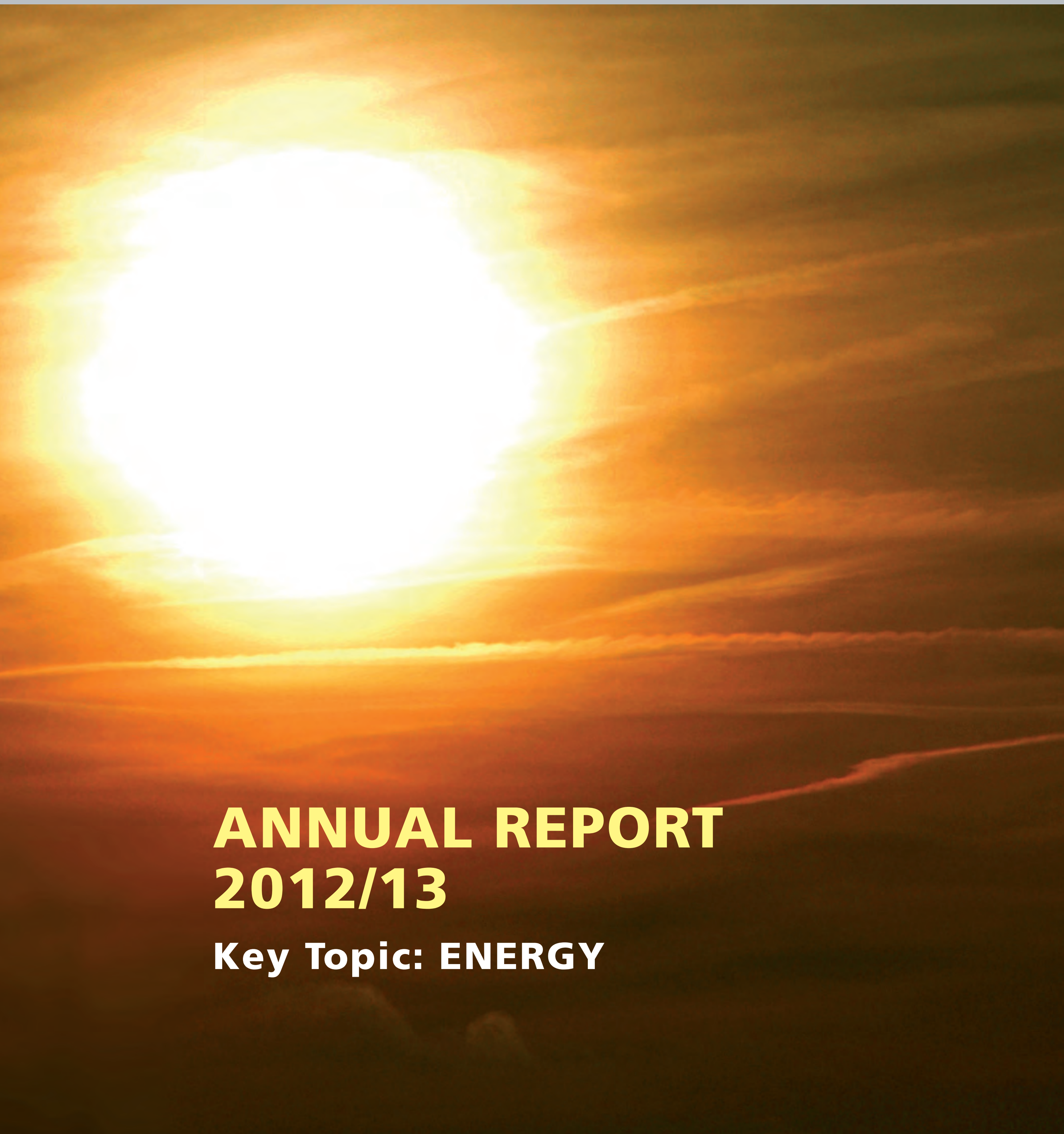
Fraunhofer ISC

FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH ISC



ANNUAL REPORT 2012/13

Key Topic: ENERGY

The sun is the largest energy source. In terms of the energy turnaround Fraunhofer ISC is working on ways and procedures to use solar energy and other renewable energy sources such as wind and water more efficiently, intelligently and safely. Another field of work is also to make more sustainable use of energy gained from fossil fuels. This year our report focuses on the issue of energy and it covers functional coatings, energy storage systems, methods of energy optimization of industrial processes and much more.

ANNUAL REPORT
2012/13

Key Topic "ENERGY"

PREFACE

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

2012 was yet another eventful and exciting year for the Fraunhofer Institute for Silicate Research ISC. With the creation and expansion of the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS at its twin sites of Alzenau and Hanau, the amalgamation of the Project Group Ceramic Composites into the Fraunhofer Center for High Temperature Materials and Design HTL in Bayreuth, and with preparations underway for the creation of new Fraunhofer application centers at the universities of applied sciences in Aschaffenburg and Hof, the ISC's activities are now spread across almost the whole of northern Bavaria, from Hof to Alzenau, with satellites in Hesse (Hanau) and Baden-Württemberg (Bronnbach). Accordingly, the institute's operating budget increased by 18.9 % from 18.5 million euros in 2011 to 20.4 million euros in 2012. At the end of 2012, the ISC had 343 employees on its payroll, including 197 permanent staff. As in previous years, the institute reported a positive result in its financial statements for 2012.

To keep pace with this growth, the institute is continuing to expand its capacity through construction projects. The new Technikum III building in Würzburg, containing ultramodern laboratories and experimental facilities, is due for completion in the summer of 2013 and subsequently will be put into operation. This exceptionally well-equipped research center was designed by the reputed office of Zaha Hadid Architects, London. Its unusual architecture mirrors the institute's intent to explore new approaches to the transformation of scientific findings into marketable products.

Another major construction project is that of the planned new laboratories and offices of the Fraunhofer Center for High Temperature Materials and Design HTL in Bayreuth, where construction work is due to start in the summer of 2013. Other new building projects are scheduled to begin in 2014 to provide accommodation for the Project Group IWKS in Alzenau and Hanau. The internal planning process is already underway.

Under the general management of Professor Rudolf Stauber, the Fraunhofer Project Group IWKS has been rapidly taking shape. By the end of 2012, more than 20 scientists had been recruited to staff the project group's two locations of Alzenau and Hanau, and immediately set to work on the first industrial projects.

The IWKS's second site at the Hanau-Wolfgang industrial park was inaugurated as planned on June 29, 2012. Until the new institute building has been completed, the IWKS will be based in premises rented from the company Umicore. The inauguration ceremony was attended by over 200 project partners and invited guests from industry and public life, including former President of the Fraunhofer-Gesellschaft, Prof. Hans-Jörg Bullinger, who retired from office in the autumn of 2012, the Deputy Prime Minister of the Federal Land Hesse, Jörg-Uwe Hahn, and the Hessian Minister of Science Eva Kühne-Hörmann. Additional funds were granted in the summer of 2012 by the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology for the period 2014-18 to finance the further expansion of the Alzenau site.

The Bavarian Ministry of Economic Affairs has also agreed to provide initial funding to support the creation of a Fraunhofer Application Center for "Product Design for Recycling" at Aschaffenburg University of Applied Sciences. This center will work in close collaboration with the Project Group IWKS in Alzenau, where most of the practical experiments will be conducted. A cooperation agreement with the university was concluded in November 2012, and the first steps to establish the application center were initiated immediately. The municipality of Alzenau has made it known that it is willing to support these activities by funding a professorship at the Aschaffenburg University of Applied Sciences.

After the establishment of the Fraunhofer Center for High Temperature Materials and Design HTL in January 2012, further important steps were taken to place the future activities of this new center on a solid basis in the course of the year. Dr. Raether was appointed as the sole director as of October 1,

2012, and the focus of the center's work was redefined, giving priority to the optimization of energy and resource efficiency, and the quality assurance of heat treatment processes. These are areas of research in which the ISC has a proven reputation as a reliable source of innovation for its industrial partners.

The Bavarian government has approved additional funding for the Fraunhofer Center HTL, part of which will go toward the construction of the new institute building in Bayreuth (see above). In August 2012, Martin Zeil, the Bavarian Minster of Economic Affairs, handed over the official letter of approval for the first tranche. The center's future is furthermore assured by a government grant, accorded in the fall of 2012, to support the project "Efficient Use of Heat Energy in Industrial Processes". Moreover, a Fraunhofer Application Center for the processing of ceramic fibers is being set up at Hof University of Applied Sciences, and is expected to open sometime in 2013.

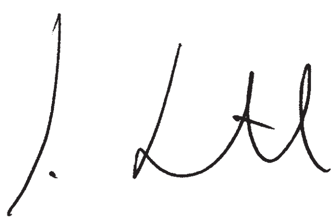
In parallel with these activities at its external sites, the institute has been drawing up a business strategy for the years 2013 to 2017, which will be assessed by independent experts as part of a strategy audit in the summer of 2013. Essentially, the institute intends to maintain its present focus on energy, environment and health. The activities of the two internal research centers, CeSMa (Center Smart Materials) and ZfAE (Center for Applied Electrochemistry) are progressing as planned. In September 2012, the Bavarian Minister of Economic Affairs, Martin Zeil, handed over the official letter of approval for a grant of 8 million euros (spread over 5 years) to fund CeSMA's work on the development of dielectric elastomer generators (DEGs), a novel technology for distributed energy production based on renewable resources.

In November 2012, the ISC celebrated the 60th anniversary of its re-establishment in Würzburg as a Max Planck institute after the dissolution of the original Kaiser Wilhelm Institute for Silicate Research, founded in 1926 in Berlin-Dahlem. To commemorate this event, the institute delved into the archives to compile a detailed historical account of the institute's origins as a research center and the social and technological developments that have influenced its work in the course of its nearly 90 years of existence. A book relating this fascinating story was published in November 2012 (see page 18).

Yet another research prize was awarded to a scientist working for Fraunhofer ISC in 2012: Gerhard Doman, who heads the Optics and Electronics competence unit, received the OE-A Demonstrator Award 2012 for the best publicly funded project demonstrator, for a pedestrian protection sensing system developed as part of the EU-funded 3PLAST project.

