMWS. A particular challenge in the development is to achieve an adequate dwell time of this mixture in the mouth. The efficacy of inorganic ingredients on remineralization of the dental enamel, tolerance of the substances used and many other questions will be examined during the project which is due to finish in 2018. The aim is for the results to be able to be used as a platform solution, which is also suitable for other forms of administration and indications.



Experimental set-up for determining the adhesive strengths of formulations according to DIN EN ISO 10873

Dr.-Ing. Sandra Sarembe
Studied materials science at the University of Halle-Wittenberg, since 2007 at the Fraunhofer IMWS, Group »Characterization of Medical and Cosmetic Care Products«
sandra.sarembe@imws.fraunhofer.de
+49 345 5589-256

Dr.-Ing. Andreas Kiesow
Studied microsystem technology at the TU Chemnitz, since 1999 at the Fraunhofer IMWS, since 2009 Group Manager »Characterization of Medical and Cosmetic Care Products«
andreas.kiesow@imws.fraunhofer.de
+49 345 5589-118

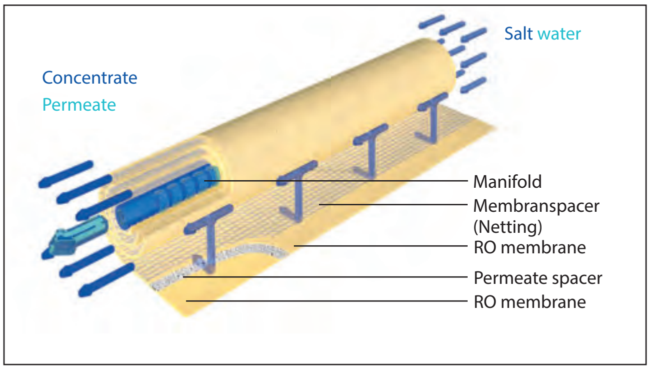
OPTIMISED SURFACES FOR REVERSE OSMOSIS MODULES RESULT IN BETTER PERFORMANCE

To improve the filtration performance and lifetime of membrane modules for drinking water production, membrane spacers are equipped with non-stick coatings that reduce the deposition of sediment and microorganisms.

Semipermeable ceramic or polymer membranes are used for reverse osmosis. Water is pressed through these membranes to separate the dissolved salt from the water; an important element in the reverse osmosis modules as used for fresh water extraction, where many membranes are layered on top of each other (also called nettings). These function as spacers between single membranes and form the channels for the salt water that flows through. These membrane spacers are prone to becoming clogged up by the deposit of soluble, suspended particles, salt crystals and microorganisms (bio-fouling). When these deposits occur, they clog up the reverse osmosis module and the filtration performance is decreased and ultimately the module fails.

With reduced biofouling it will be up to 80 percent less maintenance cycles, material damage and wear of the modules.

In the project »Innovative Membrane Spacers«, which runs until 28th February 2019, experts at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS Halle (Saale) are jointly working with IAB Ionenaustauscher GmbH Bitterfeld (LANXESS AG) on a method to stop the bio-fouling process in reverse osmosis. The explorers at the Fraunhofer IMWS want to condition the membrane spacers in such a way that none of the suspended particles and bacteria can stick to the spacers. For this, the scientists use plasma and wet-chemical technologies to produce thin, hydrophilic and charge neutral coatings on the membrane spacer surfaces. This forms a hydrogel type of barrier layer, onto which suspended particles and microorganisms can barely stick (antifouling effect). In order realise this approach, research-specific assessments of the anti-adhesive or rather anti-microbial properties of the coated surface must be carried out first. The susceptibility to bio-fouling having been tested in application-oriented scenarios, the implementation of the developed coating technologies is tested on a roll-to-roll system. For this, the IAB is conceptualising the technical implementation of the developed coating methods on an industrial level at the production site in Bitterfeld.



Reverse osmosis module: Salt water is forced through polyamide membranes and membrane spacers through a pressure process to produce drinking water through reverse osmosis.

There will be fewer maintenance cycles, less material damage and wear and tear to the modules when the process of bio-fouling can be reduced. This will facilitate a significantly more energy saving and cost effective operation of membrane modules, which will benefit many people.

Dr.-Ing. Ulrike Hirsch

Studied materials science and PhD at the Uni Halle-Wittenberg, since 2009 at the Fraunhofer IMWS

ulrike.hirsch@imws.fraunhofer.de

+49 345 5589-296

Magdalena Jabłonska

Studied chemical engineering at FHS Münster and the TU Krakow, since 2014 at the Fraunhofer IMWS

magdalena.jablonska@imws.fraunhofer.de

+49 345 5589-187

STRESS TESTING NATURAL MATERIAL COMPOSITES

Wood polymer composites are examined in the laboratory in short and long-term tests, as well as outdoors. Particular modeling approaches should indicate the behavior materials display. The aim is to develop a calculation concept for the reliable evaluation of natural material composite constructions.

Wood polymer composites, namely a mix of wood fibers or wood flour with a polymer matrix, consist largely of renewable raw materials when filled to an appropriate level. When, for example, polyethylene derived from bioethanol is used as a matrix, they are almost fully biogenic. So far, this material has primarily been used for terraces and facades, but is also in use for cladding in vehicle construction as well as for housing appliances and tools. High levels of stiffness and weather resistance, however, make these composites into alternative construction materials for weight bearing components. In order to design these safely, appropriate bases for calculations are required. Through short-term tests in the laboratory and long-term tests outdoors, Fraunhofer IMWS is creating the database for an appropriate calculation model.

Bio-based composites are a central technology of the future due to the sustainable use of resources.

A special combination of modeling approaches, with regards to viscoelasticity and break mechanics, shall show the behavior of the material over the entire term of their use. If this succeeds, various types of application for components can be simulated instead of determining them through experiments. The project focuses on a viscoelastic specification of accelerated creep tests, whereby the composites are stressed whilst in a resting state. These are supported by means of large-scale bend tests on semi-finished products. The impact of various support geometries is also examined. Parallel long-term creep tests outdoors with conventional inspection weights shall test the accuracy of the model material. Damage of components through crack growth is shown through mechanical fracture tests. A specific round plate test with tear detection was developed specifically for this. For simple elements such as beams, pipes and posts, a calculation concept can thus be developed on the basis of Eurocode 0, allowing planners to safely calculate constructions such as staircases, platforms or scaffolding.

Long-term creep tests outdoors with inspection weights

Together with the project partner NOVO-TECH GmbH & Co. KG in Aschersleben, these results allow the exploration of new areas of applications for this material class. The potential of these natural material composites can thus be demonstrated within the framework of the federal government's bio-economy initiative.

Dr.-Ing. Thomas Hanke
Studies in Engineering Sciences at the University Halle-Wittenberg, doctorate in material mechanics, since 2007 at Fraunhofer IMWS, Group »Natural Material Composites«
thomas.hanke@imws.fraunhofer.de
+49 345 5589-257

MATERIAL FLOW ANALYSIS AND LIFE CYCLE ASSESSMENT OF NATURAL PRODUCT COMPOSITES

With material and energy current models technological process chains can be evaluated to identify optimization potentials and examine changes in advance for their effects. A practice application clarified the big potential of a bio-based binder.

The bioeconomy and its innovation potential for a sustainable resource economy as well as the knowledge-based generation and use of biological processes are central topics of a future high-tech strategy.

To what extent the biologization of the industry is advantageous for both economic and ecological aspects depends on numerous factors and requires a holistic and critical approach. Energy and material flow models represent a suitable method for evaluating process chains and identifying optimization potentials. In addition, technological innovations and material substitutions can be compared with conventional reference processes. The eco-balance method is used for ecological assessment. Here, material and energy flows are balanced with the associated environmental effects such as resource extraction and emissions. Likewise, a product-related environmental impact assessment is carried out on the basis of selected categories. Climate change, acidification or toxicity to humans are examples of such categories.

Substance and energy stream analyzes make sustainability measurable.

The company betula manus in Münster addresses with its birch bark products a health and sustainability-oriented target group. As part of a knowledge transfer, the company's production plant to be expanded was examined in a material flow model, identifying key variables for optimizing the process chain. It was found that the long transport routes, which were originally considered critical, have less of an impact on the environmental impact of the product than the choice of binder and the source of electricity for the production processes.

The use of a 2-component epoxy resin based on renewable raw materials thus represents the greatest lever for reducing the environmental impact in the entire value chain. Longer setting times and higher material costs can be compensated by other measures in order to obtain a marketable product. A technologically related reduction in binder requirements can contribute just as much to sustainability as the reduction of building energy demand and the use of renewable energies.

Laminate of birch bark layers and support plate

Norman Klüber
Study of architecture at the Bauhaus University Weimar,
Research Group »Green Efficient Building«,
since 2012 at the Fraunhofer IMWS
norman.klueber@imws.fraunhofer.de
+49 345 5589-249

WE RESEARCH FOR A BRIGHT FUTURE

Interview with Prof. Dr. Stefan Schweizer, Head of Business Unit

What was your personal highlight in the year 2017 with regards to the business unit?
We are always looking for new challenges. The research project »HipE« gives us the opportunity to create a new area of research in collaboration with HELLA GmbH & Co. KGaA. Together, we are developing highly innovative pixelated fluorescent materials for laser-based emissions in headlamps – a development, which will ensure greater safety in road traffic. We are happy to be part of this development

Which industrial sectors and markets do you address? How do your customers benefit by collaborating?
Fluorescent materials and their systems are our focus, especially their efficiency, reliability and color stability. We support our project partners comprehensively with optic and spectroscopic analyses, as well as thermal and photometric assessments. Here, the Fraunhofer Application Center in Soest offers an open provision of services. The aim is to support the competitive capability and the future of the light and lighting industry but also thematically related sectors.

In 2017 we celebrated the anniversary »25 years of Fraunhofer in Halle«. What do you associate with this?
An important key to success, in my opinion, is the cooperation of the Fraunhofer IMWS with universities and colleges. In this way, Fraunhofer can train in close collaboration the new scientific-technical generation needed urgently for working on the projects. Both sides benefit from this collaboration. Fraunhofer can rely on highly motivated students and on the other hand students can research subjects, which are topical and relevant to applications. They also get to know Fraunhofer as an attractive employer.

Which activities are planned for 2018?
Optic and spectroscopic analyses, as well as thermal and photometric evaluations will play an important role as part of our portfolio in 2018. We shall concentrate increasingly on the development and manufacture of luminescent glass optics and their design. The developed fluorescent materials will not only be used for light conversion but be further structured and functionalized. When evaluating fluorescent materials, light technical as well as thermal assessment plays an important role. Apart from experiments, simulation will take an ever-increasing part in the research.

Our aim is to support the competitive capabilities of the light and lighting industry.

