Fraunhofer ISC

Annual Report 2020 | 2021

LESS IS MORE

Introduction

Dear Friends and Partners of Fraunhofer ISC,
Ladies and Gentlemen,

In addition to climate-friendly transformation and digitization, the use of resources is becoming increasingly important worldwide. The rising cost and critical availability of raw materials are being discussed openly and have also found their way into political guidelines (see "European Green Deal"). This also is a success for the lasting perseverance with which the ISC and its allies have proven and communicated the necessity of revising general opinions. A paradigm shift will be necessary that decouples economic prosperity from the consumption of resources. "Less is more" – added value must be achieved with less resources, and the resources used must be managed in a cycle. With its materials research, the ISC can make important contributions in this context as well, as the projects presented in this annual report will certainly convince you. Multifunctional coating materials play an important role here, and can make a significant contribution to the recyclability of plastic packaging, for example. Our colleague Dr. Sabine Amberg-Schwab recently received some prestigious awards for her new packaging concepts, including the Deutscher Verpackungspreis 2020 (Gold Award) and the Sustainability Award 2020 from European Packaging – a great honor and recognition of her commitment to packaging that causes less impact on the environment.

One of the pioneers in the public and scientific discussion is the research and development of batteries, which increasingly relies on a transformation towards a more careful use of resources and on the benefits of a circular economy, benefits which are also economically advantageous. This became clear in the contributions at the Green Batteries Conference 2021, which Fraunhofer ISC launched in cooperation with the Battery 2030+ initiative of the EU and the European Lithium Institute eLi. About 1400 participants from research and industry registered for the online event, which was the first of its kind – a remarkable success and a clear sign of the great interest in environmentally friendly battery technologies that reduce the consumption of resources.

Progress is also being made with Europe's first industry-related fiber pilot plant at the Fraunhofer Center for High Temperature Materials and Design HTL in Bayreuth. The plant was successfully commissioned, and in September 2021 the first SiC fiber coils were presented to the Bavarian Ministry of Commerce by project partner BJS Ceramics GmbH. This marks an important milestone for a European technology platform for nonoxide ceramic reinforcing fibers which are, for example, essential for the further development of innovative lightweight materials for more efficient, CO_2-saving energy conversion.

The development of the Translational Center for Regenerative Therapies TLC-RT in Würzburg continues to be very encouraging. For his work in the ImAi project on a new test procedure to replace the Draize Test, which has been used as a standard in testing the eye irritation potential of substances since 1944, Dr. Christian Lotz was awarded the Felix Wankel Animal-Welfare Award in Berlin this year – congratulations to the young colleague for this success! Meanwhile, the renovation of the old Würzburg Eye Clinic is progressing – even though there is still a lot of work to be done before the listed building from 1901 will shine in new splendor and with modern biolabs ...

Many thanks to you, dear friends and partners, for your interest, feedback and suggestions, as well as to the federal and state ministries for supporting our research and to the European Commission for enabling transnational approaches.

I wish all of us luck, energy and success in meeting global challenges.

And ... stay healthy!

Yours

Gerhard Sextl

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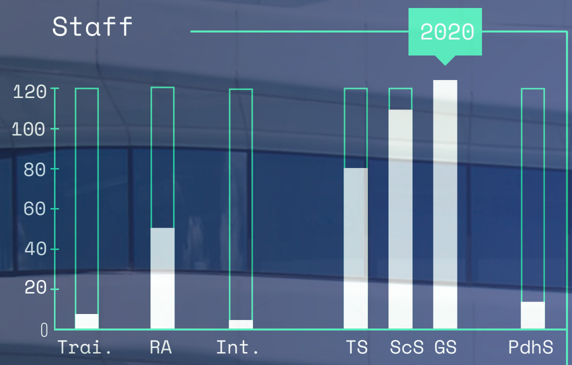
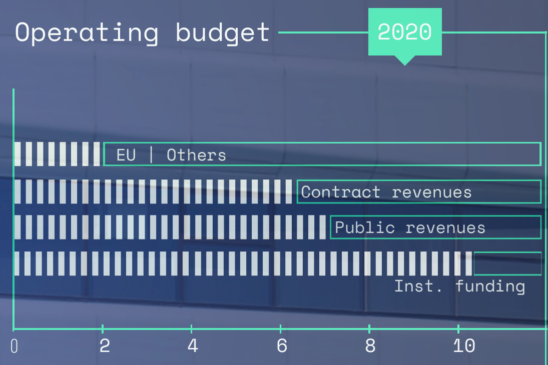
Learn more and visit us at www.isc.fraunhofer.de/annual-report

INFOGRAPHIC

100% Green electricity in the properties of the ISC





Staff

Technical staff	69
Graduate staff	125
Scientific staff	111
Phd students	17
Trainees	7
Research assistants	52
Interns	3

Operating budget

EU | Others	2,3 Mio €
Contract revenues	6,2 Mio €
Public revenues	6,6 Mio €
Institutional funding	10,3 Mio €

Annual Report – Fraunhofer ISC profile

Economic growth is still too closely linked to the increasing consumption of resources. We only have one planet Earth and we are literally digging off the ground from under our feet. That's why we need to change the way we do business, produce and create value. "Less is more" must become the new motto. With its materials research and process development, Fraunhofer ISC will and can enable its customers and development partners to work in a resource-efficient manner, i.e., to manufacture sustainable products with fair added value using as few resources as possible.

You have to start somewhere ...

"Climate change, which we are driving forward with our hunger for energy, mobility, consumption and global networking, will primarily harm ourselves and future generations. These are the challenges against which we must measure our work, and we at Fraunhofer ISC are determined to do our part to solve them."

Fraunhofer ISC had already prefaced its annual report with this sentence in previous years. With the start of the worldwide "Fridays for Future" movement, climate change has now also moved onto the political agenda, the EU has declared a "Green Deal", and achieving the climate targets is finally given a higher priority.

The Institute's slogan "Materials meet ..." focuses attention on the areas in which materials research can be effective, not only to support the achievement of climate targets, but also to facilitate the more sustainable use of limited resources.

The present annual report will concentrate on projects that are particularly important in terms of resource efficiency.

The research activities that merge under "Materials meet ... Energy" also play an important role in this context. With its Fraunhofer R&D Center for Electromobility, the Institute is currently involved in more than a dozen national and international research projects relating to the establishment of a new generation of energy storage systems and their production platforms in Europe. The declared aim of the Europe-wide activities is to create a strong competitive position for European manufacturers with regard to the stationary and mobile batteries required for energy transition and electromobility. New materials and components for lithium-based storage technologies as well as for efficient, resource-conserving energy transformation and optimized high-temperature processes for significantly reduced CO_2 emissions in particularly energy-intensive industries are being developed under the umbrella of Fraunhofer ISC. At the Fraunhofer Center for High-Temperature Materials and Design HTL in Bayreuth, a fiber pilot plant that is unique in Europe has been commissioned and is already producing ceramic fibers for high-temperature lightweight construction on an industrial pilot scale.

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... to go further into the future

3D test systems for biomedicine

However, world events continue to be dominated by the COVID19 pandemic. This brings a second research core area of the Fraunhofer ISC into focus: “Materials meet ... Biomedicine”. With the research activities of the Translational Center for Regenerative Therapies, Fraunhofer ISC is working on solutions to a global challenge here as well. For example, human 3D tissue models of the respiratory tract can be used to study the interaction of corona viruses with body cells and the efficacy of active ingredients. By combining material syntheses, cell biological systems and additive manufacturing processes from Fraunhofer ISC, new biomedical applications in regenerative medicine are being opened up. As an alternative to animal testing, human 3D test models are available that simulate healthy or diseased body barriers, thus enabling the testing of new formulations and therapeutic agents. The integration of automated production methods and robotic systems will enable reliable, rapid and cost-effective cultivation of cell models and cell-based test systems in the future.

Materials and process development is implementing more and more methods of artificial intelligence, digitization and automation to arrive at solutions faster. Fraunhofer ISC’s slogan “Materials meet ... Digitization” focuses on the elaboration of a comprehensive ontological description of the diverse classes of materials themselves and the process chains required for their processing. This is the basis for the architecture of a central data room which, in the course of its continuous growth, is fed both with real process parameters and analysis results and with output data from simultaneously created simulation models. Furthermore, the development of modular “machine learning algorithms” based on the ontological description allows to establish not directly accessible correlations between quantities, especially between parameters of materials and processes on the one hand and target properties of the materials on the other. These algorithms are intended to additionally facilitate the extraction of features from analysis data, e.g. spectral or (electron) optical, and usefully complement human expertise. The development of data structure and data procedure is intended to be an interactive process with agile methodology from the beginning, but in the end a universal tool for more efficient research should be available. Accompanying developments such as the High Throughput Screening System 4.0, the APRONA project for automated, robot-assisted particle production or highly scaled material syntheses with online recording of synthesis-relevant material parameters create the necessary interface between the real material and the digital data room.

In order to address the future issues associated with increasing digitization, such as the “Internet of Things,” robotics, autonomous driving, laboratory automation and switchable systems, new demands will also be made on the functions and properties of the materials used. Intrinsic condition monitoring through sensory functions, adaptive change of physical properties, detection of environmental influences, as well as multifunctional materials and electro-opto-mechanical systems, which are also suitable for digital manufacturing processes – e.g. high-resolution 3D printing – are some of the tasks that Fraunhofer ISC is engaged in under the heading “Materials meet ... Adaptive Systems”.

In addition to digitization, the transformation of the economy from value creation based on fossil resources to the sustainable and resource-conserving use of renewable raw materials is also gaining in importance. This is subsumed under the term bioeconomy as the knowledge-based production and use of biological resources, processes and principles to provide products and services in all economic sectors within the framework of a sustainable economic system. The concept of bioeconomy is closely linked to the circular economy and is planned to be expanded into a circular bioeconomy. However, the bioeconomy not only focuses on optimizing material flows and resource management, but also aims at developing processes of social change and the biologization of many industries, resulting in entirely new products and solutions.