Finally, I would like to take this opportunity to thank all employees of Fraunhofer ISC, the associated project groups, and the Department of Chemical Technology of Materials Synthesis at the University of Würzburg. The institute owes its success to their constructive support and outstanding R&D efforts. I would also like to thank the Fraunhofer-Gesellschaft, our industrial and public-sector project partners, customers and advisors, the members of the Advisory Board, and the Federal Ministry of Research and Education (BMBF) for the trust and confidence they have placed in us. A special word of thanks goes to the Bavarian Ministry of Economic Affairs, for its continued generous support of our projects, which in 2012 enabled us to expand our facilities once again.

Würzburg, March 2013



Prof. Dr. Gerhard Sextl

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FEATURE TOPIC "ENERGY"

FRAUNHOFER CENTER FOR HIGH-TEMPERATURE MATERIALS AND DESIGN HTL

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http://www.isc.fraunhofer.de/publikationen.html

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Porous glass flakes

KEY FIGURES

In 2012, the development of the Fraunhofer ISC was marked by a continuous evolution in the parent institute, the extension of the Fraunhofer Center HTL in Bayreuth and the establishment of the project group IWKS at the Alzenau and Hanau locations. Against the backdrop of this excellent situation, the ISC Group achieved a balanced budget and successfully ended the year 2012.

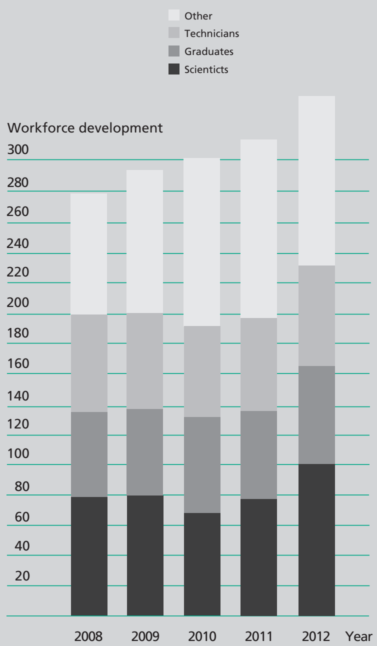
Growth in the workforce

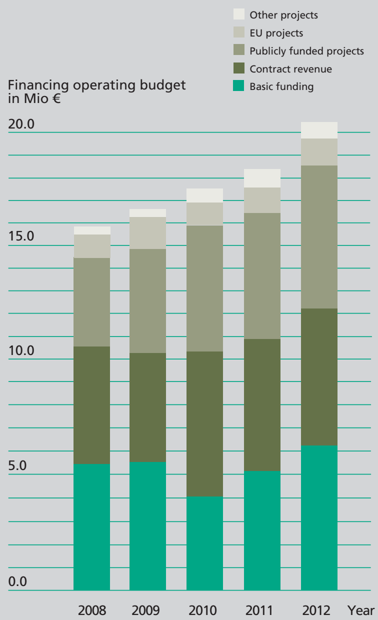
The moderate growth in the parent bank, including branches as well as the extension of project groups, especially of the project group IWKS, gave the ISC Group, in context with the provided budget planning, reason for a growth in personnel.

Approximately 57 % (197), from altogether 343 employees, are permanent staff, from which 71 % have permanent contracts. The percentage of permanent employed scientists is 43 %. Altogether, ISC has a balanced personnel structure of scientists, graduates and technicians. Furthermore, the Fraunhofer ISC offered several students internships and the possibility to do their diploma theses and dissertations. With this, ISC gave important contribution to material sciences tertiary education.

Operating budget

The situation at the Fraunhofer ISC continues to be marked by the set-up of a series of new topics and fields. In 2012, the operating budget increased by 10 % (1.9 million euros) to a total of 20.4 million euros, mainly due to the set-up of the project group IWKS. The development of personnel





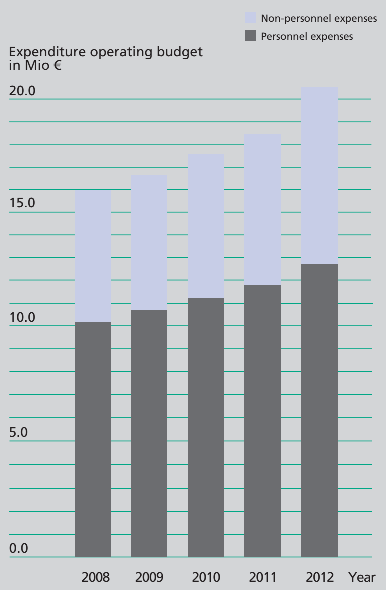
expenditure (12.7 million euros) as well as non-personnel expenditure (7.7 million euros) corresponds to the increased business volume.

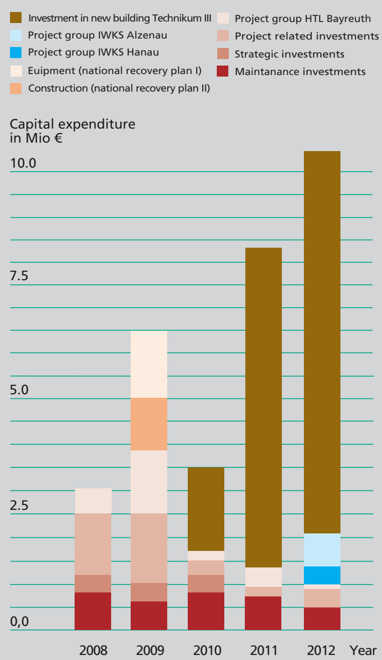
Fraunhofer ISC is funded through 30 % (6.2 million euros) institutional funding of the Fraunhofer-Gesellschaft, the percentage of contract research is 70 % (14.2 million euros). The amount of public income is 6.3 million euros and 1.2 million euros for EU project incomes. Income from industry and economy are 6.0 million euros, other income are 0.7 million euros. Fraunhofer ISC successfully ended the year 2012 with a positive annual result of 102,000 euros.

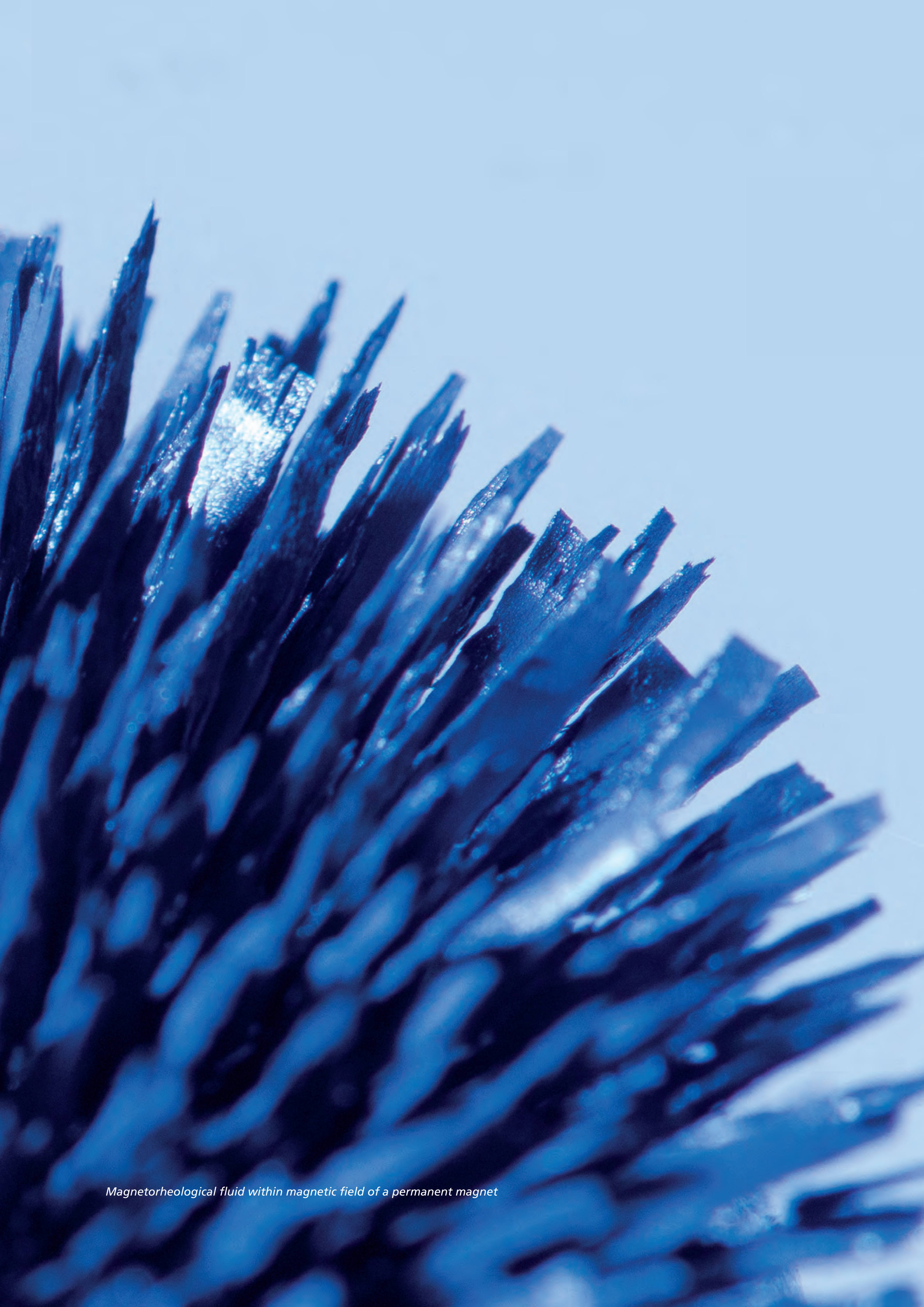
In the financial year of 2013, the ISC expects a significant growth through the project groups. Here, the focus lies on keeping balance in the financial mix through a corresponding volume of industrial income.