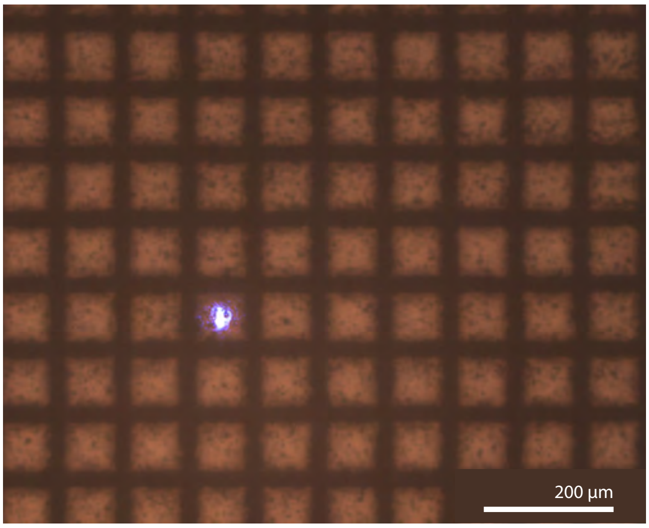
Prof. Dr. Stefan Schweizer
Studies in Physics at the University of Gießen, Doctorate and post-doctoral work at the University of Paderborn, Professor at the University of Applied Sciences South Westphalia, since 2007 at Fraunhofer, since 2013 Leader of the Fraunhofer Application Center Soest
stefan.schweizer@imws.fraunhofer.de
+49 2921 378-3410

PIXELATED FLUORESCENT MATERIALS FOR VEHICLE HEADLAMPS

Fluorescent materials, which were developed for use in white LEDs, can have another function apart from providing light. The Fraunhofer Application Center inscribes structures onto the surface of the fluorescent material with a focused laser beam and thus adapts it for use in high-resolution optic systems.

The use of LEDs instead of classic means of lighting has uncovered new functions of light. In vehicle lighting, the light distribution of the front headlamp can be adapted to different situations in road traffic and thus safety for all road users can be improved. Known examples are the cornering light and the no-glare high beam. More complex uses are possibly the targeted lighting of traffic signs or danger spots. For this, however, high-resolution systems based on a regular pattern are required. To achieve this, a blue laser patterns the individual pixels of a yellow emitting fluorescent material field. The distribution of the white light thus produced can be adapted in many ways.

The structuring of fluorescent materials opens up improved fields of application.



Light-microscopic photograph of a structured fluorescent material under pixel exact stimulation with a blue laser: The size of the pixel is 100 µm × 100 µm.

Pixels with a size of a few micrometers are required for high-resolution systems. An important parameter is the relation of the width of the structure to its depth. A very narrow trench, made with a laser beam looking like a grid, is needed for high conversion of light. A clear separation of the pixels from each other is important for high resolution. The width and depth of the trench determine how much light shines from one pixel to another.

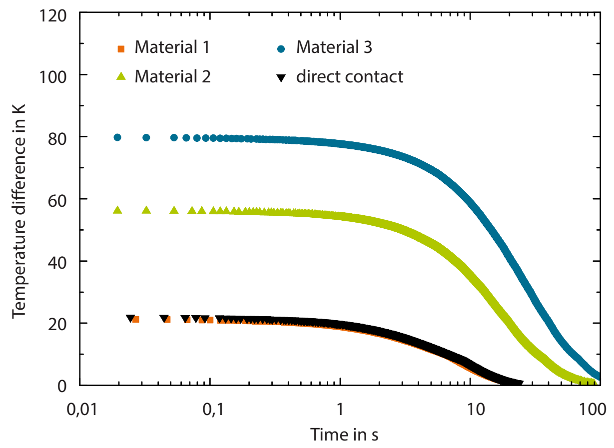
The Fraunhofer Application Center optimizes fluorescent materials for their use in vehicle headlights. Amongst other this includes inscribing structures onto the surfaces of the fluorescent materials with a focused laser beam, the so-called structuring, as well as the analysis of the spread of heat inside the fluorescent materials. Various ultrashort pulse lasers are available at the Fraunhofer Application Center for structuring the most diverse of materials and structure sizes.

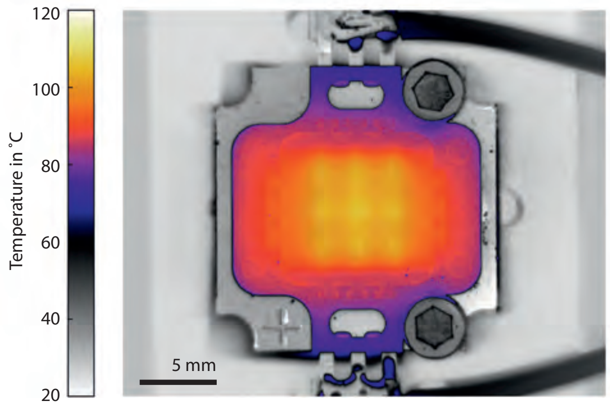
Dr. Franziska Steudel
Studies in Physics and doctorate at the University of Halle-Wittenberg, since 2010 at Fraunhofer, since 2014 at the Fraunhofer Application Center Soest, Team leader »Fluorescent material design«
franziska.steudel@imws.fraunhofer.de
+49 2921 378-3557

THERMAL EVALUATION OF LED MODULES

For the reliable operation of an LED, efficient thermal management is of crucial importance. In addition to the efficiency of the LED, the operating current and the ambient temperature, the connection of the LED module to the heat sink plays an important role.

White light-emitting diodes are increasingly replacing classic light sources in many areas. They convince with high efficiency, good color rendering, long life and high power density. Despite high efficiency, part of the supplied electrical power in an LED is not converted into light, but rather into heat. If this is not dissipated sufficiently, the LED heats up strongly. As a result, this not only shortens their service life, but it also causes a change in the color impression, even achieving an undesirably pale color reproduction. A failure of the LED often also means the failure of the entire lamp, since the LED is permanently connected to this in many cases.





Above: *Cooling behavior of the LED shown below when using different materials between heat sink and LED module*
Bottom: *Thermographic image of the examined LED*

Good thermal management begins in the semiconductor and ends with the installation of the luminaire. A crucial interface on the heat path is the connection between LED module and heat sink. A heat sink can be understood in this sense as any component that connects the LED module with the environment and thus dissipates heat. To make this thermal contact, different intermediate layers of different materials are used. The influence of these different materials on thermal contact was investigated in detail using the thermography system available at the Fraunhofer Application Center. The materials were placed between an LED module and a temperature-stabilized heat sink. Now the LED was operated until a constant temperature distribution occurred. The higher the maximum equilibrium temperature, the worse the thermal contact and thus the heat dissipation. Subsequently, the LED module was turned off and the temporal cooling behavior observed. Depending on the quality of the thermal contact, cooling happens at different speeds: the better the thermal contact, the faster the cooling.

Dr. Peter W. Nolte
Studies in Physics at the University of Paderborn, doctorate at the University of Halle-Wittenberg,
since 2014 at the Fraunhofer Application Center Soest, Team leader »Reliability of Fluorescent Materials«
peter.nolte@imws.fraunhofer.de
+49 2921 378-3555

WE ARE DEVELOPING CONCEPTS FOR A SUSTAINABLE INDUSTRIAL SOCIETY

Interview with Prof. Dr. Ulrich Blum, founding Director

What was your personal highlight in the year 2017 with regards to the CEM?

The CEM, a foundation of the Fraunhofer IMWS and the University of Halle, has started its work after an intensive preliminary phase in the summer and has already achieved important successes. I was particularly pleased that the term »Total Design Management«, in addition to looking at global value chains, the second mainstay of our work, was registered as a European trademark. The order to act as economic appraiser in the most important competition law proceedings of recent times was also a highlight for us. In the process of price fixing for truck manufacturers, we advise the side of the injured truck owners.

Which sectors and markets catch your eye?
How can your customers benefit from collaboration?

The Center for Economics of Materials combines economic and materials science excellence, in order to develop innovative, interdisciplinary solutions to the most pressing questions for a sustainable industrial society. We help to create economically and ecologically sustainable structures. Our offer is aimed primarily at companies in the primary materials industry, but also the chemical industry, the energy industry and the recycling economy. In doing so, we take a look at all activities that are connected with internal and external value creation chains. We also offer this unique combination of material technology and techno-economic expertise to clients from politics, for example in the field of technology and regulatory impact assessment.

In 2017 we celebrate the anniversary »25 years of Fraunhofer in Halle«. What do you associate with this?

The Fraunhofer Institute in Halle has established itself as a technology pool with high regional relevance, which at the same time has national and international appeal. Now we are delighted that we, as the CEM, can also make our contribution. Our portfolio of digitized material economics adds an important element to Halle's know-how and ideally fits in with the aspiration of Fraunhofer IMWS to be able to offer its customers sustainable, tailor-made solutions and a large network with excellent expertise.

Which activities are planned for 2018?

With our move into the new premises at Friedemann-Bach-Platz in Halle, the CEM will also take shape physically. We want to further increase the international visibility of CEM for our two divisions »Total Design Management« and »Global Value Chains«, with a particular focus on China. In a variety of projects, we want to support the development of sustainable structural policy concepts for a sustainable industrial society.

Prof. Dr. Ulrich Blum
Studies in Industrial Engineering, doctorate and habilitation at the Technical University of Karlsruhe, since 2004 Chair of Economic Policy and Economic Research at the University of Halle-Wittenberg,
2017 founding director of the Center for the Economics of Materials
ulrich.blum@imws.fraunhofer.de
+49 345 5589-8110

MATERIALS AND MATERIAL FLOWS BECOME INDUSTRY-4.0 CAPABLE

The continuous digitization of materials over the entire life cycle, in conjunction with Industry 4.0, provides the basis for increasing material efficiency, for new business models, and for the economic ecological optimization of value chains.

The CEM researches into the economic aspects of modern materials, in order to develop entrepreneurial and economic policy strategies. It also addresses issues from the Fraunhofer Group MATERIALS, in particular the concept of the Material Data Space (MDS). In the context of Industry 4.0, materials, substances and components along the value chain are to be »processed« digitalized. This means that over the entire life cycle from material development to recycling, a »digital twin« is involved. It allows access to and the exchange of material data and models. Thus, materials are integrated into a consistently digitalized production chain. Scope for innovation and new business models open up:

- New materials can be developed much more efficiently for specific target properties by simulating the necessary microstructure.
- In combination with flexible, learning production systems, more reliable component functionalities and qualities can be achieved despite varying raw material quality or small batch sizes.
- Due to the added value that the digitalization of materials can generate over the entire value chain or lifetime, its digital representation also becomes the subject of business models.
- This accelerates the customer's introduction of new materials with new features and better finishing, enabling reuse or intelligent recycling.
- A look at the entire value chain, including the environmental aspects, allows for a strategic macroeconomic perspective and related economic policy advice.

In addition to the work of the MDS office, implementation in practical examples is prepared in preliminary projects with business representatives, the federal ministries BMBF and BMWi, the German Research Foundation and the State of Saxony-Anhalt. Another project deals with related norming and standardization aspects. International collaborations result from institute partnerships. Under the aspect of a continuous digital material design from products to utilization at the CEM, the »Total Design Management®« was developed. It allows simultaneous economic efficiency and ecological sustainability.

A digital twin of the material is available along the value chain.

Prof. Dr. Ulrich Blum
Studies in Industrial Engineering, doctorate and habilitation at the Technical University of Karlsruhe, since 2004 Chair of Economic Policy and Economic Research at the University of Halle-Wittenberg,
2017 founding director of the Center for the Economics of Materials
ulrich.blum@imws.fraunhofer.de
+49 345 5589-8110

Prof. Dr. Manfred Füting
Studied Physics and Glass Chemistry in Halle and Jena, PhD in Applied Physics at the current Bauhaus University Weimar, at Fraunhofer since 1992,
2017 founding director of the Center for the Economics of Materials
manfred.fueting@imws.fraunhofer.de
+49 345 5589-120

CARBON CYCLE ECONOMY FOR SUSTAINABLE STRUCTURAL CHANGE

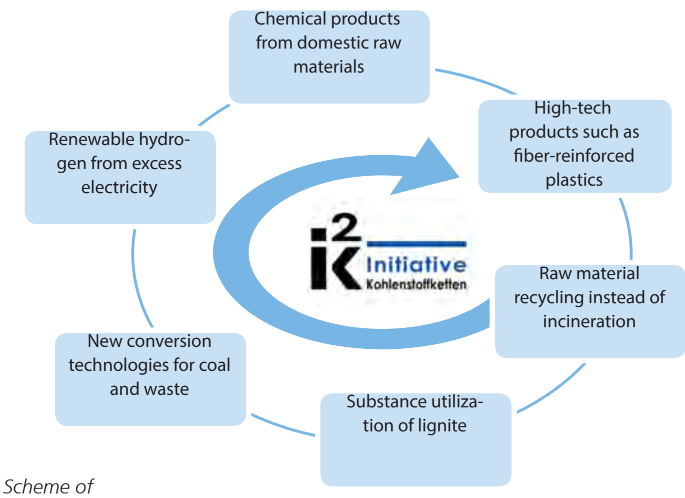
The aim of the carbon cycle economy to be developed is the introduction of innovative energy- and material-efficient processes through the economic exploitation of regional carbon sources from lignite to plastic waste.