In this context, Fraunhofer ISC is positioning itself with "Materials meet ... Clean Environment" and sustainable solutions for the refinement and efficient material utilization of biogenic materials. The portfolio of materials is being successively expanded in terms of biogenic functional materials and recyclability by simplifying complex material composites, supported by quality assurance processes. Bio-based, biocompatible and biodegradable functional materials are replacing environmentally harmful materials. Sustainable material solutions as well as energy- and resource-efficient methods and processes along the value chains are core topics.

With its chemical-synthetic expertise, the ISC supports its customers in the chemical key market on the way to more sustainable products.

And so we have come full circle, because all the developments at Fraunhofer ISC are interlinked in order to actively contribute to overcoming the major challenges of our time and to securing a future worth living for ourselves and future generations.

Materials meet … future challenges!

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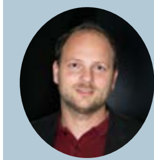

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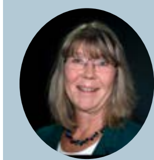

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PROJECTS

bioORMOCER® – Excellent award-winning packaging materials for the future

Polluted oceans, endless plastic waste and alarming natural disasters: We are constantly confronted with the global environmental crisis and are therefore required to revise our thinking. This also applies to the production and the use of packaging materials. While fulfilling a number of necessary properties that guarantee the safe packaging of food, conventional plastic packaging (usually non-recyclable multilayer composite films), poses a major threat to the environment and, in this context, to human health. Improper disposal favors the penetration of finely dispersed plastics – in the form of microplastics – into the biosphere, oceans, soil, groundwater and ultimately the food chain.

Multiple awards

The Sustainabiliy Awards 2020

The ORMOCER®s developed at the Fraunhofer ISC offer a possible solution to this problem. These are inorganic-organic hybrid polymers that exhibit the relevant characteristics of packaging materials, such as excellent barrier properties against water vapor, oxygen and the loss or penetration of flavors, and are thus suitable for the production of multifunctional coatings. Thanks to their high effectiveness, an extremely thin layer of ORMOCER®s is sufficient to ensure the required barrier properties.

bioORMOCER®s: from "environmentally friendly" to "biobased" and "compostable"

Against the background of saving fossil resources and presenting alternative material solutions, Dr. Sabine Amberg-Schwab and her team optimized the material class of ORMOCER®s and thereby developed the material class of bioORMOCER®s. This variant of the coating paints is not only biobased and compostable, but also represents a more sustainable approach. This is because the organic-fossil components of ORMOCER®s are replaced by bioorganic components that can be obtained both from residual materials from food production and from biological waste. As a result, biogenic, readily available raw materials form the basis for the production of bioORMOCER® coatings. On the one hand, this "upgrade" promotes the recyclability of packaging and, on the other, enables fossil resources to be saved.

Being a further development of ORMOCER®s, bioORMOCER®s have comparable characteristics and therefore also ensure excellent barrier properties. For this reason, they serve not only as a refinement of packaging materials in food production, but also in the cosmetics and pharmaceutical industries. The possibility of applying bioORMOCER®s in the form of biopaints to biopolymers, conventional plastics or even paper widens the spectrum of innovative, biogenic packaging concepts and provides sustainable alternatives. Since bioORMOCER®s can be applied using various processes, it is possible to coat flat substrates as well as complex geometric shapes, such as trays, jars, and the like.

In recent years, the research of Dr. Sabine Amberg-Schwab and her team has been recognized with several awards. In 2020, they received the Deutscher Verpackungspreis (German Packaging Award) in the category "Sustainability" in gold.

GERMAN PACKAGING AWARD
SUSTAINABILITY
WINNER 2020

GERMAN PACKAGING AWARD
WINNER IN GOLD 2020

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“MoNova” – Recyclable packaging films based on monomaterials

Heaps of garbage © unsplash

Plastic packaging is an integral part of everyday life. Whether in the food, cosmetics or pharmaceutical industries, they are used in many, different areas. The food industry, in particular, primarily uses plastic-based multilayer packaging, as up to now this was the only way to protect the packaged products against oxygen, water vapor, etc., while at the same time offering a lightweight, cost-effective and durable packaging option.

However, the drawback of this plastic packaging is hidden in the non-recyclability of the laminate. During the manufacturing process, the individual laminate layers are bonded together, but cannot be separated from each other afterwards. The resulting multicomposite films therefore have an inseparable structure of chemically incompatible plastics. This means that they can either be separated nor recycled together.

“MoNova”: a new generation of packaging monofilms

In collaboration with three other Fraunhofer institutes, Fraunhofer ISC is working on the “MoNova” project, which includes the development of an alternative to multicomposite packaging materials, thus enabling a circular economy that is sustainable and reduces the consumption of resources. The aim of the project is to replace precisely these non-recyclable multilayer composite films with monomaterials and thus provide easily recyclable, environmentally friendly packaging materials. In this context, the complete packaging film production process is considered with the aim of producing the new packaging films from (at least) 95% of a single base material and including the use of recycled material from the outset.

"MoNova" is based on monomaterial polyolefins or recyclates, special additives and their physical as well as wet-chemical post-treatment. This results in a two-stage process that adjusts the new packaging films in terms of the properties required for their respective application. A functional hybrid polymer coating in a simple coating process gives them the necessary barrier properties that qualify them for use in the food, cosmetics and pharmaceutical industries. Since the material of the packaging films is reduced to one type of plastic, they are fully recyclable. In this way, they make it possible to ensure a material circulation in which the recycled materials repeatedly serve as raw materials for new packaging films.

Within the project, the new packaging film will first be used for the production of stand-up pouches for food packaging. Subsequently, its recyclability will be proven by reusing the material for the production of stand-up pouches for the cosmetics industry.

Fraunhofer research program PREPARE

The MoNova project is funded within the Fraunhofer PREPARE program. The purpose of this program is to enable sophisticated initial research for new concepts, technologies and processes across institutes. Funding is provided for topics with high economic and social relevance that lead to innovations with enormous impact.

MoNova, with its revolutionary packaging concept, is a prime example of this. The packaging industries are facing a radical change, triggered on the one hand by social pressure and new regulations, and on the other hand by the company's own efforts to handle valuable resources responsibly and thus position itself as a responsible company. MoNova will expand the necessary know-how and effectively support the industry in the transformation of its processes with an "Open Innovation Test Bed".

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ORMOCER®-based packaging films

"NewHyPe" – Biodegradable mulch papers ensure sustainability in agriculture

Although fossil-based plastics – especially biologically non-degradable types – have many good properties, they contrast with today's future-oriented, environmentally friendly and sustainability-minded society. Fossil-based plastics are a particular problem in agriculture.

Mulch films are indispensable for extending growing seasons, influencing the water balance of the soil, or reducing pesticide use. So far, however, these mulch films have been made of conventional plastic, which contributes significantly to the pollution of agricultural soil or the environment, because they are usually not recyclable and therefore also end up in nature in the form of waste residues after a relatively short period of use.

Research institutes and companies from Norway, Finland and Germany are working together in the "NewHyPe" joint project to find a solution to this problem. At the heart of the project is the development of a sustainable alternative to previous mulch films, the components of which are made of fossil-based plastics and are to be replaced by biobased alternatives.

Novel composites: cellulose and ORMOCER®

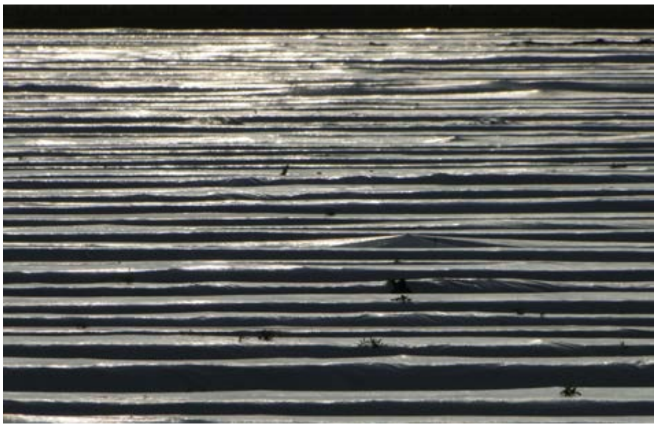
Cellulose is the most abundant biopolymer and therefore offers an attractive basis for the replacement of conventional plastics in various applications. The major advantage of this material over fossil-based plastics is its ability to be composted. Cellulose is inherently biodegradable, which means that the material would not leave any unwanted waste on the field. However, moisture resistance and tear strength are inadequate for outdoor use. To equip cellulose with the properties needed for mulch film, these two parameters in particular must be improved.

The objective of the "NewHyPe" project is to combine cellulose-based materials and specific inorganic-organic hybrid polymers – so-called ORMOCER®s – to increase the basic stability of the composite material. Thanks to their wide range of functions, ORMOCER®s contribute to the formation of chemical bonds within the cellulose fibers. This allows mechanical and chemical resistance of the hybrid composite material to be adjusted. Nanocellulose paper has emerged as a strikingly innovative substrate in this context

www.newhype-project.com

This variant of mulch paper results from the combination of nanocellulose dispersion as the carrier structure and ORMOCER®s as the matrix component. Due to their biodegradability, they can simply be plowed into the soil after their period of use.

Within the "NewHyPe" joint project, Fraunhofer ISC is taking on the particularly important role of coordinating, administering and managing the entire project. Thanks to its many years of experience and expertise in the field of coating development, Fraunhofer ISC is also responsible for the development, modification and characterization of hybrid coating materials – the ORMOCER® class of materials – and their combination with the cellulose-based base materials.