Capital expenditure

In order to ensure success in scientific competition, there was need for investments not only in high-qualified staff but also in technical equipment, office equipment and construction work. Fraunhofer ISC is investing several million euros in the construction of the new building in Würzburg, including initial laboratory equipment. Only in 2012, more than 8 million euros were spent therefore. The investment received federal, state and EU funding. In 2012, the new project group IWKS and thus new subject areas in Alzenau and Hanau locations received each 0.5 million euros and 0.7 million euros investment. Besides investment in initial equipment for the new building, 0.9 million euros were spent for new technologies and replacement investment in Würzburg. 50 % of the investment was financed from projects, the other 50 % from basic funding.







Magnetorheological fluid within magnetic field of a permanent magnet

PROFILE

PROFILE

Materials for sustainably manufactured products

How we develop new products or improve existing ones is undergoing a paradigm shift. Consumers, manufacturers and developers alike are no longer being driven by purely economic imperatives; ecological and social implications are increasingly determining the decisions they make. The growing scarcity of certain raw materials that has already made its mark in many sectors is certain to become even more critical in the years ahead. And bearing in mind our obligations to reduce CO_2 emissions, the need to optimize energy-intensive production processes continues to gain in importance. All of these factors contribute to the call for intelligent material and technology solutions that respond to much more than current needs.

This is where Fraunhofer ISC serves as a reliable partner for manufacturers and developers. The institute has several decades of experience in developing new materials and efficient processes that generate sustainable products of high added value. A focus on reliability, functionality and cost-efficiency drives forward the institute's further development of established materials, their manufacture and processing, extending all the way to the design of suitable production-ready process technologies. Ecologically sound and sustainable solutions share equal importance with recyclability and intelligent re-use in pursuit of the maxim "intelligent use of materials, low energy consumption".

More than 300 employees work closely with small or medium-sized companies and with large industry players to find solutions to these challenges. In so doing, the institute not only helps to secure the technological lead of its partners but also, and no less importantly, the jobs of those involved.

We successfully completed over 320 projects last year. These were accompanied by more than 600 analytical studies, which led to proposed solutions of direct relevance to practical application involving materials optimization, quality assurance as well as quick and precise damage evaluations.

Networked with industry and research around the world

As part of a broad national and international network, Fraunhofer ISC takes active part in the dialog that exists between the scientific and industrial communities, doing so on a variety of platforms both within Germany and around the globe.

Under the leadership of Dr. Michael Popall, the ISC business unit International has significantly intensified the institute's international contacts. In particular, Popall and his team have overseen the successful development of new relationships and collaborative ventures with partners on the Asian continent. Dr. Johanna Leißner supports the institute's European activities from the Fraunhofer office in Brussels. By taking these organizational measures and combining them with a boost in public relations activities and intensive networking at the operational level within research projects, the institute has significantly expanded its international presence.

Development trends and visions for the future

Fraunhofer ISC's new pilot-plant building at its main location in Würzburg will provide an industry-oriented development environment that can respond particularly to requirements in battery development, continuous and large-scale coating technologies, and biomedical materials.

Fraunhofer ISC's pilot plant, cleanroom facilities and GMP-oriented standards allow us not only to offer customers a single source for advanced development of materials and processes in these fields, but also to customize production and implementation in customers' production processes. State-of-the-art laboratory facilities, standalone work spaces and new electron microscopy preparation techniques mean that Fraunhofer ISC's analysis department is ideally equipped to solve even more demanding problems relevant to the areas of materials analysis, damage analysis and quality assurance.

Technikum III, facade – detail during construction
© Katrin Heyer for Fraunhofer ISC

PROFILE

Fraunhofer ISC and its locations

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Fraunhofer-Institut für
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❸

Fraunhofer-Zentrum für
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❹

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and ❺

Industriepark Hanau-Wolfgang
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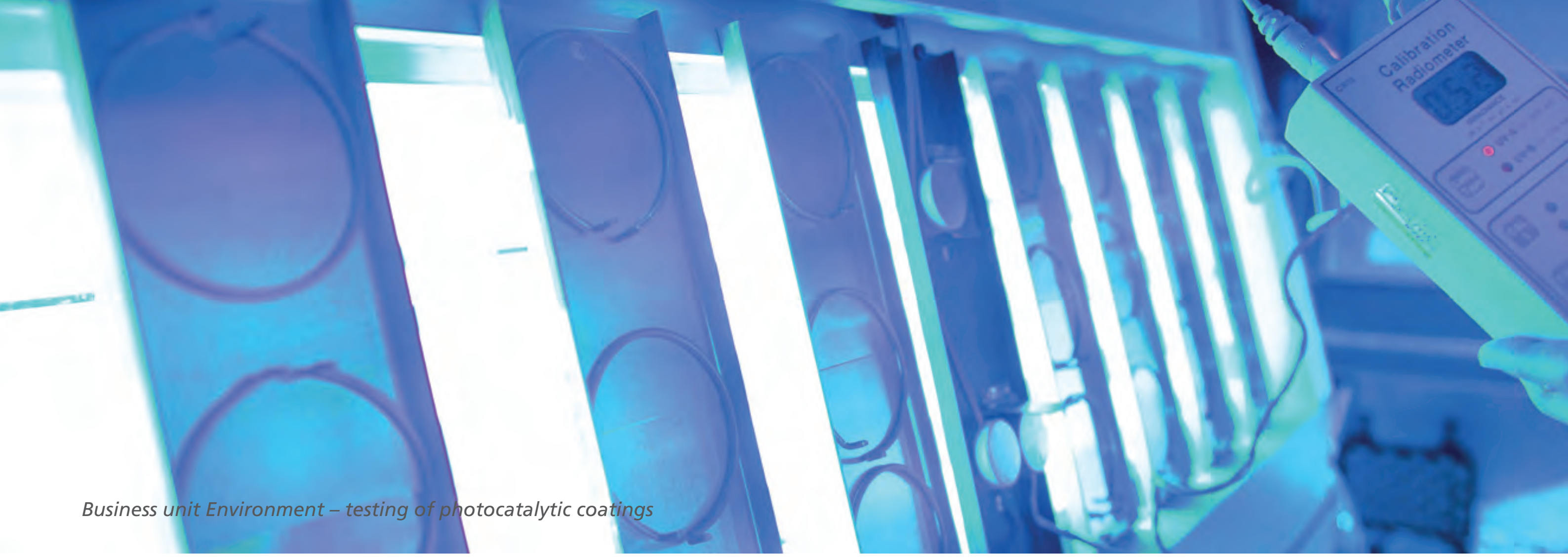

Business unit Environment – testing of photocatalytic coatings

Business units and further development of locations

The business units Energy, Environment, and Health subsume projects and research that aim to develop materials for ecologically sound products and applications, for the safe and efficient supply and use of energy, and for affordable indication-specific medications.

The Center for Applied Electrochemistry at the ISC's base in Würzburg meanwhile enjoys a firmly established reputation. In light of the global shift toward renewable sources of energy, industry's growing interest in both stationary and mobile energy storage units clearly indicates the need for research in these areas. Fraunhofer ISC was quick to recognize this pressing demand for further technological development, and invested significant amounts of its own funds to drive forward research into materials for energy storage and electrochemical applications.

An equally significant challenge affecting Germany's particular strength as a center of manufacturing, is the problem of how to secure raw materials for high-tech applications in future, as supplies dwindle in the face of growing global demand and the cost of these materials spirals. In order to provide even more support to industry in this area, in 2011 Fraunhofer ISC set up the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS in Alzenau. In 2012, this new group was already ready to expand, adding a location in neighboring Hanau in the state of Hesse. Not only does this prove the high level of demand from industry, it is also testament to the far-reaching support of government across the Länder. Working closely with industry, this support has enabled the institute to develop recycling technologies, substitute materials, and strategies for securing supplies of raw materials. In collaboration with Aschaffenburg University of Applied Sciences, work is now also underway to set up the Fraunhofer Application Center for Resource Efficiency in Aschaffenburg and Alzenau.

With the GMP facilities and biomedical laboratories at its disposal in the new Technikum III building, the business unit Health will be able to significantly expand its portfolio in the area of materials development. The establishment of a Fraunhofer Attract group to research 3D structures for use in tissue engineering, accompanied by close collaboration with other Fraunhofer Institutes and university centers, represent further cornerstones of this development.

The Fraunhofer Center for High Temperature Materials and Design HTL in Bayreuth is successfully on its way to becoming a Fraunhofer Institute in its own right. Detailed planning for a new laboratory building of its own, with office and pilot-plant facilities, began in 2012. Building started in 2013 and will be finished in 2015.

The Fraunhofer ISC now conducts materials research at five locations:

Würzburg:
- Headquarters location and Friedrichstrasse branch office

Bronnbach:
- International Convention Center for Cultural Heritage Preservation IZKK
- Center of Device Development CeDeD

Bayreuth:
- Fraunhofer Center for High Temperature Materials and Design HTL

Alzenau and Hanau-Wolfgang:
- Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS

PROFILE

60 years of silicate research in Würzburg

The Institute for Silicate Research has a long pedigree. In the course of its history, it has seen three systems of government in Germany and its scientists have belonged to three different research organizations, each with its own philosophy. Originally founded in 1926 as the Kaiser Wilhelm Institute for Silicate Research, it was re-established under the auspices of the Max Planck Society after the end of the Second World War, and then finally integrated in the Fraunhofer-Gesellschaft in 1971.

Given its historical background and research orientation, the institute has always placed a strong emphasis on the practical application of its research findings and their implementation in industrial processes. The original Kaiser Wilhelm Institute was created mainly on the initiative of the ceramic and glass industry, which was struggling under the difficult economic conditions of the Weimar Republic and was in search of innovations that would enable it to compete with its international rivals.

In the 1940s, the institute moved from its first home in Berlin-Dahlem to a secluded site in the hills of the Rhön north of Würzburg, to keep its employees, equipment and scientific work safe from the increasingly frequent air raids on the German capital. After the end of the war, the Kaiser Wilhelm Society was succeeded by the Max Planck Society and its Executive Committee agreed to integrate the institute in the newly created research organization, a decision that was supported by government and industry. Würzburg was chosen as the new location of the institute, thanks to intensive lobbying by the municipal authorities and the Bavarian government.

And so, on November 14, 1952, the institute's employees officially moved into the handsome brick building at Neunerplatz – a former officers' mess dating from 1891, which had been hurriedly converted to provide accommodation for the scientists and their equipment. Only a few years later, in 1959, the first extension containing a new glass foundry and further office space was added. The institute was growing.