The carbon cycle economy provides the basis for the transformation of the chemical industry towards CO_2-neutral added value. Currently, the German chemical industry has a need of more than 25 million tons of carbon annually, especially for mass-produced products such as plastics, organic chemicals and reducing agents. This carbon demand is mainly met from imported oil and gas. In the future, this will no longer be possible for reasons of climate policy. Sustainable carbon sources and thus innovative resource logistics, new production and production processes as well as efficient recycling systems and thus sustainable product design are needed. Ultimately, there is a shift from classic petrochemical to sustainable and cycle-controlled synthesis gas chemistry. The hydrogen required for this will, as planned in the HYPOS project, also be produced with electricity-based large-scale electrolysis and stored in large caverns.

The carbon cycle economy can make structural change in lignite regions employment-friendly.

Organizing a cycle-guided synthesis gas chemistry based on organic residues such as plastic waste, sewage sludge and biomass will require a stable source of carbon for the foreseeable future. Here, the local lignite comes into play. Established production and processing processes from lignite-fired power generation, which is increasingly being replaced elsewhere, are combined with technologically innovative chemical processes and thus fully mapped into the digitized value-added system of the Data Space department of the Fraunhofer-Gesellschaft. The implementation of the concept in the East German brown coal regions creates a basis for sustainable structural change.

With the new added value of the carbon cycle economy, technological innovations as well as economic stabilization of the overall declining coal mining are achieved. Economically positive effects result from the active shaping of structural change, the establishment of stable new cluster structures and the creation of sustainable jobs.



Scheme of Carbon cycle economy

PD Dr. Christian Growitsch
Graduate economist and doctorate at the University of Lüneburg, Habilitation at the University of Halle-Wittenberg, Director Application Research at the EWI Cologne and Director at the HWWI Hamburg, since 2017 Director of the Center for Economics of Materials
christian.growitsch@imws.fraunhofer.de
+49 345 5589-8130

Prof. Dr. Bernd Meyer
Process engineer Leuna/Merseburg, Freiberg, Director at the Institute of Energy Process Engineering and Chemical Engineering of the TU Bergakademie Freiberg, since 2017 working at the Fraunhofer IMWS
bernd.meyer@imws.fraunhofer.de
+49 3731 39-4511

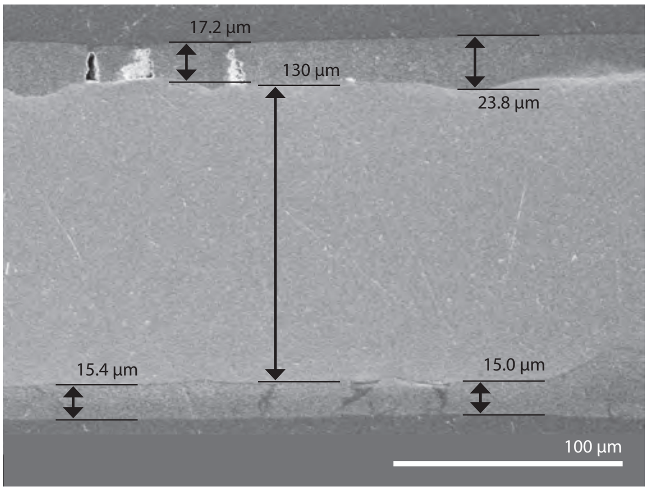
MEMBRANE ELECTRODE UNITS IN COMPARISON

Microstructural comparison of identically prepared membrane electrode assemblies for different exchange membrane technologies has shown that the Decal method is not suitable for mechanically amplified anion exchange membranes.

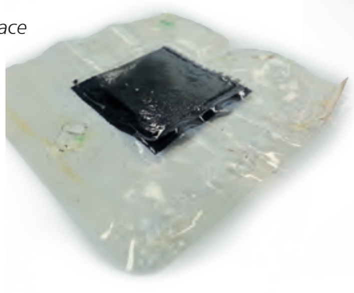
As a chemical energy store, hydrogen has great potential in terms of renewable energies. Electrolyzers are currently key technologies used to generate hydrogen. If required, it can be converted very quickly into electrical, mechanical or thermal energy or used as a raw material in the chemical industry.

Very well known in electrolysis is the field of Proton Exchange Membrane technology (PEM) centering around a proton conducting (H+) membrane. This membrane is coated with noble metal catalysts on both the anode and cathode sides. This material composite is called a Membrane Electrode Assembly (MEA). On the catalysts, the electrochemical reactions and the conversion take place for generating energy. In this department, various research and development work has been carried out in recent years to reduce costs and increase stability. The alkaline membrane (AEM = Anion Exchange Membrane) has recently emerged from this technology. It allows the use of much cheaper materials due to the use of a conductive, alkaline (OH) membrane. This method combines both the advantages of acidic and alkaline techniques and thus represents a cost-effective solution.

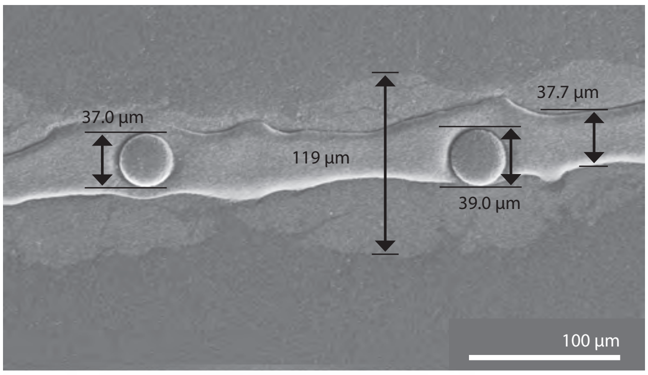
For the production of highly reproducible membrane electrode assemblies, the so-called Decal method has proven itself at Fraunhofer IMWS. A carrier film is coated with electro-

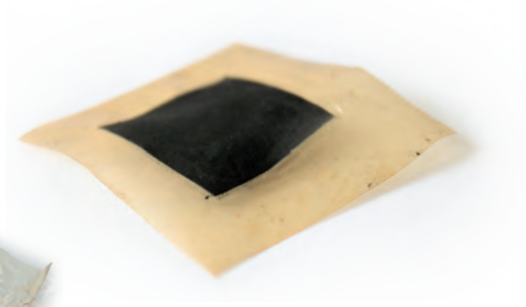


Above: *Scanning electron micrograph of a PEM-MEA cross-section with a very flat surface*

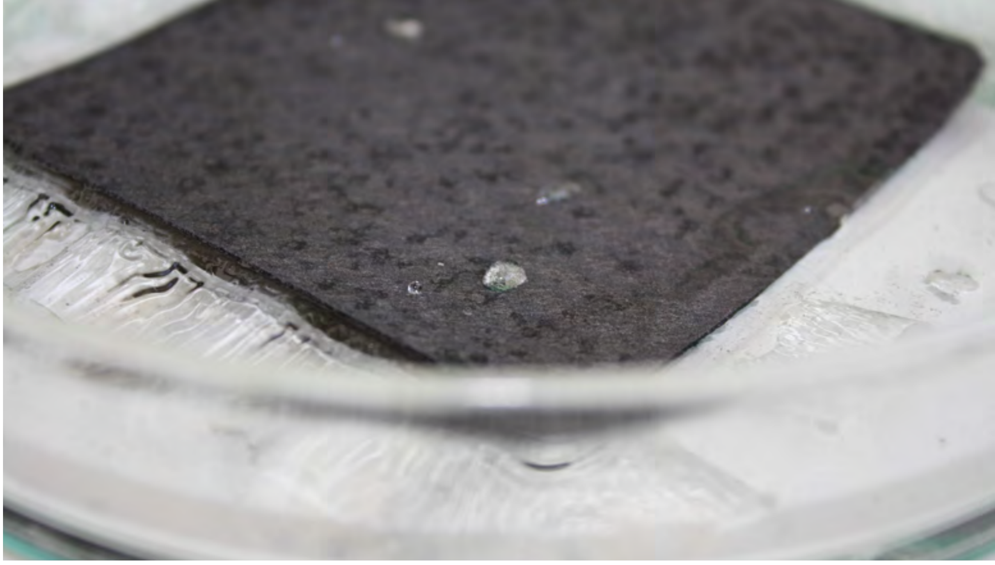


Right: *Prepared PEM-MEA using the Decal method (Nafion N115 membrane + Pt/C catalyst)*





Above: *Scanning electron micrograph of an AEM-MEA cross-section with an inhomogeneous surface Below: Decal-method-prepared AEM-MEA (Fumatech FAA-3-PK-75 membrane + Pt / C catalyst)*



Membrane electrode assembly for PEM

des and then transferred by hot pressing on the membrane. In addition to the membrane electrode assemblies for PEM technology, this method also produces MEAs for the very young AEM technology.

A direct comparison between identically prepared PEM and AEM MEAs should demonstrate the suitability of the Decal method in terms of morphology and reproducibility. In particular, microstructural diagnostic methods such as scanning electron microscopy are used to record MEA cross sections in order to demonstrate the differences in sample preparation in the context of these two technologies.

The microstructure of the membrane has a strong influence on the production of the membrane electrode assembly.

The tested samples have an active electrode area of approximately 5 cm² (2.25 x 2.25 cm). The PEM MEA was made from a Nafion N115 membrane and the standard noble metal catalyst ETEK (Pt/C). It has a very even and homogeneous electrode surface with a thickness of about 15–20 µm. The AEM MEA consists of a Fumatech FAA3PK75 membrane and also an ETEK catalyst. In contrast to the PEM MEA, the AEM MEA seems inhomogeneous. The membrane is reinforced with fabric to increase mechanical stability, which prevents uniform compression during hot pressing. These occurring problems in the preparation process create an irregular surface.

The Decal method seems to be an ideal preparation method for the production of PEM membrane electrode assemblies. In this way, powerful and homogeneous MEAs can be generated reproducibly. The AEM, however, shows weaknesses in this preparation method, as the reinforcement obstructs the pressing process. Therefore, other manufacturing techniques, such as airbrushing or screen printing should be considered for this type of membrane, or membranes without reinforcement should be used.

The next step would be an electrochemical investigation of the performance and stability of the prepared samples. The data obtained can then be compared using the excellent microstructure diagnostics of Fraunhofer IMWS in order to further optimize the materials used.

The technology of the alkaline membrane is forward-looking in terms of its benefits. Therefore, world-renowned working groups and companies are researching the optimization of this technology. There are currently no commercial alkaline conductive membranes that can compete with PEM technology. However, if it were possible to develop a high-performance and long-term stable product, this would take the energy transition a big step further.