Mulch films on a field © pixabay

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“MaNiTU” – New functional materials enable higher efficiencies

Since the 1980s, society has become increasingly aware of the need for an energy turnaround. The transition from the use of finite resources to renewable energies is also accompanied by the necessary increase in efficiency of solar energy converters. Even silicon solar cells having the highest efficiencies currently available offer clear advantages, but also face physical limitations.

On the one hand, highly efficient silicon-based solar cells deliver cost-effective electricity and consume less surface area and materials than simple photovoltaic cells. On the other hand, their efficiency cannot be increased at will. For this reason, it is important that a future-oriented research approach focuses on the combination of several materials. The lead project “MaNiTU” therefore emphasizes the development of multi-junction solar cells by concentrating on research into absorbent materials.

The starting point of the lead project is perovskite solar cell technology, which has seen its efficiency increase from 3.8 % to 24.2 % over the past ten years. This technology promises not only potential for increasing efficiency, but also minimal production costs and simple manufacturing processes. Due to their physical properties, the class of perovskite materials is also suitable for use in multi-junction structures based on silicon solar cells. Multi-junction solar cells of this type are particularly interesting because they can achieve efficiencies of over 35 %.

However, the EU RoHS Directive which restricts the use of toxic or critical materials, renders the use of perovskites problematic. This is because, in the manufacture of solar cells, the class of perovskite materials currently is dependent on lead, a material classified as critical.

Sustainable multi-junction solar cells without critical materials

Annual photovoltaic installations are expected to increase to more than 1 TWp worldwide in the next five to ten years. Consequently, the elimination of toxic as well as critical materials from the manufacture of solar modules is becoming increasingly important. The use of perovskites without the addition of lead is not yet possible. In the lead project “MaNiTU”, six Fraunhofer institutes are working together on the development of new lead-free absorbent layers as well as contact and passivation layers.

In the MaNiTU lead project, six Fraunhofer institutes are working together to develop sustainable, highly efficient and cost-effective multi-junction solar cells based on new lead-free absorbent materials.

These layers are based on well-known perovskite absorbent materials that do not contain any critical or toxic substances thanks to state-of-the-art methods of materials science. With the combination of lead-free perovskite technology and silicon technology, perovskite solar cells can be deposited directly on silicon solar cells. The individual solar cells use different parts of the solar spectrum particularly efficiently, so that the overall efficiency is increased.

As a result, the same solar cell area ultimately produces more electricity.

With its expertise in wet-chemical material synthesis and electrode applications, Fraunhofer ISC plays a key role in the "MaNiTU" lead project. In combination with its expertise, the multi-junction approach will advance solar cell research in Germany and provide an innovative edge that is also economically interesting.

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“SUPERSMART” – Sensors, displays and electronic components directly printed on paper

The development of a smart environment for production, retail and logistics is not only important at the moment, but will also play an increasingly important role in the future. Intelligent packaging not only monitors transport and logistics, but also provides tamper-proof information about the origin and authenticity of the products it contains. In this way, they create added value by helping to optimize processes within this sector.

At the same time, both the packaging market and the electronics industry are undergoing transformation. The commitment to resource conservation, climate protection and environmental conservation requires stricter guidelines and laws. The permitted components have been regulated (REACH, RoHS, WEEE) and the use of plastic packaging in particular has been restricted (EU Packaging Regulation).

This means that the implementation of a “smart environment” in general is also dependent on a new approach: environmentally friendly, preferably recyclable, cost-effective alternatives to plastic-based materials and conventional semiconductor technology are required for the realization of sustainable smart packaging.

SUPERSMART was recognized for its sustainable approach at the OEA Competition 2021.

SUPERSMART: Smart packaging made of paper instead of plastic

Paper is a long-established material that meets requirements for packaging materials in terms of resource conservation, climate protection and environmental conservation. Paper consists of renewable raw materials, is easily recyclable, durable and, if processed appropriately, biodegradable. However, it has so far proved unsuitable as a carrier material for electronic components such as sensors and smart labels. The “SUPERSMART” research project – carried out in a European consortium of eleven partners from industry and research – has now devised a smart approach that allows electronics to be printed on paper.

One of the major obstacles in the production of competitive, paper-based smart labels and sensors is the high cost associated with manufacturing the necessary materials. Until now, these could only be manufactured in small quantities on a laboratory scale, so that the overall cost of the printing process was high. “SUPERSMART” has therefore developed criteria for suitable paper substrates and solutions for industrial upscaling of the production of functional materials, high-precision aligned roll-to-roll printing of electronic components, automated assembly, and the development of precise process protocols for quality assurance.

“Paper instead of plastic – smart sensor technology for sustainable packaging”

Benefits for resource conservation, climate protection and environmental conservation

The results of the Life Cycle Assessment (LCA) show just how great the benefits for resource conservation, climate protection and environmental conservation really are: on the one hand, replacing organic or inorganic substrates with paper simplifies future recycling. On the other hand, it reduces the amount of waste generated during production and at the end of the product’s life. What is more, the necessary printing processes require less energy and raw materials than conventional semiconductor processes. In a direct comparison between paper and PET substrates, there are clear advantages in using printed electronics on paper. In almost all LCA categories – e.g., global warming, ozone depletion in the stratosphere or ecotoxicity, etc. – the use of paper substrates causes only 10–20 % of the negative effects of PET.

In the “SUPERSMART” project, paper, functional materials and production processes were adjusted to each other in such a way that electrical components can now be printed directly in a roll-to-roll process. The range of functions was exemplified by two types of “smart labels”: a shock detection sensor that can provide information about vibrations during transport, for example, and an intelligent tamper-proof label. Both can be read easily with a smartphone app. “SUPERSMAR” lays the foundation for scalable, cost-effective production of electronic components that are printed directly on paper.

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“EVOBIO” – Evolutionary bioeconomic processes

“Integrative use of material flows to produce optimized materials for innovative products in bioeconomic process cycles”

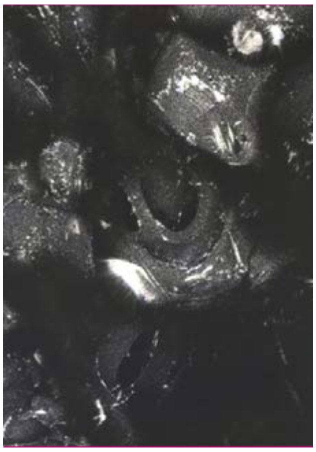
Value creation and production processes worldwide lead to harmful emissions and non-recyclable waste. They are often accompanied by irreversible exploitation of global resources and result in unbalanced land use and increasing loss of biodiversity. This has negative consequences for the habitat and quality of life of many people. Examples are the availability of clean drinking water and the competition for essential raw materials in many countries of the world, food and product crime, and low-quality products. In a bioeconomic sense, this is often caused by non-optimized processes and value chains, in addition to the general shortage or increase in price of the required resources. The Wuppertal Institute for Climate, Environment and Energy summarized a possible solution approach as follows: “A consistent orientation towards a circular economy and bioeconomy is a means for having to use fewer primary resources and thus for becoming less dependent on global supply chains and raw materials, for example functional metals.”

In the “EVOBIO” project, which is self-financed as part of the Fraunhofer Innovation Program, concepts were developed and demonstrated on selected examples that enable the transition from a unidirectional impact chain to a fully integrative use of material flows, materials and products in sustainable, resource-conserving bioeconomic process cycles.

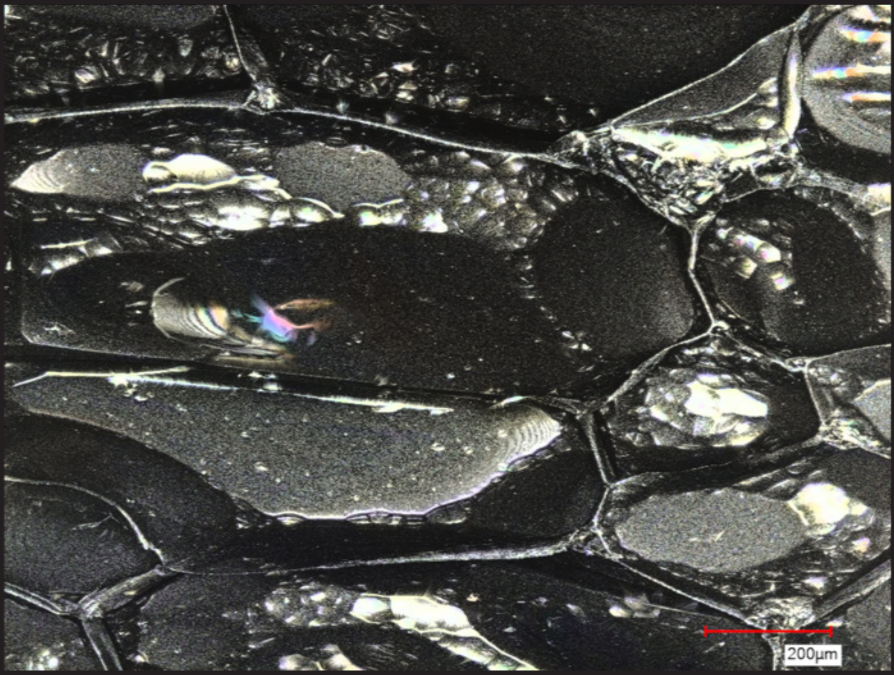
In addition to the examination of material flows and innovative materials, the focus was also on the short-term development of product ideas based on existing materials. Here, Fraunhofer ISC's specifically adapted magnetic particles (MagSilica®[1]) came to play a literally driving role, in particular in the production of novel bioinspired gradient foam materials via an induction process. Inductive heating enables rapid and direct heat generation in the component and can thus be localized more efficiently and precisely than indirect, externally acting heating methods. Locally varying graded foam structures can – analogous to bones – have a significantly lower weight than solid material with the same stability. Thanks to the easily adjustable distribution of the MagSilica® particles, the desired gradient structures in the polymer foams could be adjusted by inductive heating. Very low densities and open-pore foam structures can also be achieved. In addition, MagSilica® particles can be used for welding and subsequent simple, automatable separation by local inductive heating.