Nonetheless, the institute narrowly escaped closure when its director at that time, Professor Adolf Dietzel, retired and the Max Planck Society's Scientific Council came to the conclusion that there was little further basic research that the institute could carry out and that it therefore had no place in the Max Planck Society. Fortunately, this opinion was not shared by supporters of the institute, which in those days was Germany's chief center of glass and ceramic research. They took up negotiations with the Fraunhofer-Gesellschaft, which provided a new home for the Institute for Silicate Research, where it has remained to this day.

The institute has since grown from strength to strength:
In 1986, it inaugurated its first pilot plant, Technikum I, a building tall enough to accommodate the industrial-scale equipment needed to manufacture and process pilot quantities of sol-gel materials. The next extension followed in 1996: Technikum II, which almost doubled the total surface area of Fraunhofer ISC's office, laboratory and pilot plant facilities.
A polymer synthesis center was added in 2006, providing a further 400 square meters of space for industrial research projects. The latest new building at the Neunerplatz site in Würzburg, Technikum III, is due for completion in 2013. It will provide 2,500 square meters of laboratory space and other facilities. As a sign of Fraunhofer's sense of social responsibility and its desire to serve as a model of sustainable practices, it was decided to submit the plans of the Technikum III building for pre-certification by the German Sustainable Building Council (DGNB), making it one of the first scientific buildings to undergo this assessment.

60 years of silicate research in Würzburg: To mark this important anniversary, the ínstitute also delved into the archives and compiled a detailed historical account, from its origins in the days of the Weimar Republic to the 21st century. A book relating this fascinating story was published in November 2012 under the title "Für Industrie und Wissenschaft. Weg eines Forschungsinstitutes von der Weimarer Republik ins 21. Jahrhundert." Copies can be supplied on request.

The book about the institute's history, 155 p., hardcover

PROFILE

Materials base

Inorganic sol-gel materials

Fraunhofer ISC has profound chemical expertise in realms of synthesis of inorganic non-metallic materials from liquid precursors as well as process know-how to design tailor-made materials for manifold applications, to develop manufacturing and processing technologies or to adapt material properties to already existing processes. Thus sol-gel processing offers numerous possibilities to control the physical and chemical properties of the later material in order to optimize its behavior during processing, structuring, tempering, and application . Inorganic sol-gel materials are materials base for the manufacture of particles, coating and fibers. Spinning technologies, printing and coating technologies are available for further manufacture of the inorganic sol.

Products already established on the market are, for instance nanoporous anti-reflective coatings for solar modules and wavelength sensitive increase of transmission for window glass and facade glazings (wellness glass), sensitive layers for humidity sensors, photocatalytic coating as well as high refractive coating systems for color filters.

ORMOCER®s

Besides the class of purely inorganic sol-gel materials, Fraunhofer ISC also develops inorganic-organic hybrid polymers – so-called ORMOCER®s. This class of materials is manufactured in correspondence with the process of chemical nanotechnology and functionalized to individual requirements. By selecting appropriate monomer or polymer initial components, it is possible to create materials and surfaces with multifunctional property profiles. This enables scientists to influence a whole range of factors including optical and electrical properties, resistance to wear and corrosion, adhesive properties, wettability and surface energy, barrier properties and biocompatibility.

The know-how for synthesis through sol-gel processing as well as functionalization and further manufacture of ORMOCER®s is continuously being developed and is base for many industrial applications.

Technical specialty glass

The development and characterization of specialty glasses and glass ceramics has been one of Fraunhofer ISC´s core competencies for a long time. Properties such as homogeneity, viscosity, thermal coefficient of expansion, bending strength and chemical resistance are painstakingly optimized to meet specific industrial requirements. Besides the know-how in glass chemistry and manufacture, latest in-situ measurement methods for characterization of glass-forming melts are used as well as an automated glass screening system which is the only one of its kind in Europe. It enables the high-throughput-screening of glass with defined mixture variations for faster development of new glass compositions.

Technical and optical specialty glasses with adapted property profiles find its application in, for instance, measuring techniques, microscopy, electronics, medical technology, car industry and construction industry.

*ORMOCER® is a registered trademark of Fraunhofer-Gesellschaft für Angewandte Forschung e.V.

Specialty glass

Smart materials

Adaptive materials whose properties can be changed by electric or magnetic stimuli are known as "intelligent materials" or "smart materials". In the future they will help to simplify complex mechanical and mechatronic systems while simultaneously allowing the implementation of new additional functions.

The Center Smart Materials has amassed extensive experience and considerable expertise in development and design of components such as dampers, actuators and sensors based on Magnetorheological and Electrorheological Fluids (MRFs and ERFs) and magnetically or electrically controllable elastomers (MREs and DEAs).

Speed and reversibility, two factors which enable these materials to change their viscosity or elasticity after creation of an electric or magnetic field, make them ideal for adaptive vibration damping and impact damping as well as for haptic control elements.

Furthermore, materials which are able to turn electrical signals in mechanical movements and/or vice versa movement in electrical signals which include piezo-ceramics, electro-active polymers (EAPs) and Carbon-Nanotube-Composites (CNTs) are processed. These are suitable for actuatoric and sensory components such as ultrasonic transducer for online monitoring and energy conversion (Energy Harvesting). In the realm of energy conversion, dielectrical elastomers will gain special importance. By means of dielectrical elastomer generators (DEGs), mechanical energy from water and wind is turned into electrical energy with aim of gaining additional areas of operation, for instance small rivers or weak-wind areas which are not suitable for conventional use of turbines. Depending on scope of application and requirements, profile suitable materials will be chosen and combined.

Besides energy harvesting, smart materials are very interesting for robotics. For this purpose there are developments and implementations of smart switches and sensors for collision detection, adaptive dampers and new actuators for grippers as well as for Human Machine Interfaces.

High temperature materials and process technique

Ceramic fiber composites, CMCs, are used as a light, temperature-resistant and high-performance alternative to metals in extreme fields of application. The Fraunhofer Center HTL develops, together with partners from industry, manufacturing processes for temperature resistant non-oxidic and chlorine-free oxidic fibers from precursor synthesis to spinning on pilot scale. Besides the ceramic high-performance fibers, matrix materials for CMCs and components are being developed. Now, the focus lies on thermal-shock resistant lightweight structures which improve energy efficiency of heat treatment processes.

Manufacturing of high-performance ceramics, with or without fiber reinforcement, in high quality and with the lowest energy consumption possible requires optimal process parameters. With the aim of inherent safe and energy efficient manufacturing, the HTL Center examines and optimizes procedural steps such as design, debindering and sintering. The thermo-optical measurement method (TOM) developed by Fraunhofer ISC, is used for a contact-free in-situ examination of sensitive green bodies.

Thus the procedure of ceramics production can be precisely watched and predicted for any temperature cycle and under various atmospheric conditions. The combination of modeling and in-situ measuring enables optimization of ceramic materials´ properties and process parameters for low energy consumption.

PROFILE

Liquid repellent surface refinement "Drop Protect", in cooperation with Zwiesel Kristallglas AG

Core competencies

The main focus of Fraunhofer ISC´s work lies on application-orientated development of non-metallic materials – from precursors to functional models.

- *Chemical nanotechnology*
- *Process technology and characterization*
- *Glass chemistry and technology*

Specific competencies in the fields of:

- Nanochemistry, sol-gel materials
- Specialty glass development
- Smart Materials
- Coating technologies and materials
- Energy storage, mobile energy supply
- Micro and polymer electronics, optics
- Diagnostics, regenerative medicine
- Dental materials, micro medicine
- Functional fillers, particle technology
- Environmental monitoring and conservation sciences
- Device development
- Energy efficient heat treatment, high-temperature lightweight construction
- High-temperature materials
- Polymer ceramics
- Resource strategies, recycling concepts, design recycling, substitution of (raw) materials

COMPETENCE UNITS

DENTAL AND MICROMEDICINE

This competence unit develops biofunctionalized and actively functionalized materials for dental conservation (restoration, prophylaxis, regeneration) and dental prostheses as well as for use in bone cement and micromedical applications (2D/3D-structurization of materials). Its core competencies include development and synthesis of multifunctional precursors as well as application-tailored-materials such as monomer-free resin systems, nano-hybrid and other composites, glass ionomer cements and customized self-etch, total-etch and other adhesives that provide an excellent basis for direct and indirect restoration (fillings, crowns etc). The development is complemented by comprehensive and special application-oriented chemical/physical characterization. The competence unit employs a wide variety of processes for structuring solutions and for filler synthesis and application.

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OPTICS AND ELECTRONICS

This competence unit develops technologies (materials, processes, characterization) for applications in the fields of Optics and Electronics. Its core competencies lie in development of coating, shaping and two-dimensional and three-dimensional structuring processes including their adaptation to the production environment with particular focus on hybrid-polymers, glasses and ceramics. The competence unit is also specialized in developing directly structurable hybrid-polymers for optical and electronic packaging technologies and micromedical applications.

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Optics and electronics – two-photon absorption device

GLASS AND MINERAL MATERIALS

This competence unit covers all steps from model-based development of new glasses and inorganic mineral materials through the process engineering and the manufacture of prototype components. Particular emphasis is placed on the development of specialty glasses and ceramics in form of bulk materials, fibers and coatings. In the field of specialty glass development the automatic glass-screening-system which is one of its kind in the world, is used. If requested, it produces glasses and semi-finished products in quantities up to a maximum of 100 kg per year. In the department of mineral materials, material cycles and secondary raw materials are special emphasis of work which is performed in cooperation with the project group IWKS. Another focus lies in functionalization of conventional construction materials.

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COMPETENCE UNITS

MATERIALS CHEMISTRY

The competence unit Materials Chemistry dovetails expertise from the departments of sol-gel chemistry, coating materials and particle technology. This opens up access to a wealth of synthesis and methods for developing and optimizing materials and material components. Comprehensive solutions are developed for key applications in the fields of engineering, health, energy, construction and environment as well as conservation sciences.