Stefan Ackermann
Studies in Technical Chemistry at the University of Halle-Wittenberg, since 2013 employee in the group »Water electrolysis« at Fraunhofer IMWS
stefan.ackermann@imws.fraunhofer.de
+49 345 5589-244

Dr.-Ing. Nadine Menzel
Studies in Technical Chemistry at TU Berlin, doctorate at TU Berlin, since 2013 employee at Fraunhofer IMWS, group leader (comm.) »Water Electrolysis«
nadine.menzel@imws.fraunhofer.de
+49 345 5589-237

BOARD OF TRUSTEES

Tasks of the Board of Trustees

The Board of Trustees of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS includes personalities from politics, business and science, which are technically close to the institute and meet once a year.
Together with the Fraunhofer Board, the members of the Board of Trustees advise the institute with their expertise in strategic issues, setting the course at the institute and developing future perspectives. They are appointed by the Fraunhofer Board in agreement with the institute's management and work on a voluntary basis.

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»AN IMPORTANT INSTRUMENT FOR NETWORKING«

Interview with Dr. Roland Langfeld, Chairman of the Board of Trustees

In 2017 we celebrated the anniversary »25 years of Fraunhofer in Halle«. What do you associate with this?
Halle was already an active academic center before the reunification – one of the best electron microscopes was already in use under Professor Gunnar Berg, then Professor of Experimental Physics at the University of Halle and now Vice-President of the National Academy of Sciences Leopoldina. The Fraunhofer IMWS is embedded in a very important academic landscape and has been able to develop its competencies to its present significance over the past 25 years.

What attracts you to the work of the Board of Trustees of Fraunhofer IMWS?
First of all, I personally find the various fields of expertise of Fraunhofer IMWS, such as microelectronics, plastics and photovoltaics, very interesting indeed. Especially exciting for me is the microanalysis of materials. The material behavior is immensely important for the properties of products and says a lot about performance and durability. These are very important topics that interest industrial customers like Schott AG. We also want to develop products with a long service life and a high level of reliability for our materials such as glass and glass ceramics. This is exactly where Fraunhofer IMWS, with its competence, is a really strong partner for us and our customers.

The Board of Trustees brings together professionals with very different backgrounds from many areas. How does the collaboration work?
The Board of Trustees meets once a year and advises Fraunhofer IMWS in strategic matters. The diversity of trustee members ensures well-balanced and wide-ranging expertise to advise Fraunhofer IMWS. There is a very good collaboration, among other things, with the award of the material prize by Schott AG. Here, as a jury, we jointly evaluate the various dissertations, master or diploma theses that were produced at Fraunhofer IMWS. The different perspectives are an active part of the jury's work as well as of the Board of Trustees. Our meetings are always very lively and an important tool for networking.

What impulses would you like to give the institute for the next few years?
We are in a transitional period regarding the methods of classical material development, in which we have to deal with immense amounts of data. With its ideas, Fraunhofer IMWS is progressively involved in this worldwide change in materials and materials development. Here, the Fraunhofer IMWS is leading the way with its Materials Data Space initiative and is using these insights for new modeling and method development. I would like to actively accompany the institute on this new path.

Dr. Roland Langfeld
1985 PhD at the Institute of Nuclear Physics at Goethe University Frankfurt, 1988 entry into central research at Schott AG, including as Head of Central Research, Research Fellow at Schott AG since 2009, Chairman of the Board at Fraunhofer IMWS since 2016
roland.langfeld@schott.com
+49 6131 66 7612

FRAUNHOFER IMWS NETWORKING

FRAUNHOFER GROUPS AND ALLIANCES

Fraunhofer Group Materials, Components

Fraunhofer material research covers the entire chain from the development and improvement of materials and the manufacturing technology and characterization of the properties to the evaluation of the application behavior. The same applies to the components manufactured from the materials and their behavior in systems. In addition to the experimental investigations, the methods of numerical simulation and modeling are used equally.

Prof. Dr. Ralf B. Wehrspohn
www.materials.fraunhofer.de

Fraunhofer Microelectronics Alliance (guest membership)

The Fraunhofer Group Microelectronics is a research and development provider for Smart Systems. The currently eleven member institutes and seven guest institutes conduct internationally networked top-level research in micro/nano-electronics as well as microsystems and communications technology. They offer a globally unique range of competencies and bridge the gap between basic research and product development.

Prof. Dr. Matthias Petzold
www.mikroelektronik.fraunhofer.de

Fraunhofer Alliance Nano-Technology

From application-oriented research to industrial implementation, nano-technologies are developed for optical applications, the automotive industry and the electrical industry. Multifunctional layers, metallic and oxidic nano-particles, carbon nano-tubes and nano-composites are used in actuators, structural materials and biomedical applications. In addition, questions on the toxicity and safe handling of nano-particles are discussed.

Prof. Dr. Andreas Heilmann
www.nano.fraunhofer.de

Fraunhofer Alliance Construction

The aim of the Fraunhofer Alliance Construction is to be able to map and process all scientific and research-relevant questions on the subject of construction completely and »from a single source« within the Fraunhofer Society. The construction industry is thus provided with a central contact for integral system solutions.

Andreas Krombholz
www.bau.fraunhofer.de

Fraunhofer Alliance Energy

Ten Fraunhofer Institutes offer research and development work from a single source. The focus is on efficiency technologies, renewable energies, buildings and components, planning and operation of integrated energy systems as well as storage and micro energy technology.

Dr. Hartmut Schwabe
www.energie.fraunhofer.de

Fraunhofer Alliance Lightweight Construction

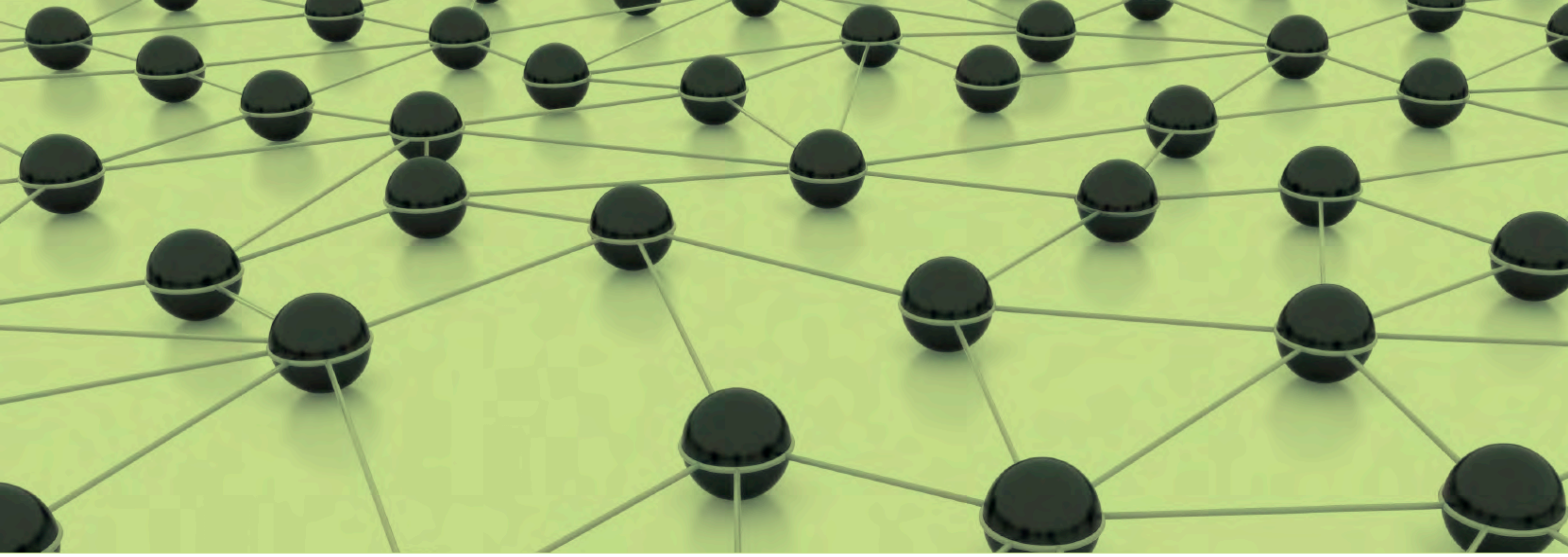
The quality of a lightweight structure is essentially determined by its material properties, the structural design, its construction and the manufacturing process. For this reason, the Alliance Lightweight Construction considers the entire development chain from material and product development and series production and approval, through to product use.

Prof. Dr. Peter Michel
http://s.fhg.de/allianz-leichtbau

Fraunhofer Alliance Textile

In order to fully exploit the potential of high-performance fibers for textile-reinforced lightweight structures, innovations are to be created through application-oriented and product-specific developments of textile-based technologies and systems directly linked to preform and component production. The entire textile production chain is modeled on fiber production and functionalization in the alliance.

Prof. Dr. Peter Michel
www.textil.fraunhofer.de



ACTIVITIES IN SPECIALIZED RESEARCH AREAS, FRAUNHOFER INTERNAL PROGRAMS AND TOP CLUSTERS

Fraunhofer lead project: criticality of rare earths

Fraunhofer Institutes develop more efficient manufacturing processes for high-performance magnets, optimize their component design and research recycling possibilities. The goal is to halve the primary requirement for heavy rare earth elements in two demonstrator permanent magnets. Fraunhofer IMWS is looking for substitute magnetic materials, as far as possible without rare earth elements with electron theoretical material simulation and electron microscopic material characterization.
Prof. Dr. Ralf B. Wehrspohn (coordinator)
www.seltene-erden.fraunhofer.de

Fraunhofer lead project: eHarsh

The aim of the »eHarsh« lead project by Fraunhofer Institutes IMWS, ENAS, IKTS, ILT, IMS, IPM, IPT and IZM is to develop and provide a technology platform based on sensor systems and electronics for use in extremely harsh environments. The consortium thus addresses the rapidly growing demand for intelligent control and communication technologies in industry and society, especially in the fields of research that are of interest to Fraunhofer: »mobility and transport«, »energy and raw materials«, and »production and services«.
Prof. Dr. Matthias Petzold
http://s.fhg.de/eharsh

Max-Planck - Fraunhofer cooperation project HEUSLER

Together with two Max-Planck institutes in Dresden and Halle, Fraunhofer IMWS is researching the structural and chemical possibilities to produce innovative materials based on intermetallic Heusler phases that have good hard magnetic properties but contain no rare earth elements.
Prof. Dr. Thomas Höche
http://s.fhg.de/heusler

MAVO biomimetic synthetic rubber in innovative elastomer composites (BISYKA)

Together with the Fraunhofer Institutes IAP, IME and ISC, Fraunhofer IMWS is researching the causes of the unique mechanical properties of natural rubber and their transfer to synthetic rubber in order to produce an innovative product with high value-added potential with a »biomimetic synthetic rubber«.
Prof. Dr. Mario Beiner

MAVO process chain for flexible, ceramic and glass-based switching and display elements (CeGlaFlex)

The Fraunhofer association project is pursuing the production of thin, flexible and thus pliable transparent ceramics, which are used in portable electronics such as smartphones or in medical technology. The research projects by the Fraunhofer Institutes IMWS, ILT, IKTS, IPT specifically have the goal of assembling thin-glass-based switching and display elements in a ceramic thin-glass composite with a thickness in the range of 100 µm. Transparent and flexible ceramics as well as ceramic thin glass bundles are processed with high three-dimensional geometrical flexibility without damaging the material functions.
Falk Naumann

Fraunhofer Materials Data Space

The Fraunhofer Materials Data Space provides cross-company digital data on materials and substances along the entire value chain. Networking will enable shorter development times, learning manufacturing processes and new business models, as well as enormous potential for material efficiency, production efficiency and recycling. With this platform, the Fraunhofer MATERIALS group provides the basis for material development, production and processing within Industry 4.0.
Prof. Dr. Ralf B. Wehrspohn
www.fraunhofer-materials-data-space.de

FRAUNHOFER IMWS NETWORKING

Center of Excellence for Chemical and Biosystems Technology

The Center of Excellence »Chemistry and Biosystems Technology« brings together basic research, application-oriented research and industrial development in order to decisively stimulate added value in the Halle-Leipzig region. The center will stimulate excellence in research as well as sustainable regional economic development. The strategic goal is the research and optimization of method-related process chains in the plastics processing, chemical, biotechnological and biomedical industries from the raw material to the finished product.