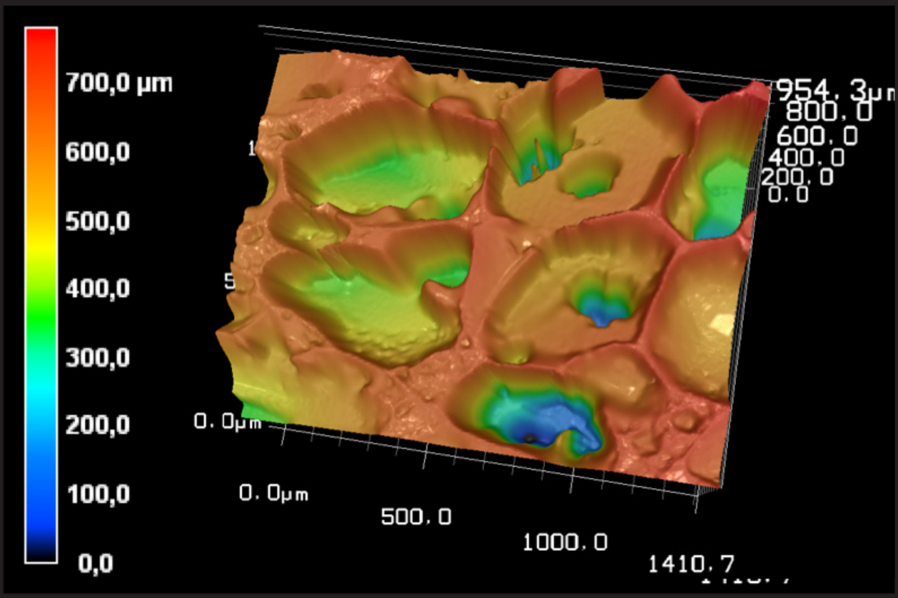
This facilitates cost-effective and unmixed recycling of all materials.

Subsequently inductively opened pore structure in magnetic additives in a doped polystyrene foam



1 MagSilica®: registered trademark of Evonik, which is being developed exclusively at Fraunhofer ISC.





Uniform pore structure of an inductively foamed polystyrene

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Carbon Black © Orion Engineered Carbons GmbH

"HiQ-CARB – greener carbons" – Milestone for sustainable batteries

Large parts of European industry, including the European automotive industry, are increasingly dependent on imported lithium-ion cells. The European Green Deal and various supporting measures aim at exploiting the employment, growth and investment potential of batteries. The objective is to create a competitive "battery" value chain in Europe – not least to make battery technologies more environmentally friendly and "greener".

Lithium-ion batteries require a number of special functional materials in addition to lithium for their performance, some of which, i.e., conductive additives, sound rather unspectacular. In fact, conductive additives such as conductive carbon black or carbon nanotubes are crucial building blocks for the performance and environmental compatibility of lithium-ion batteries, and they are essential for achieving fast charge and discharge rates. In the rapidly growing battery market, raw materials account for the majority of costs in production. Carbon, specifically conductive carbon black in this case, is usually produced with high energy and process material input.

The "HiQ-CARB" joint project, coordinated by Fraunhofer ISC, aims at providing new carbons with superior performance and a low carbon footprint for future "greener" batteries in Europe.

Less carbon for the same conductivity

The "HiQ-CARB" approach to "green" carbon additives is to combine thin carbon nanotubes and acetylene black, which score high in conductivity and low in CO_2 emissions during production. In combination, they form a nearly ideal conductive network within the battery electrode. This contributes significantly to improving the environmental balance, e.g., by reducing the carbon footprint of material production. In addition, the standard carbon nanotubes (CNTs) that have already been commercialized are being replaced by new, much thinner CNTs. This allows to reduce the amount of carbon materials for the same or even better battery performance and leads to improved resource efficiency. Moreover, this is the only CNT material in the world made from a renewable bioethanol feedstock.

eit RawMaterials
Connecting matters

Co-funded by the European Union

Renewable raw materials further reduce carbon footprint

In addition, a life cycle analysis will be carried out as part of the project to assess the sustainability of the production process.

On the one hand, the “HiQ-CARB” project team relies on high-profile companies such as ARKEMA or ORION for the production of advanced additives and Customcells for battery cell production. On the other hand, well-known R&D partners such as the Fraunhofer Institute for Silicate Research ISC, Aalto University and the University of Bordeaux are involved in the scientific part of evaluating and testing the new material combinations themselves and the battery cells produced from them. The project is funded by the European Union through EIT RawMaterials.

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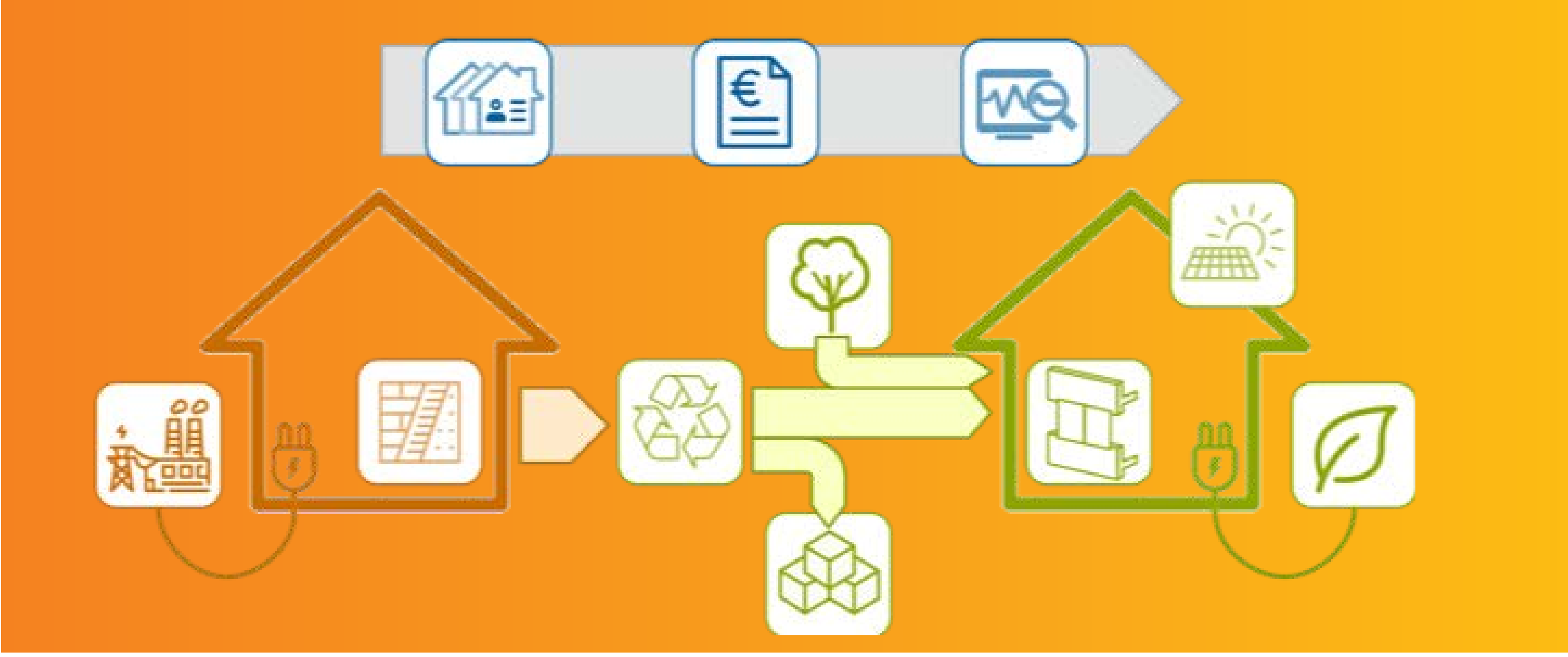
"DeCaBo" – Saving CO_2 and resources in building

The DeCaBo (DeCarbonization of Buildings and Operation) project was launched as part of the Fraunhofer-Gesellschaft's self-financed innovation program. With a duration of just five months, the project investigated solutions for four relevant technology areas that support the Fraunhofer-Gesellschaft's goal of being climate-neutral by 2030: low-CO_2 building products, planning and operation of buildings as well as recycling of building materials.

Construction waste © pixabay

The broad know-how of 16 Fraunhofer Institutes was incorporated into the various issues. With the aim of developing methods and tools for the transformation of the Fraunhofer-Gesellschaft towards climate-neutral operation, performance models for renovation roadmaps and potentials for renewable energy sources were identified. For the digitization of building operation to increase energy performance, a roadmap was drawn up for the nationwide introduction of intelligent building monitoring and initial innovative financing models were also developed for the public sector.

But we also wanted to find new solutions for the production, use and efficient recycling of building materials because the development of new building materials and methods can make an important contribution to reducing CO_2 emissions. In addition to methods and processes for new building products, such as insulating materials made from recycled rotor blades and renewable raw materials or hybrid wood-concrete building components, the project also successfully tackled restoration render and new technologies and materials for composite heat insulation systems. In this context, Fraunhofer ISC played a key role in the development of joining technologies in glass technology using inductively fusible glass solders for energy-saving vacuum heat-absorbing glazing, which enable rapid and energy-saving gas-tight bonding of the glass panes.



DeCaBo- DeCarbonisation of Buildings and Operation

The key to success here was the bonding of special magnetic particles (MagSilica®[1]) particles (MagSilica®) with low-melting glass.

More environmentally friendly alternatives for PVC frame profiles and sealing compounds based on renewable raw materials in combination with rPET/rHDPE recyclates were also tested. Fraunhofer ISC contributed know-how and material for long-term temperature and UV protection of the novel extrusion materials with its ORMOCER® coatings. ORMOCER® know-how was also used to improve natural-fiber-reinforced geopolymers, which have a significantly better carbon balance than concrete with steel reinforcement.