SOL-GEL MATERIALS AND PRODUCTS

In this field researchers synthesize precursors for non-metallic, inorganic materials using the classic sol-gel chemistry route. These precursors serve as basis for chemical synthesis of inorganic coating solutions, fiber spinning melts and mesoporous materials used in the development of multifunctional materials for applications such as building materials, architectural glazing and products in realms of regenerative medicine. The focus also lies on products for affordable health care in future markets and technical tailor-made solutions for an efficient usage of solar plants in dust-laden desert regions.

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HYBRID COATINGS AND COATING TECHNOLOGY

In the process of chemical nanotechnology multifunctional hybrid polymer coating materials are synthesized. This involves the use of substrate-specific, material-specific and component-specific application and process techniques tailored to production requirements as well as curing methods for coatings. The scope of properties and applications includes protective effects, adjustable permeability and migration barriers, catalytic effects, special chemical sensitivity, variable optical properties and switchable, active functions.

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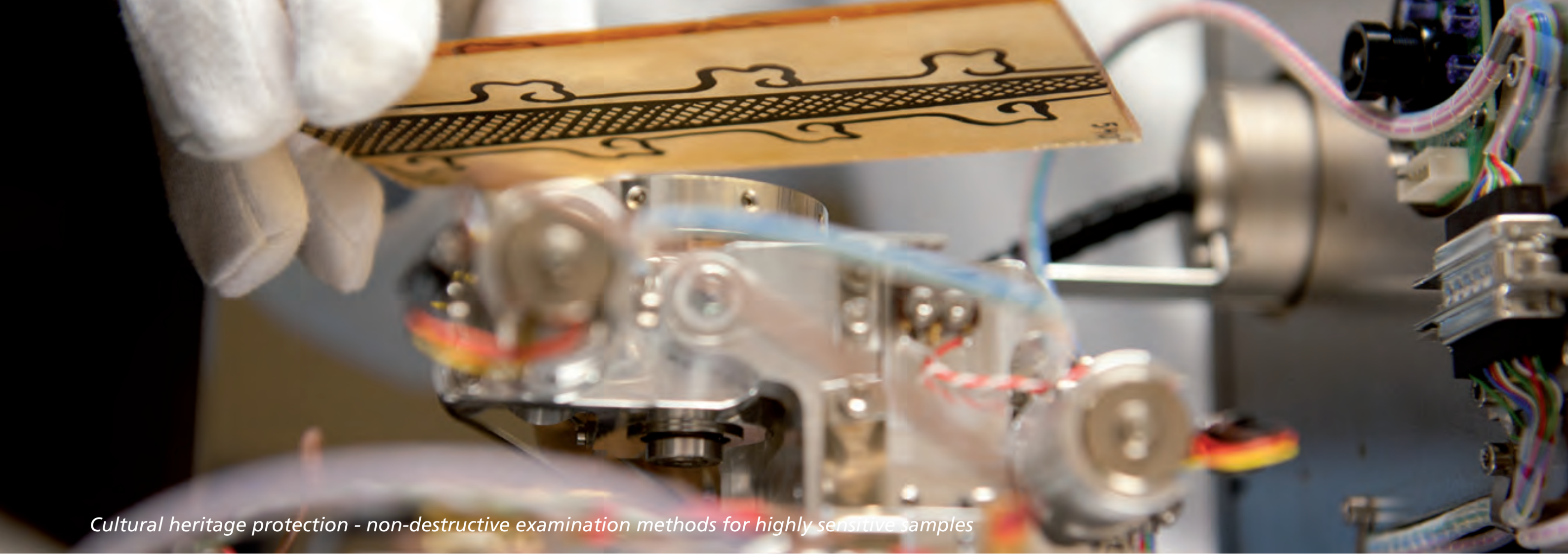

Cultural heritage protection - non-destructive examination methods for highly sensitive samples

PARTICLE TECHNOLOGY AND INTERFACES

Interfacial phenomena gain more and more importance due to the growing functionality and complexity of materials and components. Wherever large surfaces come into play, for instance in particle systems for diagnostics or in composite materials, the chemistry at the interfaces is determined by quality or even property. In the light of longstanding experience in the field of wet-chemical synthesis of multifunctional particles for dental applications, surface functionalization and composite manufacturing, the team´s expertise has been expanded to include the fields of medical diagnostics and theranostics, drug encapsulation, targeted release, and self-healing.

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CULTURAL HERITAGE CONSERVATION

This competence team, which has a longstanding experience background in the realms of glass and metal corrosion, lays its focus on the effects of environmental influences on endangered cultural heritage especially made of glass, metals and ceramics. Measurements of environment impacts using specially designed glass and light dosimeters enable the preventative protection of artworks and cultural heritage. The service includes the development of new conservation materials and methods for the protection of historical cultural and industrial monuments. Projects include, for instance, development of a special glass-in-glass solidifying agent designed to enable careful and gradual repair of micro-cracks in corrosion-damaged church windows.

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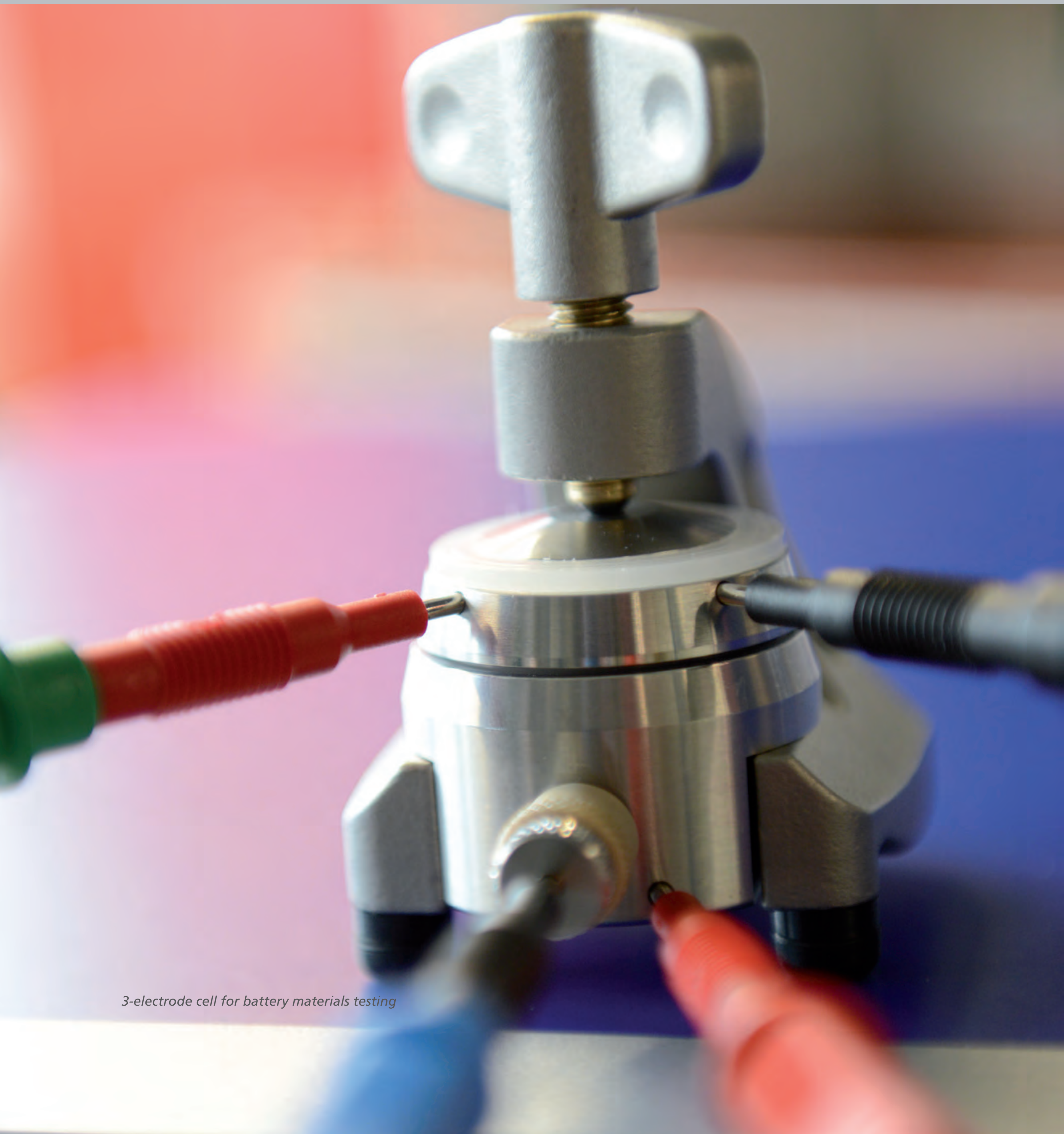
CENTERS



3-electrode cell for battery materials testing

CENTER FOR APPLIED ELECTROCHEMISTRY

Focus on battery development

The Center for Applied Electrochemistry is central point of contact for the development and optimization of materials and processes for efficient storage and use of electric energy for mobile and stationary applications.

The Center was founded in October 2011 as part of "Bayerisches Forschungs- und Entwicklungszentrum Elektromobilität" which is funded by "Aufbruch Bayern", a programme of the Land of Bavaria at the Würzburg and Garching locations. Both centers see themselves as essential link between university basic research and industrial application. The Center for Applied Electrochemistry in Würzburg pursues the aim of laying foundations for a widespread usage of electromobility. In close co-operation with industry the center develops future-oriented electrode materials, electrolytes and other cell components as well as processes for their manufacture and processing at a technical scale.

Emphasis of development

- Development of materials and components for electrochemical energy storage – anode material/cathode material,
- Electrolytes
- Electrochromic layers
- Batteries
- Supercaps (double-layer capacitor)
- Fuel cells
- Process development
- Recycling of batteries and electronic components

Tuning of components

In this field optimal adjustment of the individual cell components such as electrodes, electrolytes and separators is very important. Therefore separators are optimized and environmentally friendly binding systems are developed. In this case, not only own developments but also commercial products which can be modified to meet requirements are used. Modern devices and techniques allow a comprehensive analysis of reaction processes in-situ and post-mortem which arise in cell components.

Materials characterization and tests

Materials and cell components are tested in accordance with DIN EN ISO/IEC 17025-2005 accredited analytics.