Prof. Dr. Andreas Heilmann
Andreas Krombholz (deputy spokesman)
www.chemie-bio-systemtechnik.de

Collaborative research area polymers under forced conditions

In this joint project funded by the German Research Foundation (DFG) since 2011, the Fraunhofer IMWS, together with the Martin Luther University Halle-Wittenberg and the University of Leipzig, is researching fundamental questions in the field of the structure and dynamics of soft matter. The main focus is on the influence of constraints on structure formation processes in synthetic and biological polymer systems and composites.

Prof. Dr. Mario Beiner
www.natfak2.uni-halle.de/sfbtrr102

BioEconomy top cluster

The cluster connects the bio-economic relevant research and industrial sectors in Central Germany with the goal of promoting the development, scaling and application of innovative technical processes. Particular attention is paid to the sustainable use of bio-based, renewable raw materials from the non-food sector (especially wood) and the production of valuable products for various industrial sectors, combined with the energetic use of residual materials throughout the entire value chain.

Prof. Dr. Ralf B. Wehrspohn (deputy chairman),
Andreas Krombholz (head of the bioplastics department)
www.bioeconomy.de

SolarValley Central Germany top cluster

At the heart of the cluster's work is the aim of making solar power even more competitive. This is achieved by implementing a strategy concept in which business, science and education work closely together to provide renewable and decentralized electricity for generations. At the same time, photovoltaics are to be established as the most important energy technology of this century.

Prof. Dr. Ralf B. Wehrspohn
www.solarvalley.org

Twenty20 HYPOS

The HYPOS Hydrogen Power Storage & Solutions East Germany project aims to produce »green« hydrogen from renewable electricity on an industrial scale for energy-related applications - as an efficient energy source with excellent transport and storage capacity. The HYPOS project is funded by the Federal Ministry of Education and Research (BMBF) as part of the »Twenty20 - Partnership for Innovation« program.

Prof. Dr. Ralf B. Wehrspohn (deputy chairman),
Dr.-Ing. Nadine Menzel (power supply subject field)
www.hypos-eastgermany.de

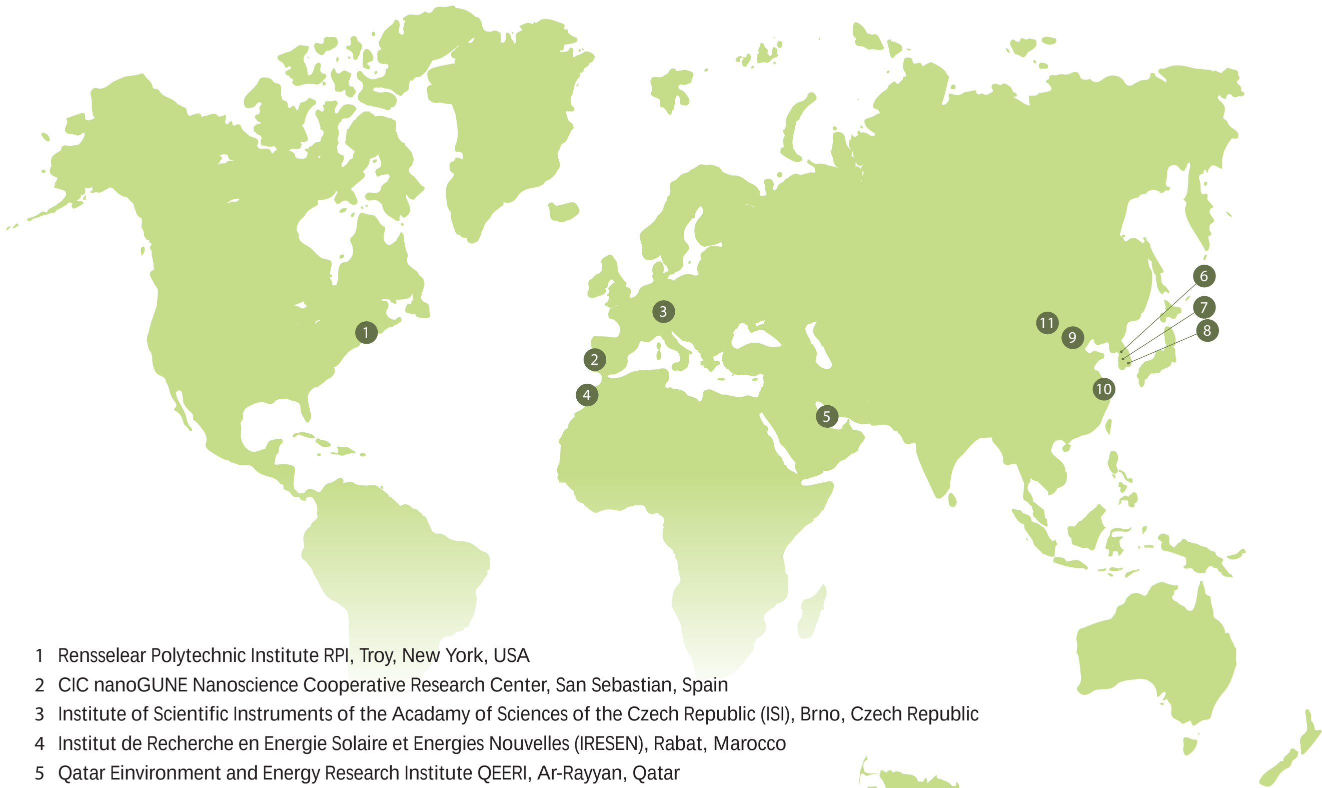
NanoMicroNetwork Saxony-Anhalt

IIn the NanoMicroNetwork Saxony-Anhalt, nano-technology and micro-systems technology are particularly promoted as sources of innovation and key technologies for the state of Saxony-Anhalt. The network is coordinated by the science2public – Gesellschaft für Wissenschaftskommunikation e.V. With an orientation towards the regional lead markets, we want to help shape developments in the fields of nano-technology and micro-system technology and boost the competitiveness of Saxony-Anhalt companies. The NanoMicroNetwork includes universities and non-university research institutions as well as companies - especially micro enterprises and small and medium-sized enterprises - from Saxony-Anhalt, but also actors such as the Ministry of Economics, Science and Digitalization at state level and the Federal Environment Agency based in Dessau-Rösslau at fede-

ral level, as well as intermediaries. The network is funded by the state of Saxony-Anhalt and the Federal Republic of Germany.
Andreas Dockhorn
www.nanomikro.com

In a research project by the top cluster BioEconomy, Fraunhofer IMWS and its partners have developed plastic tall oil foams that can be used in home and furniture construction. The photo shows the raw materials for bio-based plastics.

UNIVERSITY PARTNERSHIPS



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

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

ORGANIZATION CHART

DIRECTOR	DEPUTY DIRECTORS	HEAD OF ADMINISTRATION	JOINT FACILITIES WITH OTHER FRAUNHOFER-INSTITUTES
Prof. Dr. Ralf B. Wehrspohn	Prof. Dr. Matthias Petzold	Thomas Merkel	

POLYMER APPLICATIONS	BIOLOGICAL AND MACROMOLECULAR MATERIALS	CENTER FOR APPLIED MICROSTRUCTURE DIAGNOSTICS CAM	FRAUNHOFER CENTER FOR SILICON PHOTO-VOLTAICS CSP	FRAUNHOFER-PILOT PLANT CENTER FOR POLYMER SYNTHESIS AND PROCESSING PAZ	CHEMICAL CONVERSION PROCESSES
Prof. Dr. Peter Michel Prof. Dr. Mario Beiner (Scientific Head)	Prof. Dr. Ralf B. Wehrspohn (prov.)	Prof. Dr. Matthias Petzold	Dr. Karl Heinz Küsters (prov.) Prof. Dr. Peter Dold *	Prof. Dr. Michael Bartke **	Prof. Dr. Bernd Meyer (prov.)
Polymeric Material Design Prof. Dr. Mario Beiner	Technologies for Biofunctional Surfaces Dr. Stefan Schulze	Assessment of Electronic Systems Integration Sandy Klengel	Department Reliability and Technology for Grid Parity Dr. Karl Heinz Kuesters (prov.)	Department Polymer Processing Prof. Dr. Peter Michel	Water Electrolysis (Fraunhofer Electrolysis platform Leuna***) Dr. Nadine Menzel (prov.)
Assessment of Composite Systems Dr. Ralf Schlimper	Charakterization of Medical and Cosmetic Care Products Dr. Andreas Kiesow	Nanomaterials and Nanoanalytics Prof. Dr. Thomas Höche	Diagnostics of Solar Cells Dr. Christian Hagendorf	Thermoplastic Semi-Finished Fiber Composites Ivonne Jahn	Circular Carbon Technologies Dr. Denise Klinger (prov.)
	Assessment of Materials of Medical Technology Dr. Andreas Kiesow (prov.)	Diagnostic of Semiconductor Technologies Frank Altmann	Reliability of Solar Modules and Systems Dr. Matthias Ebert	Thermoplastic Composite Parts Dr. Matthias Zscheyge	Synthesis Processes Gerd Unkelbach ***
	Green Composites Andreas Krombholz	Fraunhofer Application Center for Inorganic Phosphors Prof. Dr. Stefan Schweizer	Silicon Wafers Dr. Sylke Meyer	Department Polymer Synthesis Prof. Dr. Michael Bartke **	
			Module Technology Prof. Dr. Jens Schneider	Synthesis and Product Development Dr. Ulrich Wendler **	
			Department Crystallization Technologies Prof. Dr. Peter Dold *	Scale-up and Pilot Testing Marcus Vater **	

* Fraunhofer ISE
** Fraunhofer IAP
*** Fraunhofer IGB / CBP

INFRASTRUCTURE Thomas Merkel	Finance Sven Heßler	Technical Support & IT Sebastian Gerling	Staff & Travel Constanze Pälecke	
STRATEGIC MANAGEMENT Prof. Dr. Ralf B. Wehrspohn	Director`s Office Heike Gehritz	Public Relations Michael Kraft	Director`s Staff Andreas Dockhorn	Center for Economics of Materials CEM PD Dr. Christian Growitsch

NEW DEVICES AND METHODS

- X-ray microscope ZEISS XRadia Ultra 810
- Digital microscope
- Corrosion measuring cell with potentiostats
- Arburg injection molding machine, Allrounder 320S 500150, universally applicable hydraulic injection molding machine for small amounts of plastic to be processed to various test specimens
- UD-Tape system for the production of 500 mm wide unidirectional continuous fiber filled thermoplastic tapes using melt direct, foils and powder impregnation, processing temperature up to 350°C, up to 120 roving bobbins, static and dynamic spreading system, production speed 2-20 m/min, total throughput max. 260 kg/h
- NETZSCH hammer mill type CHM 450/300 with retraction device type CEV 300
- Injection molding tool compressor spindle Proto
- Upgrade Thermo Sensoric InSb Camera to High Speed Digital Camera
- 3D-printer Flashforge Type: Finder
- 3D-printer Markforged Type: Mark One
- µXRF system with W and Rh tubes