When building materials are recycled, the separation of the different material components poses a key challenge. Within the scope of the project, processes for the application of thermal separation methods to adhesives were successfully refined.

Here, too, specially adapted MagSilica® particles from the ISC were used, which can be readily dispersed in resin systems. This enabled inductive processes to be successfully used for the simple separation of bonded joints of composite heat insulation systems and precast concrete parts.

With the DeCaBo project, a number of interesting and creative solution approaches were conceived and tested that can greatly contribute to the CO_2-saving construction and operation of buildings. What initially generated ideas for the Fraunhofer-Gesellschaft itself will also be able to provide important impetus for the construction industry in the future for the further development of building materials and methods to reduce the high CO_2 emissions from this sector.

1 MagSilica®: registered trademark of Evonik

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“EWA” – Efficient water treatment

Reuse the resource water several times!

Many industrial processes rely on water as a resource – both as a raw material for production and as a means of transport, a solvent or a separating agent. In order to use water as resource-efficiently and sustainably as possible and to conserve drinking water reserves, new solutions are needed for more efficient water use and recycling.

In the KMU-akut project “Efficient water treatment” – abbreviated EWA for “Effiziente Wasseraufbereitung” – a number of Fraunhofer Institutes under the leadership of Fraunhofer ISC and IFAM are pooling their expertise in electrochemical process technology, particle technology, and materials analysis. Together with industrial partners, they are working in four subject areas on the efficient treatment and multiple use of water, an important resource.

For many small and medium-sized companies, conventional commercial process water treatment is either oversized, too specific, too expensive, or simply unsuitable. The EWA project aims at closing this gap and developing solutions that meet the needs of small and medium-sized enterprises through their flexibility, scalability and comparatively low cost. Together with the three other Fraunhofer Institutes IKTS, ISE and IGB as well as five industrial partners, they carried out exemplary feasibility studies and validation projects in the fields of battery recycling, lithium extraction, alginite in sewage treatment processes and seawater desalination for the lead markets energy industry, chemical industry, health industry as well as plant and mechanical engineering.

A good overview of the working methods of the EWA project partners is provided, for example, by the subproject on the efficient and sustainable treatment of process water from lithium-ion battery recycling plants. The increasing number of electric vehicles produces more used traction batteries. The ISC’s goal in the EWA project is to recover valuable battery materials as efficiently as possible and to purify process water such that it can be recirculated.

Ideally, the materials should then be sorted by type so that they can be directly reprocessed into new batteries. The starting point for the project work was the electrohydraulic shredding process (referred to as EHZ, elektrohydraulische Zerkleinerung) – a development of the project partner Impulstec – with which the batteries can be broken down into individual material fractions. The water-based process produces coarse and fine material fractions as well as substances that go into solution.

Project partner MAB Recycling is a user of the EHZ and was looking for a suitable treatment method to remove valuable battery materials as completely and separately as possible and to free the process water from disturbing impurities.

The recycling specialist supplied the process water as a raw material and in return received analysis results and important know-how to advance its own water treatment.

Another industrial partner in the project was CEPA, a manufacturer of industrial centrifuges.

Valuable materials from process water treatment

Cost-effective, environmentally friendly replacement for activated carbon

The company has been working for some time with Fraunhofer ISC on the further development of centrifuge technology.

In the EWA project, the three companies worked together with Fraunhofer ISC on specific issues to reduce the volume of process water, to recycle it as far as possible, and to promote the separation of materials by type as far as possible. As a result, processes are improved, water is saved, and further ideas for joint projects beyond EWA are generated.

"Selective adsorption of metal ions and environmental pollutants"

In this process, magnetic adsorbent particles are used to selectively and efficiently remove (heavy) metal ions and pollutants such as drug residues from process and sewage waters.

Terra Natural Resources GmbH is also on board as an industrial partner. Magnetic and silicate particles are combined with a particularly efficient and selective adsorbent for environmental pollutants: alginite. It is a special, naturally occurring, recyclable mineral that, unlike the activated carbon currently used, is cost-effective and has high environmental compatibility and very good separation performance for both hydrophilic and hydrophobic substances. The clever modification of alginite with magnetic particles ensures a consistently efficient adsorption performance and also guarantees residue-free separation of the absorbent particles from the treated sewage waters. The cost-effective and sustainable process has great potential and will be a valid alternative for use in sewage water treatment plants in the future.

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3D printing – with less material and energy input to the finished product

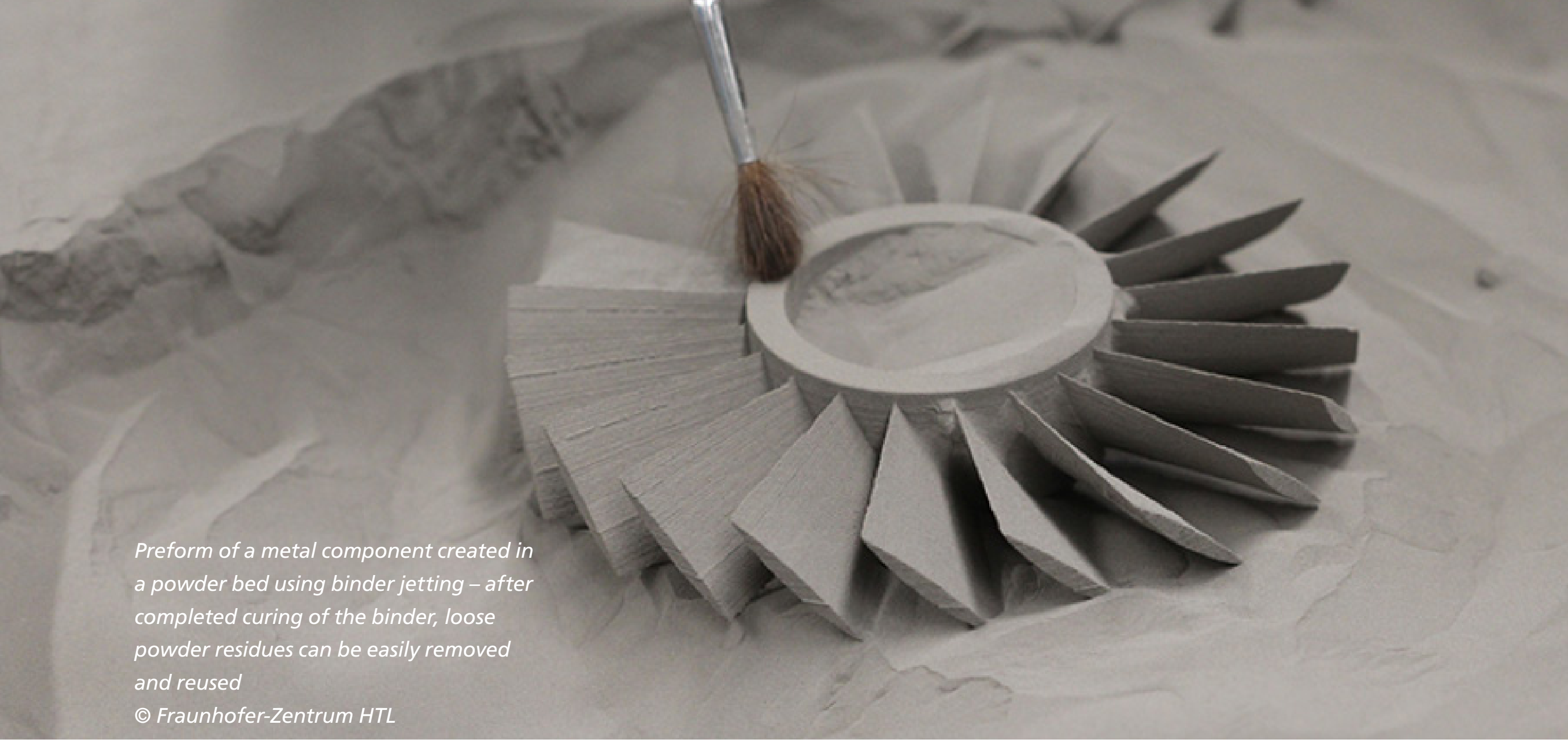
Future manufacturing processes will be digitally controlled and automated. In addition, they should be resource-conserving and energy-efficient and create products that are as fully recyclable or biodegradable as possible. In combination with the right material concepts, additive manufacturing can be a good solution and therefore has great potential in certain areas of application. Another advantage of additive processes is that individual components and entire systems can be customized easily and cost-effectively – keyword "batch size 1". This applies in particular to energy-intensive manufacturing processes such as in special ceramics or novel material composites in the field of high-temperature lightweight construction, but also to the use of biological materials and their system integration, especially in the field of medical engineering and medical product development. For example, this technology is interesting for biofunctionalized carrier materials or individualized implants. And the manufacture of specific (micro-)electronic and (micro-)optical components also benefits from the variability of additive manufacturing processes.

In addition to the advantages in customization, resource efficiency is also playing an increasingly important role in the use of additive processes. Near-net-shape manufacturing by 3D printing without material losses is also attractive for the series production of complex components and structures, especially where highly qualified materials are used. The Fraunhofer Institute for Silicate Research ISC uses a range of processes in combination with customized material concepts for a wide variety of applications and continues to develop additive techniques. Common 3D printing processes build up workpieces layer by layer. Depending on the material, chemical (2C) or physical (temperature, light) initiation is used. Typically, 3D printing processes are used as stand-alone systems. For industry-related processes, however, concepts for the automation of process chains with integrated 3D printing are required. In terms of products, different 3D printing processes can even be combined to achieve optimally adapted material combinations and functions.

Fraunhofer ISC is working on the system integration of different 3D printing technologies in one device and is developing in-process measuring and monitoring systems. In this context, the focus is on issues such as automated material supply, post-processing (3D polishing), or the standardization of interfaces in order to facilitate implementation in existing processes.