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TOMMI TLF

CENTER OF DEVICE DEVELOPMENT CeDeD

Development and services

Principal task of CeDeD is to develop scientific research systems for use in both the characterization of new materials and the quality control in production processes. CeDeD offers the full scope of expertise required for scientific development, this includes planning, design and construction of research systems. This offer covers the entire line of development from the institute´s own research systems starting from the design and concept stages based on 3D structure right through computer-operated construction components in the fine mechanical workhop. CeDeD is a central point of contact for internal and external research groups and also acts as a direct partner to industry in the field of technical implementation of research results. In close co-operation with the competence teams at Fraunhofer ISC, CeDeD develops prototypes, demonstrators and pilot plants for the manufacture and processing of newly developed materials and research instruments used for process control at the end of the value added chain.

Partners for industry and research

Particular emphasis is placed on the development of thermo-optical measurement systems (TOMs) designed for in-situ characterization of materials during heat treatment. Measurements can be made under temperature conditions ranging from room temperature to more than 2000 °C. Demand for the center´s services is currently particularly strong in the specialty glass high-tech ceramics industries, as well as in the ongoing development of refractories. The newly developed processes are expanded into industrial scale systems using vacuum engineering, laser technology and robotics. However, thermo-optical measurement methods are an excellent choice for all groups of materials that undergo heat treatment, such as materials used in powder metallurgy and injection molding processes. CeDeD, certified under ISO 9001:2008, guarantees full reproduction of the process chain and is annually audited for its quality management system. The center is a reliable partner for organizations seeking to develop new technologies.

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X-ray diffractometry for crystal structure analysis

CENTER FOR APPLIED ANALYTICS ZAA

Precise materials analyses are basis of materials and process developments and play an important role in failure analysis. Claims in production or "in field" often occur due to material defects or usage of materials whose conditions were previously not considered. The Center for Applied Analytics is central point of contact for internal and external clients in the fields of analysis of structure, properties and correlations between micro structure and material properties. Furthermore, the center offers a combination of most modern material analysis and application-related scientific advice. Analytical results are used to develop suitable solutions together.

The main emphasis here lies in chemical analysis for non-metals, nano analytics, failure analyses, characterization of structure and layer properties, product testing as well as in interfacial and surface analysis. Chemical routine analyses using X-ray fluorescence methods are supplemented by resistance tests on a variety of materials. Advanced techniques such as inductively coupled plasma-atomic emission spectrometry (ICP-AES) and atomic absorption spectrometry are capable of analyzing even a few millionths of a gram of a material in solution. X-ray photoelectron spectroscopy (XPS) detects surface chemistry and binding state. High resolution scanning electron microscopes allow researchers to analyze microstructural properties such as surface topography and surface properties of specimens. A scanning transmission electron microscope (S/TEM) is used to analyze microstructural features down to the nanometer scale.

The extensive equipment for artifact-free sample preparation enables electron microscopic analysis even of very challenging specimens. The center uses ion-beam cross-section polishers which also enable the preparation of porous specimens. The manufacture of ultra-thin slices of lamellae for the transmission electron microscopy, which is technically very demanding, is obtained by using the focused ion beam (FIB). Now, the Center additionally has an ion-slicer system equipped with nitrogen cooling. The device, which is one of its kind in Europe in this combination, enables the preparation of extensive specimens of materials whose microstructure reacts sensitively to changes in temperature during preparation, particularly in cases of glass and building materials.

Fraunhofer ISC uses more than 50 different analysis techniques which allow correlative analytics. Furthermore, the Center for Applied Analytics has a network of analytic service-providers inside and outside the Fraunhofer-Gesellschaft to offer more processes, if requested.

The Center for Applied Analytics is accredited according to DIN EN ISO/IEC 17025 and RAL- and EUCEB-testing laboratory for mineral wool.

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MRE – variable geometry

CENTER SMART MATERIALS CeSMa

CeSMa develops customized materials and components based on the use of electronically and magnetically switchable material properties. It is largely a matter of using fast conversion of mechanic energy into electrical energy for sensors and vice versa for actuators. New solutions are possible due to the physical effects which switch reversibly within few milliseconds and which can be regulated continuously. Thus conventional mechanic solutions can be simplified, additional functions can be customized and finally mass can be saved. CeSMa lays its focus on the rapid implementation of "smart materials" in components such as actuators, sensors, dampers, coupling, energy harvesting and even in "smart windows" which change color at the touch of a button and in this manner, allow control of incidence of light.

The center enables its clients to gain access to new products and technologies. Since its establishment in May 2009, CeSMa is growing steadily and will do so in 2013 according to available figures and planning

Materials – functions – components

"Smart materials" or so-called "adaptive materials" describe a very unequal material family. It encompasses polycrystalline solid objects such as piezoceramics, electronically or magnetically switchable fluids (ERFs and MRFs) and dielectrical elastomers which can be implanted either as actuators or sensors (DEAs and DES) or, in case of magnetizable particles filling, change their stiffness and/or form reversibly within the magnetic field (MREs). Another class of materials with good switching properties are metal polyelectrolytes (MEPEs) which provide a wide range of color spectrum for technical applications. They are initially being qualified for "smart windows" but further applications will follow.

The strategy of materials selection and optimization starts with the analysis of the respective application for which the required power, paths, dynamics and temperature ranges are specialized. Mechanical optimization steps can be derived from this and then the design for the laboratory demonstrator will be created, in which the selected materials can be implemented and tested. Examinations also include cyclical stress and climate tests (according to DIN or EN).

The following materials and components are implemented at CeSMa and are further developed in co-operation with partners:

- Dielectrical Elastomer Ectuators DEAs
- Dielectrical Elastomer Sensors DES
- Dielectrial Elastomer Generators DEGs
- High-temperature resistant Magneto-Rheological Fluids MRFs
- New parametric piezoelectric loudspeakers
- High-temperature ultrasonic transducers

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Church window with partly destructed glass painting

INTERNATIONAL CONVENTION CENTER FOR CULTURAL HERITAGE PRESERVATION IZKK

With the motto "knowledge-sharing, research and the pooling of resources" the IZKK sees itself as an educational institute and thus contributes to the Fraunhofer-Gesellschafts´ principles of sustainability.

Housed in a living monument, Bronnbach Abbey, the center gives information on cultural heritage and particularly on possibilities of its prevention. The modern conference rooms in the historical 12th century abbey building enable the IZKK to offer a broad range of seminars, training courses and conferences to an international customer base. Thus expertise plus new developments can be discussed and further developed and used in the prevention of historical monuments. The center´s target audience includes restorers, architects, master craftsmen, plasterers, artists and curators. In terms of its research activities, the IZKK fosters intensive cooperation and dialog with universities of science and applied sciences, research institutes, museums and offices and agencies responsible for cultural heritage preservation. Furthermore, the center plays an active role in creating awareness of society for understanding the necessity of preventing our cultural heritage as an economic factor, as witnesses of our ancestors and as memorial for future generations by offering presentations and workshops.

Since the center´s establishment, realized by Fraunhofer ISC and Main-Tauber regional administration in 2008, the IZKK works in close co-operation with the competence team Cultural Heritage Prevention, also located in the Bronnbach branch. This team deals with research of conservation and restoration materials as well as development of processes and products for measurement and evaluation of industrial impacts on environment and cultural heritage.

izkk
Internationales Zentrum für Kulturgüterschutz
und Konservierungsforschung

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PROJECT GROUP IWKS

Securing supplies of raw materials – through sustainable use rather than consumption

The scarcity of natural resources has become a key issue of political debate in the industrialized nations due to its impact on social and economic progress. There is a pressing need for measures to secure sustainable sources of raw materials for industry. The IWKS addresses this challenge by researching and developing new technologies for use in recycling processes, identifying substitutes for materials in short supply, assessing the viability of materials reuse, and by drawing up technology forecasts.

The basic structure of the project group

The IWKS has combined its core competencies in three business units:

- Resource strategy
- Recycling and reusable materials cycles
- Substitution

The business units work together under the joint leadership of a management team comprising Prof. Dr. Armin Reller (University of Augsburg), Prof. Dr. Stefan Gäth (Justus Liebig University of Giessen), Prof. Dr. Oliver Gutfleisch (Darmstadt University of Technology), and executive director Prof. Dr. Rudolf Stauber. This permits a holistic approach to research covering the entire supply chain.

Applied research is only successful if it results in marketable products. The IWKS therefore offers its customers an up-to-date portfolio of research and development services. In close collaboration with its industrial partners, the IWKS develops innovative separation, sorting and recycling processes and products that give companies in Germany and Europe in all sectors of industry a technological lead. The latest scientific and technological advances are transformed into sustainable applications and products tailored to each customer's needs, with a strong emphasis on cost-effectiveness and technical feasibility. Customers can expand their market position both by making more efficient use of resources, including energy and time as well as materials, and by optimizing their allocation of these resources. The project group also offers consulting services to government and industrial decision-makers, for instance by providing forecasts of the future resource demands of manufacturing industries and their relevance in terms of resource strategies.

Overview of market segments:

- Electrical and electronic waste
- Magnets
- Industrial slag, landfill waste
- Biomaterials, foodstuffs
- Lighting systems

The specialist skills we employ in research projects are selected on the basis of the customer's needs and broadly cover the following focal areas of research:

- Strategies, studies and modeling
- Analysis
- Crushing and screening technologies
- Physical, chemical and biological separation technologies
- Material technologies

If necessary, the IWKS can call on the support of the parent institute, Fraunhofer ISC, a Fraunhofer-wide network of experts, and specialized university departments. Access to this extended network guarantees excellent advice. The researchers work together in multidisciplinary teams, enabling them to develop new ideas beyond the confines of their individual areas of specialization. The IWKS currently employs

The Project Group IWKS team from Alzenau and Hanau

over 20 scientists with specialist knowledge in the fields of environmental management, process engineering, materials science, industrial engineering, biology, chemistry and physics, and intends to build up further capacity in the years ahead. In 2013, the project group plans to recruit another 10 or so scientists. The longer-term objective is to establish a fully-fledged Fraunhofer Institute, in 2016 or later.