DEVICES AND METHODS THE MICROSTRUCTURE DIAGNOSTICS CORE COMPETENCE

Ion/electron microscopy

- Transmission electron microscope (TEM / STEM 200 kV) with X-ray analysis system (NanospotEDX)
- Transmission electron microscope (EFTEM 60300 kV) with Cs-image correction, EDS, EELS, HAADF, STEM, NBD, and tomography
- Focusing ion beam system (FIB) with integrated IR microscope
- FIB / REM plant with gas inlet system in situ-liftout syste
- FIB/SEM system with gas inlet system, EBSD and EDX analytics and in situ manipulator
- Plasma FIB system with gas inlet system
- scanning electron microscopes (SEM) with X-ray analysis (EDX, WDX) and diffraction analysis (EBSD)
- SEM with electron beam-induced current measurement (EBIC) and 4-fold nano prober system
- Atmospheric SEM (ESEM) with in situ tensile module and in situ heating module
- Combined ESEMFIB system with cryo transfer chamber and in situ cryo-preparation devices

Preparation techniques

- Precision wire saws, various grinding/polishing machines, precision grinding machines for target preparation
- laser preparation system
- Arion etching equipment, PlasmaCleaner, C-evaporation and platinum sputter coating
- Soft-matt preparation with rotary microtome, ultramicrotome, cryo-ultramicrotome, critical-point drying and cryofixation

Destruction-free test method

- X-ray microscope ZEISS XRadia Ultra 810
- 3D X-ray inspection systems (180 kV nano-focus, 225 kV micro-focus) with in situ forming equipment
- X-ray diffractometer for voltage measurement, texture and phase analysis with high-temperature device up to 1200 K and thin-film analysis device
- Bruker X-ray diffractometer AXS D8 Advance
- Air-coupled ultrasonic measuring station (scan area 1500 x 1000 mm²)
- Acoustic scanning microscopes (15 MHz – 400 MHz and 400 MHz – 2 GHz)
- Pulse-phase thermography
- Upgrade Thermo Sensoric InSb Camera to High Speed Digital Camera

Physical and chemical surface analytics

- µXRF system with W and Rh tube
- Time of Flight Secondary Ion Mass Spectroscopy (ToF SIMS)
- Photoelectron spectroscopy with ablation mode, depth profile (XPS, UPS) and Auger electron spectroscopy
- (AES) contact angle measurement
- Plasma analysis system (OES, VIProbe, SEERS)
- Material and trace analysis
- Inductively coupled plasma mass spectroscopy (ICP MS) with laser ablation, chemical extraction and electrothermal vaporization
- Optical emission spectrometry with ICP with electrothermal evaporation
- Density and porosity measuring equipment
- Residual gas analyzer
- Gas permeation meter

Topography and contour measurement

- Atomic Force Microscopes (AFM) in combination with light and fluorescence microscopy
- White light interferometer
- Confocal laser scanning microscopes (CLSM)
- Profilometers and roughness measuring devices
- Interferometric residual stress measurement
- Determination of wafer geometry (thickness, thickness variation, etc.)
- Interferometer with phase shifter for contour measurement of aspheres

Light-optical and spectrometric IR-UV methods

- Light microscope, light/dark area and DIK mode
- Digital microscope
- Quantitative image analysis systems
- UV/VIS/NIR spectrometers and spectral ellipsometers
- Electron luminescence and photoluminescence spectroscopy

- Infrared microscopy
- FTIR spectroscopy and microscopy with ATR measuring equipment
- Confocal Raman microscope and Raman spectrometer
- IR voltage optics measurements
- Method for measuring carrier lifetime (microwave photoconductance decay, quasi-static photoconductivity)
- Colour analyzer
- Time-resolved fluorescence and spatially resolved electroluminescence in the UVVISNIR range
- nano and femtosecond laser systems
- Photoluminescence measuring station for the spatially resolved characterization of Si-blocks, wafer and cell

Electrical characterization

- Measuring stations for charge carrier lifetime measurement (Si-block, wafer)
- 4-point method and eddy current method for conductivity measurement
- Electron luminescence measuring station for cell characterization
- Electron luminescence measuring station for PV module characterization
- Thermography measuring station for PV module characterization
- Measuring station for determining the internal and external quantum efficiency of solar cells
- Solar simulator for solar cells
- Solar simulator for PV modules
- Measuring equipment for free field characterization of PV modules
- Inverter testing station

Electro-chemical characterization

- Rotating disks and ring disk electrodes
- Voltametric methods (cyclic voltammetry – CV, linear voltammetry – LSV)
- Corrosion measuring cell with potentiostats
- Electro-chemical impedance spectroscopy – EIS
- Chrono methods (amperometry, potentiometry, coulometry)
- Cyclic charge and discharge processes – CCD
- PEM electrolysis test stand for single cells (50 cm^2) and short stacks (10 x 50 cm^2) up to 30 bar

Thermophysical measuring procedure

- Dynamic differential calorimetry up to 1500°C
- Thermogravimetrical analysis (TGA)
- Differential thermoanalysis
- Dilatometer for measurements up to 1400°C
- environmental test chamber

Polymer analytics

- Dynamic Differential Scanning Calorimetry (DSC)
- Dynamic Mechanical Analysis (DMA)
- Thermo-Mechanical Analysis (TMA)
- High pressure capillary viscometer
- Smelt index measuring units (MFI)
- HDT heat distortion temperature and Vicat softening temperature measurement
- Dielectrical Analysis (DEA)
- TGA with FT/IR coupling
- Karl Fischer Titration for determining moisture in plastics
- Light climate test cabinet and climate test cabinet
- Rotation rheometer
- Temperature and thermal conductivity measurement (Light Flash method) up to 300°C
- Soxhlet extractor

Test of micro-components

- In situ forming devices for raster and transmission electron microscopes
- Pull and shear tester for microelectronic connection technology
- Micro-optical force measuring station with manipulation devices
- Microsystem analyzer (MSA) for non-contact deformation and vibration analysis
- Test rigs for strength and service life measurement of microsystems

DEVICES AND METHODS THE MICROSTRUCTURE DESIGN CORE COMPETENCE

Surfaces and adjacent surface technologies

- Multi-chamber coating machine for ceramic and metallic multilayers and composite coatings
- Plasma CVD coating systems
- High frequency magnetron coating systems
- Plasma treatment systems for polymer foils
- Plasma etching systems
- Wet-chemical coating systems (spin coating, knife coating, dip coating)
- Electrostatic spinning device
- Ion etching machine for sample preparation and surface treatment Climate test chambers
- Wafer bond system with plasma activation
- Wire bonding technology for contacting microelectronic components
- System for laser welding polymer foils

Wafer production

- Wire and band saws for squaring, cropping
- Wire bonding technology for contacting microelectronic components
- IR screening system for identification of SiC/SiA inclusions in blocks
- Wire saws for multi and monocrystalline wafers (slurry-based sawing, diamond wire saws)
- Pre-cleaning plant for detaching the wafers after sawing

- Inline precision cleaning system for final wafer cleaning
- Inline measuring system with sorting unit for final wafer inspection and classification

Solar module production

- 3D vacuum laminator
- Automatic dispensing system for conductive adhesive
- Variable cell string layup station
- Fully automatic industrial TabberStringer for whole and half cells with 3 or 4 bus bars
- Semi-automatic cell soldering system
- Laboratory glass cleaning machine
- Laboratory and large module laminator
- Precision testing machines for bonding and soldering materials
- RTP furnace
- Screen printer
- Thermoshock test cabinet
- Universal test machines from 1N to 400kN, uni and multiaxial
- UV crosslinking unit
- Vacuum laminator
- Tension / torsion test machine 10 kN

Yield and power measurement

- High voltage test equipment with up to 1 kV applied voltage
- Performance measurement in the laboratory with class AAA module flasher up to 2.6 x 2.6 m²
- Power measurement in the free field with continuous UIC characteristic line recording, temperature and irradiance on the module
- Environmental measuring technology for direct, indirect and global irradiation, air pressure and humidity as well as wind speed and direction

Polymer processing

- 3D-printer Flashforge Type: Finder
- 3D-printer Markforged Type: Mark One
- NETZSCH hammer mill type CHM 450/300 with retraction device type CEV 300
- Injection molding tool Compressor spindle Proto
- Mini-compounder with conical twin screw
- Measuring mixer with 60 or 300 ml chamber volume for thermoplastic and elastomer processing, torque up to 300 Nm, electrically and liquid tempered
- Mini injection moulding machine
- Arburg injection molding machine, Allrounder 320S 500-150, universally applicable hydraulic injection molding machine for small amounts of plastic to be processed to various test specimens
- Injection Moulding Compounder KM 1300 to 14 000 IMC, closing force 1 300 tons, max. hot weight 5 300 g (PS)
- Injection Moulding Compounder KM 3200 to 24 500MX IMC, closing force 3 200 tons, max. shot weight 20000 g (PS)
- Injection molding machine KM 200 to 1000 C2, clamping force 200 tons, max. shot weight 476 g (PS), mold temperature control up to 140°C, separate second injection unit SP 160, vertical, max. shot weight 68 g (PS)
- Fully automated processing cell with infrared heating station for the processing of continuous fiber reinforced thermoplastics in hybrid injection molding
- Twin screw extruder ZE25A x 48D UTX screw diameter 25 mm, flight depth 4.2 mm, process length 48D, D/d = 1.46, max. screw speed 1200 min1, torque 2x103Nm, throughput up to 100kg/h
- Smelt pump Maag extrex® 28¬5 GP
- Twin screw extruder ZE40A x 48D UTX screw diameter 44 mm, flight depth 7.2 mm, process length 48D, D/d = 1.46, max. screw speed 1200 min1, torque 2x580Nm, throughput up to 400kg/h
- Twin screw extruder ZE40R x 56D/93D UTX screw diameter 47 mm, flight depth 10.3 mm, process length 56D or 93D, D/d = 1.46, max. screw speed 1200 min1, torque 2x530Nm, throughput up to 400kg/h
- Smelt pump Witte EXTRU 92.6
- Single screw extruder KME45XS, screw diameter 45 mm, process length 30D smooth tube cylinder, screw speed 200 min1, torque 1000 Nm, throughput up to 100 kg/h
- Downstream equipment for profile extrusion with up to 425 mm wide profile geometries
- UD-Tape system for the production of 500 mm wide unidirectional continuous fiber filled thermoplastic tapes using melt direct, foils and powder impregnation, processing temperature up to 350°C, up to 120 roving bobbins, static and dynamic spreading system, production speed 2-20 m/min, total throughput max. 260 kg/h
- Polyurethane plant for Clear-Coat-Molding in pilot scale
- Fiber cutting edge, staple lengths 1.5-98 mm
- Dry air dryer, drying temperature setting up to 160°C
- Polymer powder mill, shredder system
- Laminate press (400 x 400 mm), temperature-controlled up to 400°C, temperature-controlled up to 400°C, clamping force 51kN-1647 kN, lifting height 350 mm
- Double belt press (width 1 000 mm) temperature controlled up to 250°C, pressing pressure 0-80 N/cm², speed 0.2-8 m/min, gap height 0-150 mm, heating power 84 kW, cooling capacity 60 kW
- powder diffuser for plastic grinding material, grain size 50-500 µm, bulk density 0.5-0.7 kg/l, application weight 5-800 g/m², speed 0.5-20 m/min

Best Paper from the ESREF Best Paper Award committee for
Dr. David Poppitz
*»Correlation of gate leakage and local strain distribution in GaN/AlGaN HEMT structures (Exchange Paper IPFA 2017)«,
22.09.2016, Halle (Saale)*