Special ceramics / metals / metal-ceramic composites

The Fraunhofer Center for High Temperature Materials and Design HTL uses two-stage additive manufacturing processes for the production of metals, ceramics and multi-material composites. To create what is called a green component, the low-energy additive manufacturing process is separated from the subsequent furnace treatment that usually demands a great deal of time and energy and is needed for debinding and sintering or infiltration. This has the advantage of avoiding thermal stresses and warpage that occur in other 3D printing processes. In addition, the simultaneous firing of many components makes these processes very attractive in respect of economic efficiency. In addition to feedstocks and printing parameters, HTL is developing analysis methods for quality assurance of green-state components. This enables efficient optimization along the first half of the process chain. For the design of the subsequent thermal processes, HTL determines the material properties that are crucial for the process kinetics. For this purpose, HTL uses, among other things, conventional thermal analysis as well as in-situ analysis in the in-house developed thermo-optical measuring systems (TOM). The measurement data are then used in a coupled FEM-based simulation that takes thermal, mechanical, chemical and geometric aspects into account for optimization. This allows the material, component design, furnace chamber and thermal processes to be simulated in interaction. This forms the basis for the a priori prediction of potential sources of defects, shrinkage and warpage with regard to specific components and materials and for designing the entire process chain for reliable, economical and yet flexible series production.



Preform of a metal component created in a powder bed using binder jetting – after completed curing of the binder, loose powder residues can be easily removed and reused
© Fraunhofer-Zentrum HTL

Sensors / actuators / optical components

Miniaturized sensor and actuator elements are also to be integrated into the manufacturing process via 3D printing. Fraunhofer ISC is developing the associated new material combinations, which can be operated in a piezoelectric, thermal, electrostatic, optical, chemical or mechanically responsive manner. The production of optical components requires particularly homogeneous, transparent and light-resistant 3D molds that are free from internal interfaces and have a very high surface quality. Aspheres and gradient-index (GRIN) lenses are difficult to manufacture using conventional methods. 3D printing offers optical designers the chance to design and rapidly test new components as free-form surfaces far from the usual spherical and rotationally symmetric geometries.

Biomedicine / medical devices

In addition to its use for dental products and custom earmolds, the use of additive manufacturing processes is also of interest for biomedical applications. For example, new biodegradable and/or 3D-printable materials offer solutions, e.g., for the production of support structures (scaffolds) or functional elements that are only needed temporarily and are subsequently degraded by their physiological environment. The growth process and behavior of cells and microorganisms can be specifically influenced with biocompatible and bioactive materials (stimulation, release of nutrients, support of wound healing). The combination of 3D printing processes with living cells (bioprinting) can offer completely new possibilities for biomedical and pharmacological issues. For this purpose, gentle printing technologies are being further developed together with cooperation partners.

Resource-conserving recycling / secondary raw materials

The 3D printing process requires highly specialized primary materials with precisely defined properties, because resource-conserving use of recyclates or secondary raw materials has not been possible to date. Fraunhofer ISC aims at harnessing this valuable reservoir of materials with its chemical synthesis expertise. Production waste or recycled materials are to be modified such that they are available as secondary raw materials with the specifications required for 3D printing processes.

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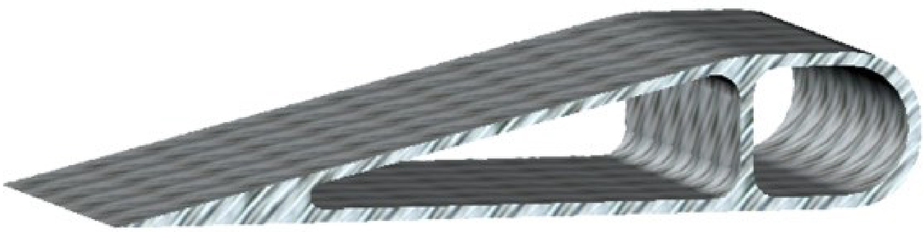
"AirfOx" – Development of a fiber-reinforced near-net-shape airfoil made of oxide ceramics with high-modulus strength

CMCs can help save resources and reduce CO_2 emissions.

In the field of aviation, weight reduction and energy efficiency are at the top of the list of requirements – also for new materials and components. Ceramic matrix composites (CMC) offer significant advantages for use in aircraft gas turbines: CMC components are only one-third as dense as conventional metal components, so they contribute to a significant reduction in weight. They can also be used at temperatures up to 300 K higher. In the hot section of gas turbines, CMC components therefore enable more efficient and complete combustion, save fuel and thus reduce CO_2 emissions. Oxide ceramic matrix composites (O-CMC) also naturally ensure high oxidation resistance and a low tendency to corrosion in the combustion atmosphere, thus increasing the service life of the components.

Since the beginning of 2021, the Fraunhofer Center HTL has been working within the scope of the "AirfOx" project, funded by the Bavarian aerospace program BayLu25, to develop a process that can be automated and technologies with which near-net-shape engine blades for aircraft gas turbines (airfoils) can be integrally manufactured from oxide ceramic fibers in series production.



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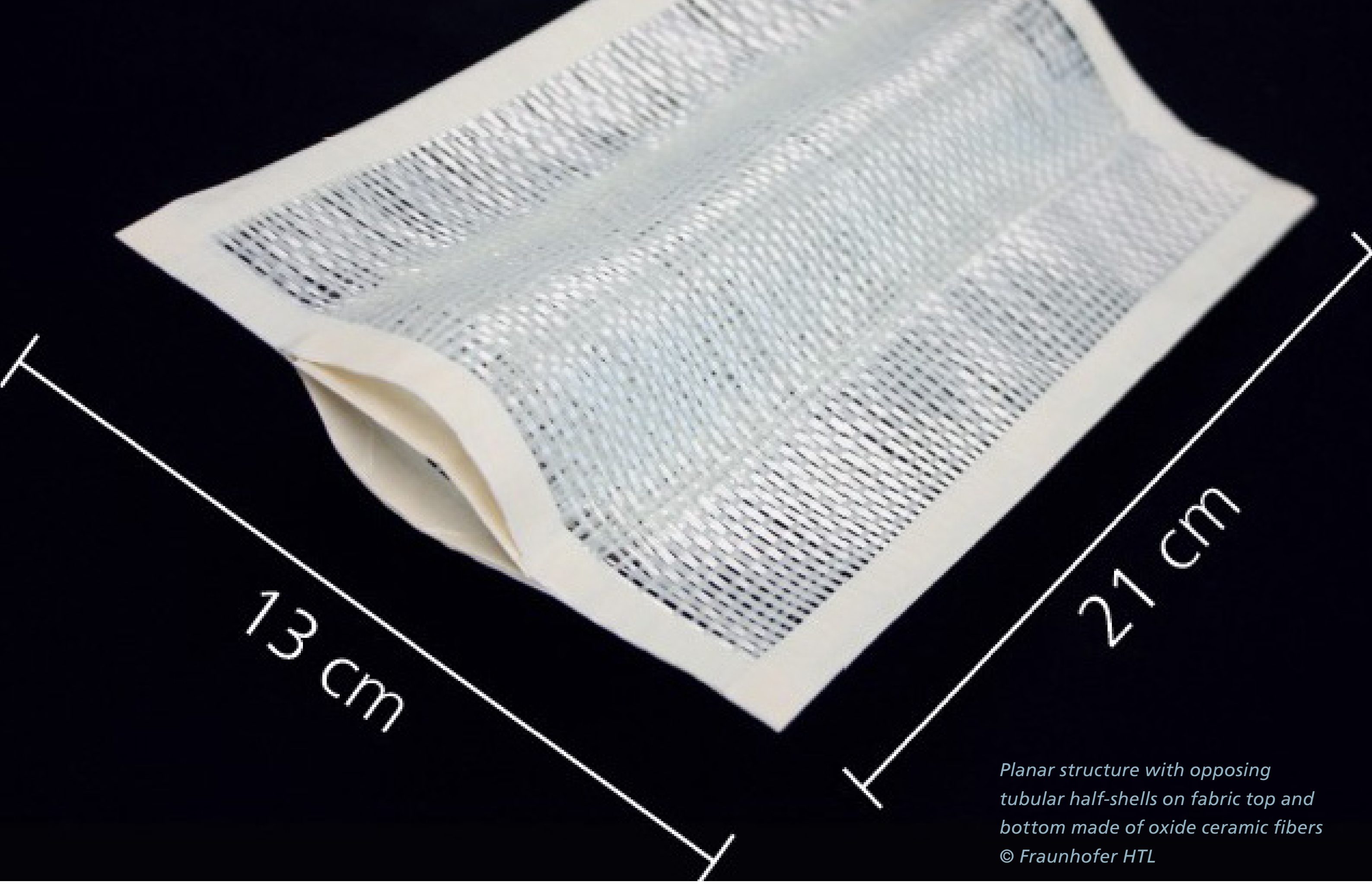
Airfoil geometry to be translated into a textile ceramic fiber preform.

By using multiscale simulation and CAD programs for load-oriented fiber design, an airfoil will be used as an example to demonstrate how a complex 3D preform can be developed in CMC manufacturing. Innovative weaving techniques are being used to develop a new manufacturing method for three-dimensional fabric preforms made of ceramic reinforcing fibers for CMC components with cover surfaces of different lengths, while at the same time allowing support structures in the form of



Planar structure with opposing tubular half-shells on fabric top and bottom made of oxide ceramic fibers © Fraunhofer HTL

webs to be woven in. Locally occurring stress peaks, which are detected during modeling, can also be taken into account as early as in the fabric design phase. The transfer of textile 3D weaving techniques to ceramic fibers is a particular challenge due to their brittleness. With the special manufacturing technology, the textile-ceramic 3D preforms are produced in one piece close to the final contour. This ensures high resource efficiency in the manufacturing process. In the project, a digitization concept for the production of the preform is being developed in order to continuously record and evaluate the production data, which are essential for the component properties, during the weaving implementation of the textile semifinished product. The aim is to set up a data management system as a preparatory measure for certifications to ensure the traceability of all process parameters, thus facilitating subsequent aviation approval.