Resource strategy

The business unit Resource strategy identifies critical primary and secondary resources, determines their availability and importance to present and future technological development, and assesses the degree to which they are critical at each stage of the cycle, from extraction or harvesting of the raw materials to their use and post-consumer recycling. The economic, ecological, geopolitical and sociocultural factors affecting the availability and utilization of resources are studied in order to establish a basis for developing sustainable-use strategies. The resource strategy concept involves defining a number of quantitative and qualitative criteria with which to evaluate the potential benefits and risks associated with the use of specific resources, materials, processes and technologies.

The following aspects have been investigated so far:
- Resource conflicts
- Geopolitical dependencies
- Secure global supply paths and efficient supply chain design
- Potential economic benefits
- Sociocultural factors and the acceptance of new technologies.

The business unit Resource strategy is led by Armin Reller, Professor of Resource Strategy at the University of Augsburg.

Recycling and reusable materials cycles

The business unit Recycling and reusable materials cycles develops innovative recycling concepts, as well as materials flow, waste and resource management solutions in collaboration with industrial partners. A full systems analysis is conducted in the conceptual phase, which takes into account the interlinked aspects of (reverse) logistics, technology and socioeconomic factors. Technologies tailored to the specific application are then developed and implemented. Additional advice on practical concepts of design for recycling (or design for disassembly) is provided in the product development phase. The business unit's solutions are adaptable for use in many different industrial sectors, including the food processing, electrical and electronics, automotive and lighting systems industries, and are developed in collaboration with specialists in the relevant fields. They cover a wide range of raw and processed materials and manufactured products, including electrical components and assemblies, fluorescents and packaging materials.

Other investigated sources of reusable materials include:
- Industrial slag, landfill waste
- Ash
- Adsorbents
- Wastewater
- Food waste

The business unit Recycling and reusable materials cycles is led by Stefan Gäth, Professor of Waste and Resource Management at the Justus Liebig University of Giessen.

PROJECT GROUP IWKS

Substitution of raw materials

This business unit deals primarily with the task of finding substitutes for rare or costly raw materials currently used in a wide variety of products, applications and technologies, without compromising quality. This aim is pursued through the development of innovative materials and through substitution at the component, process and technology level.

One major focus of this work lies in the development of permanent magnets with a significantly reduced rare earth content offering an equivalent or even improved operating performance when used, for example, in electric motors or wind turbines. Another central aim is to optimize and develop:

- Critical functional materials
- Optical materials
- Optoelectronic components
- Lighting systems
- Cooling systems

The business unit Substitution of raw materials is led by Oliver Gutfleisch, Professor of Functional Materials in the Department of Materials Science at Darmstadt University of Technology.

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Silica glass – recycling potential of process waste

REVIEW

Bavarian environment minister Marcel Huber in Alzenau

WÜRZBURGER WIRTSCHAFTSTAGE

In 2012, Fraunhofer ISC participated for the fourth time in the "Würzburger Wirtschaftstage", this time in connection with the "Career navigator" initiative. On 28 February, under the slogan "Working in research to develop the products of tomorrow", the institute opened its doors to visitors wishing to find out more about the training opportunities offered by the ISC in various technical, engineering and business professions. More specific information on training for research scientists was provided on February 29, while the following day was devoted to career opportunities for engineers. On each of these open days, junior members of staff who had already embarked on similar career paths talked with the visitors about their personal experiences – a sure way of encouraging youngsters to opt for a career in science and technology.

CESMA WORKSHOP

INDUSTRIAL CHALLENGES FOR SMART MATERIALS

The annual workshop organized by CeSMa in collaboration with the Bavarian innovation clusters for new materials and for mechatronics and automation has become an unmissable event. In 2012, its focal themes were the required properties of materials for use in drive systems and automation, control mechanisms for magnetorheological dampers in combination with 3D magnetic field sensors, and acoustic control systems for transportation processes. The guest speakers were Dr. Volker Seifert of Bosch Rexroth AG, Lohr am Main, Dipl.-Ing. Andreas Buchholz of Robert Seuffer GmbH & Co. KG, Calw, and Prof. Dr. Gerhard Lindner of Coburg University of Applied Sciences, whose lectures provided participants in the one-day workshop with fascinating insights into the world of smart materials.

DISTINGUISHED VISITOR IN ALZENAU

March 20, 2012, was a momentous day for the IWKS project group in Alzenau. The Bavarian State Minister of the Environment and Public Health, Marcel Huber, made time in his busy schedule to spend several hours learning about the work of the project group and keep abreast of its development. He gave a speech underlining the urgent need for new solutions to facilitate materials recycling, and praised the Fraunhofer-Gesellschaft's exemplary initiative of establishing a special project group to deal with this issue

Hessian research minister Eva Kühne-Hörmann with Professor Bullinger and the Hessian deputy prime minister Jörg-Uwe Hahn

IWKS OPEN DAY

On the afternoon of June 4, 2012, the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS in Alzenau invited members of the public to attend an open day organized as part of the German Day of Action on Sustainability, in the run-up to the three-day United Nations Conference on Sustainable Development, Rio+20 (June 20 – 22, 2012). Around 200 visitors profited from the occasion to gather first-hand information on the IWKS's activities and showed a great deal of interest in the resource strategies, recycling technologies and approaches to materials substitution being developed by the new Fraunhofer project group.

FRAUNHOFER IWKS INAUGURATES SECOND LOCATION IN HESSE

On June 29, 2012, Eva Kühne-Hörmann, the Hessian Minister of Higher Education, Research and Arts, handed over the official letter of approval granting a funding package totaling 24 million euros to the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS for the establishment of its second location in the Hanau- Wolfgang industrial park. The official document was accepted on behalf of the project group by Prof. Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft at that time. Coming less than a year after the foundation of the project group in Alzenau, Bavaria, the creation of this location in Hesse is indicative of the great importance accorded to the issues of recycling, materials substitution and resource strategies by the industrial, business and political communities.

In keeping with Hanau's central role in the chemicals industry, the activities of the new Fraunhofer project group at this location will concentrate on the substitution of raw and processed materials – an area of research of vital importance to the future business success of the manufacturing industry. "We are aware that the ability to develop substitutes for critical materials will be crucial to our technological, industrial and social progress in both the immediate and long term. And for this reason we consider ourselves fortunate that a research partner with such an outstanding international reputation and such innovative power as the Fraunhofer-Gesellschaft has decided to establish a base in one of Hesse's strongest and most attractive industrial parks, serving companies throughout the region and beyond," commented Eva Kühne-Hörmann.

REVIEW

EXHIBITION

ON RESOURCES IN CASTLE MICHELBACH

Science Year 2012, an initiative of the German Federal Ministry of Education and Research (BMBF), is dedicated to research for sustainable development. To illustrate the theme "Project Earth: Our Future", Fraunhofer ISC and the Fraunhofer Project Group IWKS in Alzenau organized an exhibition in Castle Michelbach, from July 1 to 29, 2012, with demonstrations enabling visitors to see for themselves how scientists approach the issue of sustainable development. The exhibition included presentations of the different aspects of sustainability research dealt with by the Fraunhofer-Gesellschaft, with particular emphasis on the work conducted by the project group in Alzenau, which focuses on noble metals, non-ferrous metals, polymers, and rare-earth elements.

FUNDING APPROVAL

FOR THE FURTHER EXPANSION OF THE FRAUNHOFER CENTER HTL

On August 1, the Bavarian Minister of Economic Affairs, Martin Zeil, delivered the letter of approval granting funds for the further expansion of the Fraunhofer Center HTL in Bayreuth. The hosts of the day's event emphasized the importance of efforts to promote energy efficiency and the conservative use of resources, and pointed out that the center would help to strengthen the role of Upper Franconia in this respect. Martin Zeil described the expansion of the Fraunhofer Center HTL as a further significant milestone in the process of establishing Bavaria, and more particularly Upper Franconia, as a high-tech business location, adding that "by strengthening the research environment in Bayreuth, we hope to attract new investors to Upper Franconia."

SCIENCE YEAR 2012

The city of Würzburg organized a program of lectures on sustainable development to tie in with the BMBF's chosen theme for Science Year 2012, "Project Earth: Our Future". The speakers included scientists from Fraunhofer ISC. On June 14, the head of the business unit Environment, Dr. Gerhard Schottner, teamed up with Matthias Rothkegel of Rothkegel Glas GmbH to deliver a lecture entitled "Preserving our cultural heritage through the united efforts of scientists and craftsmen".

On July 5, it was the turn of Prof. Dr. Armin Reller, who heads the business unit Resource strategy of the Project Group IWKS in Alzenau, to address the question: "Where will we source future supplies of raw materials?" The lectures, held in the magnificent council chamber of Würzburg's Town Hall, enabled interested members of the public to gain an insight into some of Fraunhofer ISC's current research projects.

Part of the "Resources" exhibition.

Funding approved for DEGREEN project.