Best Poster Award of the 26th International Photovoltaic Science and Engineering Conference for Dr. Volker Naumann
*»Outdoor PID testing of modules in PV systems«,
28.10.2016, Singaporr*

DIN-Innovation Prize 2017 for
Dr. Volker Naumann
*»DIN SPEC 91348 - Testing of crystalline silicon solar cells for susceptibility to potential-induced degradation«,
25.04.2017, Hannover Expo*

Heinz-Bethge-Young Talent Award from the Heinz-Bethge-Foundation for
Dr. Susanne Richter
*»Formation and characterization of non-metallic foreign phases in silicon crystallization processes for photovoltaics«,
17.11.2016, Halle (Saale)*

Best Poster Award in the Scientific committee of the 3rd international Conference on Desalination using Membrane Technology for
Magdalena Jablonska
*»Antifouling modification of reverse osmose membrane modules by functional coatings on feed spacers«,
05.04.2017, Gran Canaria*

Best Student Paper Award from the IEEE for Klemens Ilse
*»Comparing indoor and outdoor soiling experiments for different glass coatings and microstructural analysis of particle caking processes«,
30.06.2017, Washington DC*

DISSERTATIONS

Cecilia Aguiar da Silva
Martin-Luther-University Halle-Wittenberg
Influence of morpoology on the relaxation behavior of vulcanized PB-SBR diblock copolymers

Tamoor Babur
Martin-Luther-University Halle-Wittenberg
Structure an relaxation dynamics of comb-like polymers with rigid backbone

Katrin Unterhofer
Otto-von-Guericke-University Magdeburg
Characterization of macro- and microscale thermo-mechanical material properties of thin polymer films

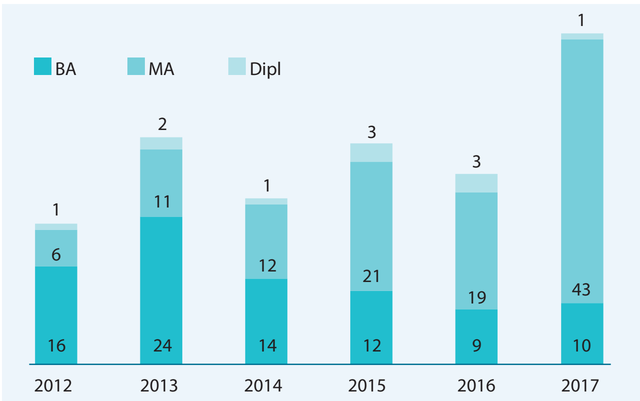
Material Prize 2017 from Schott AG for
Dr. Rico Meier
*»Method development for the mechanical and microstructural characterization of copper strips using guided ultrasonic waves (lamb waves)«,
12.06.2017, Halle (Saale)*



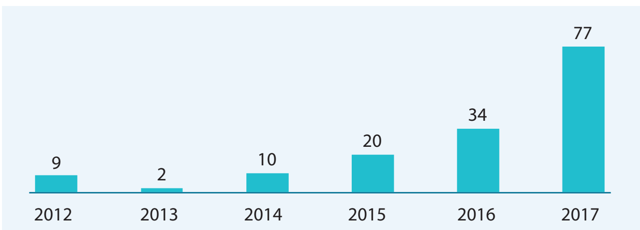
Best Student Paper Award of the 18th International Conference on Electronic Packaging Technology for
Frank Altmann, Prof. Matthias Petzold and Falk Naumann
»On reproducing the copper extrusion of throughsilicon-vias from the autonomic scale«, 17.08.2017, Harbin (China)

Heinz-Bethge-Award from the Heinz-Bethge-Foundation for
Richard Busch
*»Localized ion beam erosion of surfaces on initial edges«,
14.11.2017, Halle (Saale)*

Student projects



Guest researchers



Winter semester lectures 2016/2017

South-Westphalia University of Applied Sciences

- Photovoltaic, Energy efficiency
  Prof. Dr. Stefan Schweizer
- Wind Generation and Energy Management
  Prof. Dr. Stefan Schweizer
- Physics I
  Prof. Dr. Stefan Schweizer
- Physics III
  Prof. Dr. Stefan Schweizer

Anhalt Köthen University of Applied Sciences

- Microsystem Technology
  Prof. Dr. Andreas Heilmann
- Diagnostics Solar Cells
  Dr. Christian Hagendorf

Merseburg University of Applied Sciences

- Material diagnostics and reliability of microsystems
  Prof. Dr. Matthias Petzold
- Photovoltaik
  Dr. Christian Hagendorf

Martin-Luther-University Halle-Wittenberg

- Microstructure-based material design
  Prof. Dr. Ralf Wehrspohn
- Polymer Processing
  Prof. Dr. Peter Michel
- Polymer in Industry
  Prof. Dr. Peter Michel

Summer semester lectures 2017

South-Westphalia University of Applied Sciences

- LED-Technology
  Prof. Dr. Stefan Schweizer
- Physics II
  Prof. Dr. Stefan Schweizer

Anhalt Köthen University of Applied Sciences

- Snail Trails
  Stefanie Meyer

Merseburg University of Applied Sciences

- Material diagnostics and reliability
  Prof. Dr. Matthias Petzold
- Introduction to microsystem technology
  Prof. Dr. Matthias Petzold
- Special plastic processing methods
  Prof. Dr. Peter Michel

Martin-Luther-University Halle-Wittenberg

- Structure Analysis and Proteomics
  Dr. Christian Schmelzer
- Structure and Morphology
  Prof. Dr. Mario Beiner

Professional events organised by Fraunhofer IMWS

27th European Symposium on Reliability of Electron devices, Failure physics and analysis (ESREF)
19.–22.09.2016, Halle (Saale)

CAM-Workshop
21.09.2016, Halle (Saale)

PV Days 2016
27.–28.9.2016, Halle (Saale)

Colloquium »Plastics Technology Through the Ages« in honour of Prof. Dr.-Ing. Peter Michael
29.09.2016, Merseburg

First round table of training and development providers in the automotive industry »Pooling Competencies and Addressing Further Education Requirements«
07.02.2017, Halle (Saale)

Scientific Seminar »Flexibility in the Electricity Market – The Business of Supply and Demand«
16.02.2017, Halle (Saale)

Strategy workshop »KoMinaKu«
23.03.2017, Halle (Saale)

Symposium on Heusler compounds as hardmagnetic materials
24.03.2017, Dresden

Guest lecture Dr. Xuejun Fan: »Investigation of dimensional and heat source effects in Lock-In thermography applications in semiconductor packages«
06.04.2017, Halle (Saale)

First performance center transfer workshop »Chemical and Biosystems Technology«
06.04.2017, Halle (Saale)

Scientific seminar »Design of nanostructured materials for fuel cells and electrolyzers«
10.04.2017, Halle (Saale)

Elite User-Workshop
25.04.2017, Halle (Saale)

6th CAM-Workshop 2017 »Innovation in Failure Analysis and Material Diagnostics of Electronics Components«
26.–27.04.2017, Halle (Saale)

SAM3 project meeting
27.–28.04.2017, Halle (Saale)

First Annual Meeting and Symposium GEXOS Society for Experimental Osteology e.V.

17.06.2017, Halle (Saale)
Workshop
»Material Mechanics from the Cell to the Reliability of the Module«
22.06.2017, Halle (Saale)
Specialist lecture »Thermoelectrics«
14.09.2017, Halle (Saale)
Second performance center transfer workshop
»Chemical and Biosystems Technology«
16.10.2017, Halle (Saale)
PV Days 2017
24.–25.10.2017, Halle (Saale)
Alliance lightweight construction conference »High-Volume Lightweight Construction in Cars«
13.–15.11.2017, Schkopau
Third Fraunhofer symposium »Magnetic Materials, Rare Earths and Value Chains«
11.12.2017, Halle (Saale)

Other publicity events

Mint Select
06.02.2017, Halle (Saale)
Careers day
15.03.2017, Halle (Saale)
Future day for girls and boys 2017
27.04.2017, Halle (Saale)
20 years of the materials group
19.06.2017, Halle (Saale)
16 . Science night Halle
23.06.2017, Halle (Saale)
Fraunhofer football tournament
24.06.2017, Halle (Saale)
Third alumni meeting at Fraunhofer IMWS
24.06.2017, Halle (Saale)
Preview of science communication symposium
04.09.2017, Halle (Saale)
Fraunhofer AWZ Soest autumn party
29.09.2017, Soest
Open day with »Sendung mit der Maus«
03.10.2017, Soest
Talent School with Sience Slam
20.–22.10.2017, Halle (Saale)
Tenth anniversary of Fraunhofer CSP and photovoltaic system groundbreaking ceremony
25.10.2017, Halle (Saale)
Fraunhofer IMWS autumn party
09.11.2017, Halle (Saale)

Exhibitions attended by Fraunhofer IMWS

K 2016 Trade fair for the plastics and rubber industry
19.–26.10.2016, Düsseldorf
New Energy World
03.–07.04.2017, Leipzig
Hanover Expo
24.04.2017, Hannover
Electro-mobility day
05.05.2017, Barleben
SMT Hybrid Packaging 2017
16.–18.05.2017, Nürnberg
PCIM Europe 2017
16.–18.05.2017, Nürnberg
67th Electronic Components and Technology Conference (ECTC) 2017 IEEE
30.05.–02.06.2017, Orlando, USA
Intersolar Europe 2017
31.05.–02.06.2017, München
IEEE PCSEC
25.–30.06.2017, Washington DC
Conference EU PVSEC
25.–29.09.2017, Amsterdam

Issued patents 2017

- *Hirsch, Jens / Lausch, Dominik / Gaudig, Maria / Bernhard, Norbert*
  Process for texturing the surface of crystalline silicon, in particular for reducing reflection in solar cells
  Patent no. DE 10 2016 201 827 B3
- *Henning, Sven / Heilmann, Andreas / Schwan, Stefan / Friedmann, Andrea / Meisel, Hans Jörg / Ganey, Timothy / Herbst, Christian / Hillrichs, Georg*
  Three-dimensional, porous structure of nanofiber nonwoven fragments and methods for its production
  Patent no. EP 3 014 005 (B1)
- *Schulze, Stefan / Ehrich, Christian*
  Process for lamination and molding of solar modules on support structures
  Patent no. EP 3 028 854 (B1)

PUBLICATIONS AT FRAUNHOFER IMWS

Publications highlights

Kleebusch, E.; Patzig, C.; Krause, M.; Hu, Y.; Höche, T.; Rüssel, C.
The formation of nanocrystalline ZrO_2 nuclei in a Li_2O-Al_2O_3-SiO_2 glass – A combined XANES and TEM study

(2017) Scientific Reports, 7 (1), art. No. 10869
DOI: 10.1038/s41598-017-11228-7

Ackermann, S.; Steimecke, M.; Morig, C.; Spohn, U.; Bron, M.
A complementary Raman and SECM study on electrically conductive coatings based on graphite sol-gel composite
electrodes for the electro-chemical antifouling

(2017) Journal of Electroanalytical Chemistry, 795, pp. 68-74
DOI: 10.1016/j.jelechem.2017.04.029