The textile semifinished product is converted into a CMC component in four steps, with the special process for infiltration being used for the first time for this type of 3D preform. Focal points are the development of the technology for the infiltration process and the ability of the process to be automated.

CMC airfoils can significantly contribute to reducing fuel consumption and lowering CO_2 emissions. "AirfOx" will make a significant contribution here towards series production and is intended to pave the way for establishing the new resource-efficient technology for producing complex 3D fiber prefoms for CMCs, which can then also be used for other CMC types, e.g., SiC/ SiC-CMC.

Funded by the Bavarian State Ministry for Economic Affairs, Regional Development and Energy.

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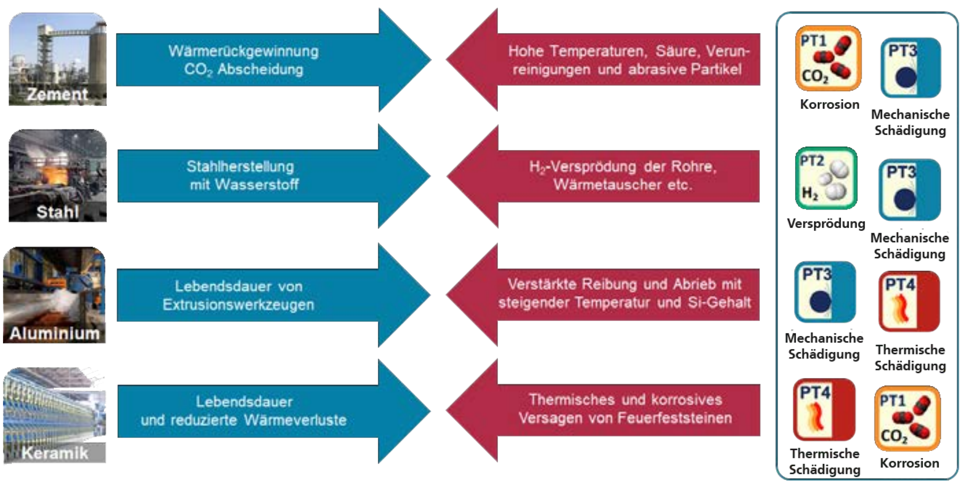
“FORGE” – Development of novel and cost-effective coatings for high-temperature applications

Achieving a lot with little material

The EU Horizon 2020 funding program aims at supporting the transformation process of energy-intensive manufacturing industries towards carbon neutrality in 2050. The SPIRE joint project “FORGE” addresses four essential challenges in the four key technologies of cement, steel, aluminum and ceramic production: H2 embrittlement, corrosion, abrasion as well as mechanical and thermal damage.

Equipment currently used in energy-intensive industries is susceptible to corrosion and erosion, as well as brittle fracture and cracking caused by the gas atmosphere and thermal stress during furnace operation. Increasing the production efficiency and service life of plant components is essential for more environmentally friendly cement, steel, aluminum and ceramics production, also in view of plants with reduced CO_2 emissions planned for the future. The EU-funded “FORGE” project aims at developing new cost-effective coating solutions specifically for the protection of particularly vulnerable plant components. The focus here is on novel compositionally complex materials, which in theory promise outstanding mechanical, chemical and thermal stability due to their special composition. FORGE will explore this new material range of compositionally complex alloys (CCA) and compositionally complex ceramics (CCC).

Within the scope of the “FORGE” project, the Fraunhofer Center for High Temperature Lightweight Materials and Design HTL is responsible for the development of novel coatings to reduce thermal and corrosive degradation of refractory material in tunnel furnaces. The focus is on ceramic coatings based on CCC with complex, entropy-stabilized compositions. These compositions will be developed by combining methods dealing with machine learning, artificial intelligence and computational chemistry, as well as by thermodynamic considerations and high-throughput experiments.

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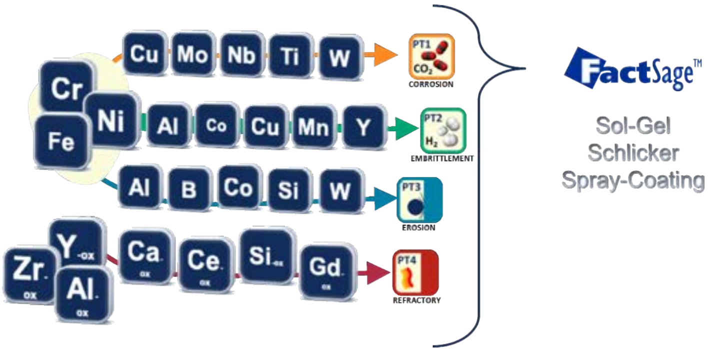
Entropy-stabilized compositions ensure high durability

The project will use the new CCA and CCC high-performance coatings in particularly vulnerable process steps such as carbon capture and waste heat recovery, as well as directly in the furnaces to combat the degradation forces that occur there. As a result of the FORGE project, it is expected that the operating life of the vulnerable components in the addressed industries can be considerably increased, leading to a significant minimization of costs as well as CO_2 emissions.



More about the project

Sustainable Process Industry through Resource and Energy Efficiency

This project has received funding from the European Union's Horizon 2020 research and innovation programme. Grant agreement 958457

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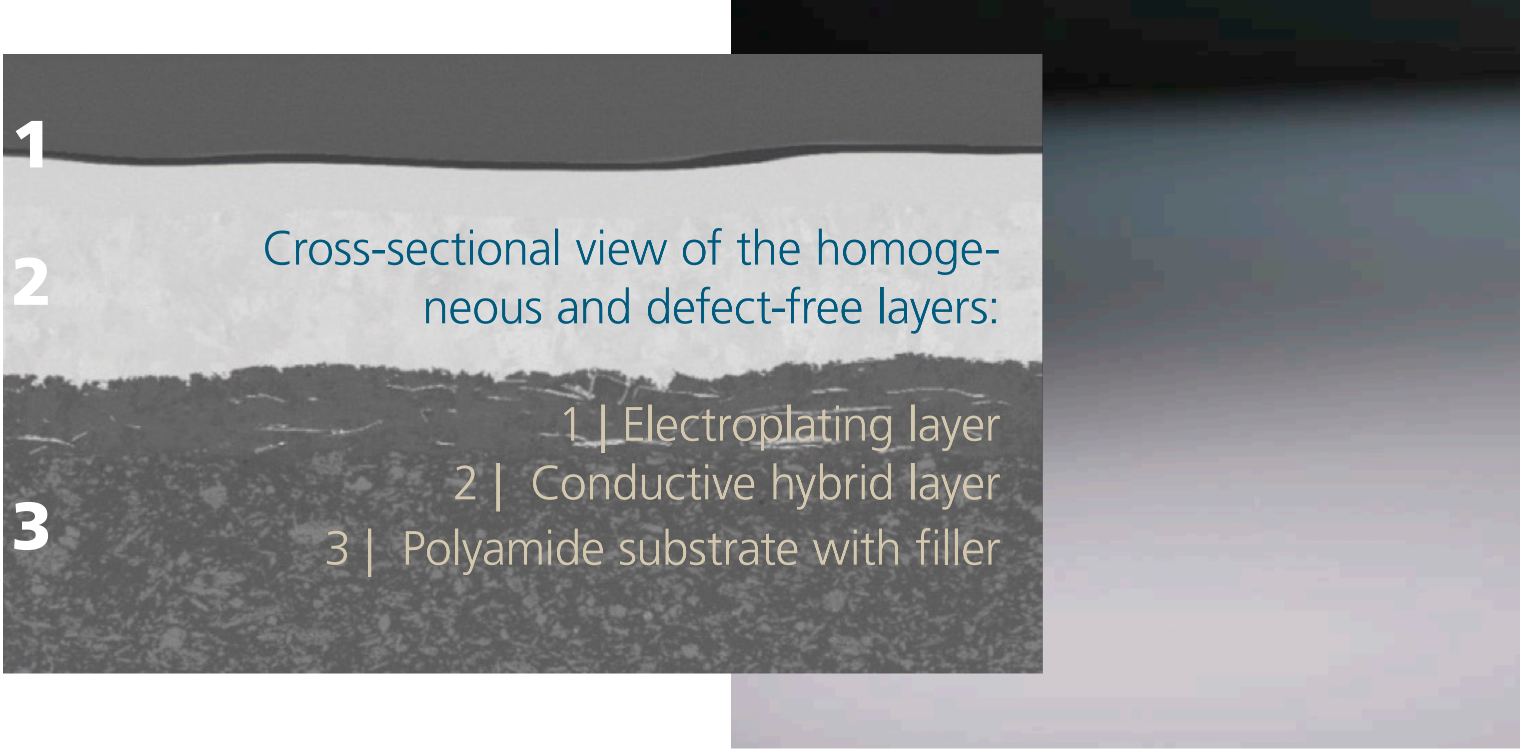

Cross-sectional view of the homogeneous and defect-free layers:

1 | Electroplating layer
2 | Conductive hybrid layer
3 | Polyamide substrate with filler

"digaP" – Coating process saves critical resources during electroplating

The first thing that literally catches the eye in most products is their surface. That is why its texture is enormously important. Innovative coatings not only give surfaces a fine appearance, they above all create new functionalities and added value with little material input and can help replace critical materials or process steps in production.

Galvanized plastics, for example, are manufactured and used in the automotive industry and in many other sectors. The galvanized surfaces give plastic components, which are inexpensive and easy to manufacture, a high-quality metallic appearance and pleasant feel. However, electroplating requires very complex procedures and processes using rare metals of the platinum group as well as highly toxic and/or harmful substances (e.g., acids such as hydrofluoric acid or chromosulfuric acid). It is therefore economically and ecologically necessary to make existing electroplating processes for plastic parts more environmentally compatible, to simplify the process and also to greatly reduce the amount of rare metals in the process. In order to refine polymers, but also other electrically non-conductive materials, with a metal layer in an electroplating process, a thin, electrically conductive coating must first be applied through "chemical metallization". Thin copper or nickel layers are usually used to do this.

The chemical metallization process requires a catalyst on which copper or nickel is deposited. This catalyst is palladium (Pd), an element of the platinum noble metal group. In the processes commonly used today, all materials to be chemically metallized are first given a palladium layer by dip coating. Before the palladium coating is applied, the plastic surface is "roughened" by etching with chromosulfuric acid. This step is particularly critical because hexavalent chromium is still used here.

Fraunhofer ISC is working with two well-known industrial partners from the plastics and electroplating sectors to develop a more environmentally friendly and faster process. It eliminates the need for palladium as a conductive metallization material, avoids the use of environmentally harmful chemicals and significantly reduces the number of process steps previously required. This is made possible by specially designed multifunctional hybrid polymers. Thanks to their chemism and special structure, they provide good adhesion between the plastic surface and the electroplated metal layer, and doping provides the conductivity required for the electroplating process. The raw materials required for their manufacture are inexpensive and commercially readily available, and they are applied in a single, simple painting process. The sometimes toxic chemicals for etching steps and activation, as well as the critical palladium, are thus completely replaced.

STANDARD ELECTROPLATING PROCESS	NEW ELECTROPLATING PROCESS
Plastic substrate	Plastic substrate
↓	↓
Surface swelling with solvent for acid treatment	Conductive ORMOCER® layer (wet paint)
↓	↓
Chromosulfuric acid – etching of the plastic material	Deposition of Cu – followed, e.g., by Cr
↓	
Deposition of Pd compounds and reduction of Pd0	
↓	
Chemical deposition of Ni0 on Pd0	
↓	
Deposition of Cu – followed, e.g., by Cr	

In the ongoing joint project, the material and process are being optimized to ensure that the surface quality of the electroplated product meets the highest demands. At the same time, the material synthesis for the conductive hybrid polymer is being scaled up in order to already have capacities for sampling and testing under pilot conditions at the end of the project. Fraunhofer ISC's material innovation could make electroplating much more environmentally friendly and simpler by eliminating critical process chemicals.

For the industrial companies involved, not only the environ mental aspects but also the simplification and acceleration of the process are very attractive from an economic point of view.

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"OASIS" – EU project enters next round with SME democases

As part of the EU "OASIS" project, 12 pilot lines for innovative lightweight composites – including nanoparticle production at Fraunhofer ISC – have been set up and expanded so far. These pilot lines have already proved their worth in the OASIS showcase projects. Fraunhofer ISC was involved in the Acciona Construccion SA construction group's showcase for the development of a new CO_2-saving production technique for reinforced lightweight concrete components. To this end, the ISC's particle technology contributed inductively heatable nanoparticles that were used to uniformly cure the resin matrix of glass fiber reinforcement (GFRP) during extrusion. The advantage of the new process is the rapid inductive heating. This allows the entire cross-section to be cured uniformly and reliably. Defects and incompletely cured areas are avoided. The new lightweight reinforcements can thus save energy and weight, a step forward in reducing CO_2 emissions in building and construction. The magnetic particles were used to preheat the resin in the production process via an induction coil, thus achieving a 100% increase in production speed in practice. The final concrete components reinforced with GFRP bars have achieved good results in terms of mechanical properties and fire behavior. At present, durability tests in a real marine environment are being conducted, the results of which will provide further interesting information.

However, "OASIS" actually aims at a steady use of the pilot lines beyond the showcases carried out in the project and, above all, at making this infrastructure available to small, medium and large companies. For this reason, there have already been two open calls to companies to apply with project ideas. Interesting projects for the ISC pilot line emerged from both the first and second calls. With a well-known Polish manufacturer of railroad seats, the nonhalogen flame-retardant particles of the ISC pilot line, in combination with nano-based products of other "OASIS" pilot lines, will be used for a new product that is lightweight, customizable according to customer requirements and environmentally friendly. For the manufacturer, the new development may mean a significant competitive edge in the rail sector.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814581

Centrifuged nanoparticles

More about the pilot line for particle production at https://www.partikel.fraunhofer.de/

More about the "OASIS" project at https://project-oasis.eu/

Key technology for recycling composite materials – simplified bonding/debonding with inductively heatable particles

The second call involves a project by another well-known German supplier working on a concept for improved recycling of composite materials in novel lightweight structures for the mobility sector. Here, the purpose of the inductively heatable particles from the ISC pilot line is to enable simple bonding/debonding and break adhesive bonds by inductive heating. In both cases, the particulate additives from the expanded co-pilot plant at Fraunhofer ISC, with their quality-assured particle production on a kg scale, make a significant contribution to the success of new, more environmentally friendly and resource-conserving industrial products, and do so with a comparatively low material input – less is (often) more.

The "OASIS" concept, an open access single-entry point for companies wishing to use an infrastructure for innovative lightweight materials that is based on research but is also capable of pilot production, is obviously proving its worth.

Thus, in the two open "OASIS" calls, eleven so-called democases for new product ideas have already been carried out or at least started, with industrial customers from different sectors. In addition to the construction and mobility branches, OASIS customers also come from the medical engineering and sporting goods sectors. For this reason, work is currently underway to establish a corresponding facility that will continue to offer the services developed to date even after the end of the EU "OASIS" project – a project result that is also positive for the ISC pilot line.

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“ImAi” – New test method to replace worldwide standard animal test

The “ImAi” project, funded by the German Federal Ministry of Education and Research, aims at creating an animal-free replacement for the Draize test on rabbits used worldwide to evaluate the eye irritation potential of chemicals. The new test is based on tissue models of the cornea cultivated in the laboratory in conjunction with impedance spectroscopy.

Every chemical substance that is put into circulation must undergo various tests to define its hazard potential and declare it accordingly. One of these mandatory tests examines the potential hazard for eye irritation and classifies the substances accordingly into categories “1” for irreversible damage, “2” for reversible damage, or “3” not requiring labeling if the substance is not irritating. To classify the harmfulness of substances to the eye, a stressful toxicological test is performed worldwide on live rabbits, the so-called “Draize test” (according to OECD test guideline TG 405), in which the substances are dripped into the eye of living rabbits. This test has been in effect since 1944.

In order to replace this painful procedure, several attempts have been made to cultivate tissue models of the human cornea in the test tube (in vitro) and to use them as test systems. However, since previous tissue models do not allow to differentiate between irreversible and reversible damage, only a reduction, not a replacement of animal experiments has been achieved so far.

For this development, our colleague Dr. Christian Lotz received the Felix Wankel Animal-Welfare Award.

The Translational Center for Regenerative Therapies TLC-RT of the Fraunhofer ISC, the Federal Institute for Risk Assessment and the Goethe University Frankfurt are working together with the companies Clariant Produkte GmbH and Courage Khazaka Elektronik GmbH on a powerful test system in the “ImAi” project. The new method is not only intended to completely replace the “Draize Test”, but also to allow more reliable predictions, since the tissue model will be based on human cells.

The core of the test system will be the modified, long-lived cornea model of the TLC-RT. In order to distinguish between the different categories of ocular damage, a non-invasive measurement methodology will also be developed, which will allow repeated examination of the artificial cornea without additional disturbance. In this way, a potential damage to the eye can be reliably predicted.

The first milestones – test setup and adaptation of impedance spectroscopy to the cornea models, i.e., how can the damage and modes of action on the cornea be easily measured, distinguished and evaluated by impedance spectroscopy – have already been passed. The prototype of the handy and easy-to-use mobile spectrometer is also already being used to measure the test substances.

3R principle

As a principle of experimental scientific work: replace animal testing as far as possible by other methods (Replacement), reduce the number of animals (Reduction) and minimize their suffering in the tests (Refinement).

In the coming months, the device software, the parameterization of the test procedure, the standardized test procedure and the measurement protocols will be optimized to enable the most comprehensive statements possible about the modes of action of the test substances and a reliable and rapid prediction about the irritant potential of chemicals. Subsequently, the new test procedure will be validated in a multi-laboratory validation study.

3R principle saves animal lives and resources

In the medium term, if validation is successful, the results obtained in the project will allow implementation as a stand-alone method in an OECD test guideline. Then, after about 80 years, the end of the "Draize Test" might finally be in sight – and not only the rabbits will not shed a tear. This is because the new procedure not only spares the test animals, but also saves personnel resources and time, and ultimately reduces the costs of a test. In the future, it is conceivable that the measurement method can be transferred to other in vitro models (skin, blood-brain barrier) and serve as a platform technology. There is already great interest in the method from industry.

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LESS IS MORE

Making more out of fewer resources is becoming an increasingly important goal for humanity. Consumption and population growth increase, but the reserves that our planet holds are naturally finite. A paradigm shift is needed - also to create fair living conditions for all. Growth and prosperity must be decoupled from resource consumption. Research and innovation must work on this even more than before. In this annual report, we have compiled many examples of how we are already making progress along this path with our materials research - from the responsible use of the vital element water to resource-saving printed electronics on paper.

And here too, good stewardship of resources starts on a small scale. That is why we have reduced the printed version of the annual report to the project section. The cover paper is made of recycled cardboard, and grass fiber, certified with the FSC® Mix credit eco-label, was used for the top and bottom sides. This means that the grass cardboard significantly reduces the consumption of water and resources during production. The inner paper is made of 100% recycled paper, FSC-certified and has been awarded the Blue Angel and the EU Ecolabel.

You can find more information about the work behind the projects and what else has been going on on our website at **https://www.isc.fraunhofer.de/annual-report**

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