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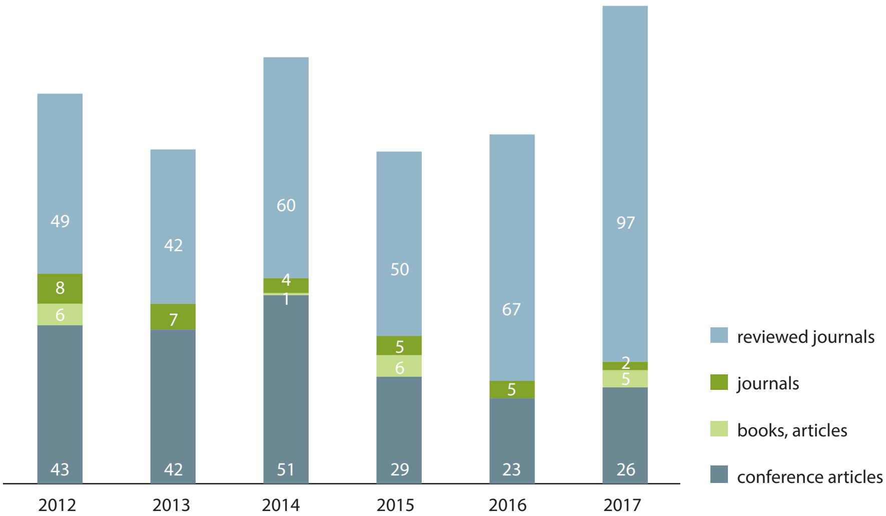
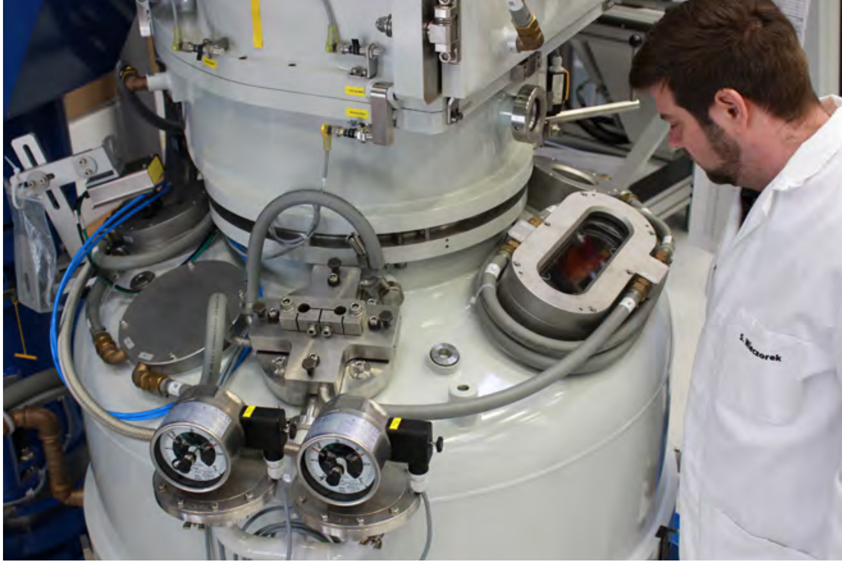
Publications





A bulk consumer is the crystallization plant in the Fraunhofer CSP technical center. Here, silicon is melted to produce wafers for solar plants.

SUSTAINABILITY REPORT

The strategic goal at Fraunhofer IMWS is to develop synergies between the research tasks at our institute and the operating costs. The sustainability management work group bundles these efforts and has methodically expanded its activities in 2017, not only through its own ideas, but also through cooperation and the integration of external service providers.

New energy consumption meters at Fraunhofer CSP were used for more detailed consumption detection as a basis for identifying further savings potential. High savings could be achieved, above all, in the production of cooling water and compressed air, as well as in the ventilation technology. For example, the optimization of refrigeration systems has led to efficient and cost-effective refrigeration despite the increased need for process and air conditioning through the interconnection of systems, adjustments to supply and return temperatures, systems switching times, and cleaning interval changes. The operation of ventilation and extraction systems has been optimized for scientific processes.

The operation of large consumers such as crystallizers or laminators has been coordinated to avoid peak loads. Furthermore, summer heat insulation and lighting scenarios were efficiently adjusted to the needs and weather conditions with the help of KNX technology. Light bulbs are consistently converted to energy-saving LED technology. Thanks to further improved »standby management« of the compressed air consumers as well as refined compressor operation management, a significant saving could be achieved in compressed air generation. The same applies to cooling by adjusting the control parameters of the chillers and making adjustments in the cooling circuits.

The experiences gained in Otto-Eißfeldt-Straße will now be transferred to the other properties. For example, the now well established load management is taken over into the individual processes. The bulk consumers have already been identified in the part of the institute in Walter Hülse Straße. For 2018, a division of the existing measuring points for electric energy or the extensive new installation of energy meters is planned. At the same time, it is also necessary to check whether electricity consumption metering can also be carried out alternatively by upgrading the existing building management system, in order to combine the detection of electrical loads symbiotically with the control of building systems.

In order to optimize district heating consumption at Walter Hülse Straße, a concept for the installation of individual room regulations for the office space has been developed (»Smart Home«). This should now be tested using test rooms. Besides optimizing consumption, it is also about a better room climate and more comfort. Furthermore, the optimization of the KNX lighting control will be planned and set up.

Investments will also be made in power generation from renewable energies. At present, a photovoltaic system with 100 kWp is in the approval process with the responsible authorities. Set up is planned for the first quarter of 2018.

LEADING MINDS OF 2017

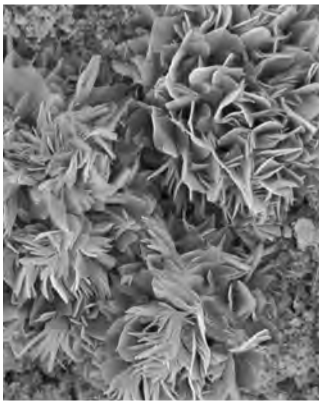
Dominik Lausch *and* Sascha Dietrich *were successful in the Fraunhofer Innovator Program with their »Smart Magnetic Fields« project. The innovator is an exploitable program for the development of marketable products. As part of the program, the idea of non-contact real-time measurement in the production of photovoltaic modules is now to be developed to market maturity.*

Reiner Haseloff *was one of the guests of honor at the symbolic ground-breaking ceremony for the new solar system at the Fraunhofer CSP. The Minister President of Saxony-Anhalt also congratulated them on the 10th anniversary of the institution and expressed its conviction that Fraunhofer CSP will »remain an important pillar in the research landscape of our home country«.*

Not only following the megatrend of digitalization, but actively using and developing the possibilities offered by this at the institute is the idea behind the »IMWS 4.0« project, which is coordinated by Ralf Schäfer. *With the goal of stronger internal and external networking, for example, the technical equipment at the institute, organizational processes, training and qualification as well as business models are considered. As a result, a new kind of scientific work becomes possible.*

The Materials Data Space® platform, initiated by the Fraunhofer MATERIALS Group under the coordination of Prof. Ralf Wehrspohn, received its own office in the spring of 2017, headed by Ursula Eul. *The Materials Data Space® is designed to provide users with »digital twins« of materials and collect and process material-related data across the product lifecycle. This will enable faster material and product developments and completely new business models.*

Matthias Mader *from Berlin won the first Science-Slam at Fraunhofer IMWS on 22nd October 2017. In this format, several scientists present their own research within ten minutes in the most informative and entertaining way; the audience then votes which presentation was the best. The Science-Slam at Fraunhofer IMWS was part of the Talent School, during which 13 students interested in the natural sciences informed each other about the institute's topics in a three-day workshop.*



Frank Altmann *is head of the Core Competence Group Microstructure Diagnostics, created at Fraunhofer IMWS in 2016. The competencies for microstructure analysis are bundled and initiatives beyond the boundaries of the business fields are developed. In the past year, methodical development in the areas of failure diagnostics, as well as 4D and multi-scale analysis were particularly promoted.*

Sandra Sarembe, Ute Heunemann und Maria Morawietz *produced the best microstructure image at Fraunhofer IMWS in 2017. Traditionally, at the end of the year, employees choose the best motif created by the various microscope techniques used at the institute. The picture shows a treated dentin surface with crystal formation.*

The new business unit »Chemical Conversion Processes« will start in 2018 under the direction of Bernd Meyer. *The preparations for this started in 2017. The business unit will include the activities of water electrolysis, including the resulting electrolysis platform in Leuna and carbon cycle technologies.*

As last year's winner, Fraunhofer IMWS once again hosted the football tournament, in which the various Fraunhofer institutes from all over Germany competed against each other. This time the title went to Fraunhofer IWU in Chemnitz, whilst Fraunhofer IMWS took third place. Two trophies remained in Halle: René Slawinsky *(left) was the top scorer of the tournament,* René Möbius *(right) was awarded the title of best goalkeeper.*

Katerina Morawietz *(2nd from left) participated in the third Fraunhofer IMWS alumni meeting. She is now working in the Saxon Ministry of Economics, Labor and Transport and informed herself on June 24, 2017 together with other former employees about the current activities of the Fraunhofer IMWS. The Fraunhofer IMWS alumni network, created in 2015, now comprises more than 150 people.*

In 2018, the extension of the Fraunhofer CAM will be completed. On an additional area of 770 square meters, the researchers use new methods to look into the very core of materials.

OUTLOOK

Digitization, networking and sustainability are the topics that will shape our activities in 2018. Against the background of an increasingly digitalized world of materials, we offer solutions for Industry 4.0 and the efficient use of materials.

In digitalization, work in the existing Material Data Space use cases will be a focus, as well as winning new partners and exploring further application areas for this platform, where we provide data on the »digital twin«. The work in our core competencies of microstructure diagnostics and microstructure design will provide important impetus, because data from high-resolution diagnostics or microstructure kinetics, which represent the entire life cycle of a material, are the prerequisite for efficient use with maximum reliability and service life as well as accelerated material development and generating new business models.

Thus, we contribute significantly to a more sustainable use of materials. Another milestone for this goal will be when the system for the production of UD-Tapes is commissioned in the spring of 2018 at the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ in Schkopau. UD-Tapes are continuous fiber reinforced thermoplastic systems characterized by unidirectional fibers. Already in the manufacturing process, their fiber orientation can be adapted directly to the load curve in the subsequent application, so that particularly high-performance components or semi-finished products can be manufactured. This approach sets new standards in the field of lightweight construction.

We will also start operations in 2018 in the extension of the Fraunhofer Competence Center for Applied Electron Microscopy and Microstructure Diagnostics at Fraunhofer CAM. In the future, we will offer our customers even better conditions for the development of reliable microelectronics. One focus will be on the use for automotive applications – a key prerequisite for autonomous driving to become a reality.

The Center for Economics of Materials CEM, which we operate together with the Martin Luther University Halle-Wittenberg, will combine our materials expertise with economic expertise in its new home at Friedemann Bach Platz in Halle in 2018 and will offer analysis and strategies for material efficiency enhancement and substitution or advice for the design of a sustainable regional economic and structural policy. Likewise, the new business unit »Chemical Conversion Processes« will expand our portfolio. Here, too, the issue of sustainability is at the top of the agenda: The business unit develops processes and technologies for the material use of primary and secondary carbon carriers with the input of renewable energy.

With these projects, we are strengthening our strategic focus and establishing even better prerequisites for offering our customers the maximum of know-how for their future viability.

IMPRINT

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Fraunhofer Institute for Microstructure
of Materials and Systems IMWS
Walter-Hülse-Straße 1
06120 Halle (Saale)
Germany
+49 3 45 55 89¬0
info@imws.fraunhofer.de
www.imws.fraunhofer.de

Editorial Team
Christiane Rex, Michael Kraft, Fraunhofer IMWS
Annette Lippstreu, Pandamedien GmbH & Co. KG
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Editorial Team address
Fraunhofer Institute for Microstructure
of Materials and Systems IMWS
PR Work
Walter-Hülse-Straße 1
06120 Halle (Saale)
Germany
+49 3 45 55 89¬204
info@imws.fraunhofer.de
www.imws.fraunhofer.de

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