EXHIBITION SHIP MS WISSENSCHAFT

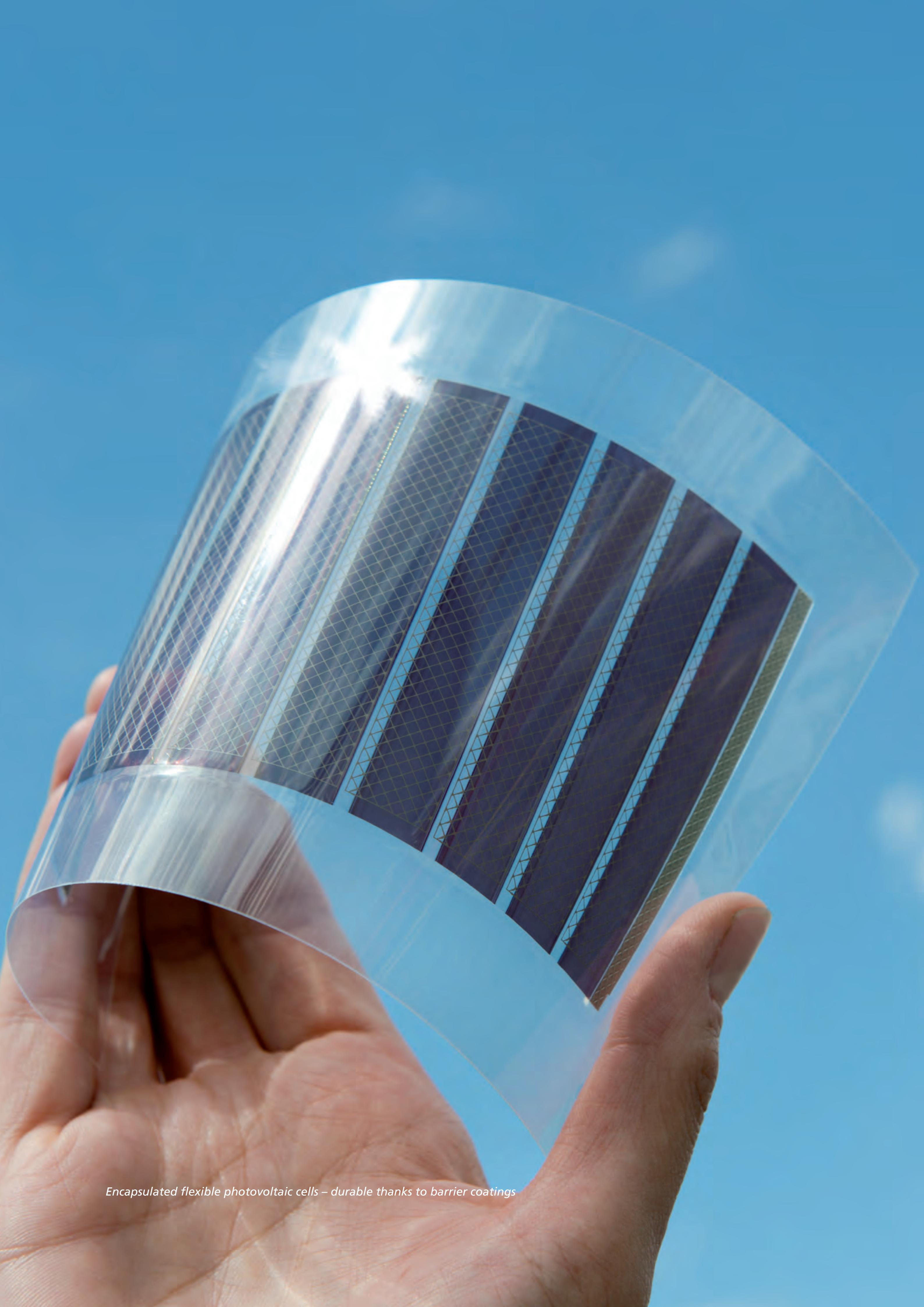
MAY 30 TO OCTOBER 12 – FLOATING EXHIBITION ENDS TOUR IN WÜRZBURG

In October 2012, the exhibition ship MS Wissenschaft, sent on its journey by the Federal Ministry of Education and Research, docked in Würzburg – the last of the 36 cities it had visited that year along the rivers of Germany and Austria. The exhibits it carried aboard illustrated various aspects of sustainable development, in keeping with the Science Year theme "Project Earth: Our Future". A large number of research institutions had contributed to this floating exhibition – including Fraunhofer ISC. The Institute's hands-on exhibit entitled "The Life of Everyday Things" was designed to make information on the history, origin and uses of critical resources accessible to the general public – an invitation that visitors of all ages took up enthusiastically. The ship's crew confirmed that "The Life of Everyday Things" was one of the most frequently used exhibits and also one of the most robust, standing up to wear and tear throughout the duration of the floating exhibition.

DEGREEN

INNOVATIVE APPROACHES TO DECENTRALIZED POWER GENERATION BASED ON DIELECTRIC ELASTOMERS

On September 19, 2012, the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology officially launched the DEGREEN project, in which Fraunhofer ISC's Center Smart Materials CeSMa intends to develop a new generation of efficient, environmentally compatible technologies for decentralized power generation based on the use of dielectric elastomer generators (DEGs). The official letter approving allocation of the necessary funds was handed over by the Bavarian Minister of Economic Affairs, Martin Zeil, in person. He sees this project as an excellent opportunity to support local industry with targeted research that will enhance the reputation of Bavarian companies as technological leaders and drivers of innovation. The mayor of Würzburg, Georg Rosenthal, gave a welcoming speech on behalf of the municipality. The ceremonial event was attended by numerous high-ranking representatives of the government, business and scientific communities, including Dr. Paul Beinhofer, president of the regional government of Lower Franconia.



Encapsulated flexible photovoltaic cells – durable thanks to barrier coatings

BUSINESS UNITS

ENVIRONMENT

Business unit ENVIRONMENT

The business unit Environment focuses on challenges gradually emerging from the finite nature of material resources supply. Our approach to solving this issue involves developing materials and processes that use resources efficiently (material efficiency) and reclaiming reusable materials within a closed material loop (secondary materials). Our expertise relating to the impact of chemical and mechanical factors on surfaces, in both natural and artificial environments, underlies the development of highly effective, multifunctional coating systems.

The business unit Environment maintains close links to the business units Energy and Health. The focus is on building and living in a way that is resource-efficient and healthy. Materials designed for heat storage and insulation act as a bridge to the business unit Energy. The topic of resource efficiency also provides a close thematic link with the Project Group for Materials Recycling and Resource Strategies IWKS in Alzenau and Hanau, whether this involves the use of secondary resources in building materials, analysis assignments, or developing and constructing specialist equipment. This expertise is extended by testing methodologies for environmental monitoring and the protection of cultural assets.

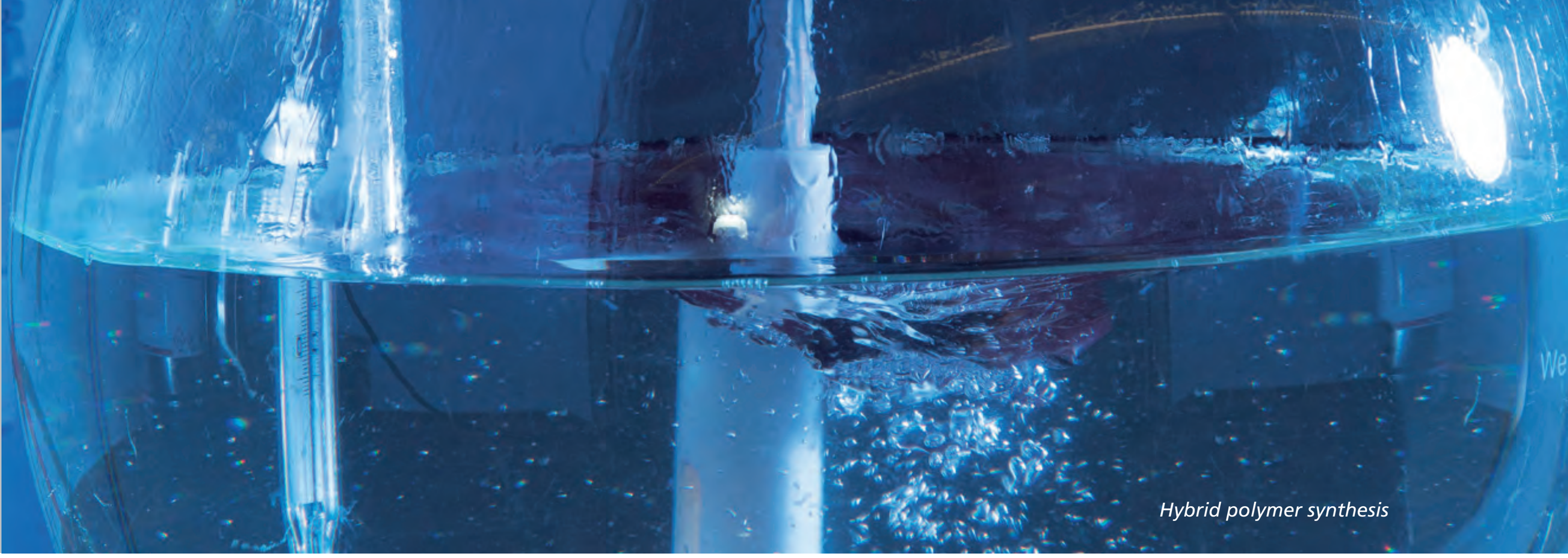
Through the development of coatings, the impact of environmental factors on surfaces is precisely regulated and controlled. Work focuses on chemical development of coating materials using nanotechnologies, as well as on application methods to increase the functionality and service life of components and goods. Packaging is an indispensable part of hygiene in our daily lives, but is already responsible for significant environmental problems that have carried waste products all the way to our oceans.

Compostable packaging materials – now oil- and watertight thanks to PlasmaNice

These days, many packaging materials consist of a variety of constituent parts, with the aim of achieving the best possible protection against a range of substances. In many cases, this is to protect packaged goods from environmental influences. But just as often it is the environment which needs protecting – from leaked liquids, for instance. It is becoming increasingly important to extend the use of renewable raw materials (such as paper) to packaging, while reducing the share of organic polymers used for this purpose. The reasons for this lie in the insufficient recyclability and compostability of packaging derived from crude oil, which has become much more costly to produce and is less widely available.

The need to significantly reduce the growing heaps of waste led initially to greater use of paper as a compostable packaging material. In order to improve holding strength and stability, and to prevent the leaking of fluids, either laminates made from plastic films or coatings of fluoropolymers or silicones were used, but the use of such materials is increasingly undesirable in view of more urgent calls for packaging that can be recycled or composted. Accordingly, the project was facing the task to replace these materials with a coating system that would possess the following combination of properties:

- Impermeable to fluids, particularly oil and fat
- Good adhesion to bio-based polymers such as paper or polylactide
- Easily processed, and able to be integrated into industrial in-line production at high processing speeds
- Biodegradable



Hybrid polymer synthesis

Due to the positive results obtained previously when an atmospheric pressure plasma process (EU SOLPLAS project) was used to process and deposit hybrid coating materials, yielding coatings with demonstrated oxygen barrier properties, the same technique was now applied to development of fat barrier coatings. However, it became evident that when permeable, porous and absorbent substrates like paper were used, the coating thickness and film formation required to achieve a good barrier effect were not attainable at high processing speeds. For this reason, efforts were simultaneously made to develop a UV-curable coating able to be processed by spray application and curable at high speeds.

The end of the four-year, EU-sponsored "PlasmaNice" project yielded an ORMOCER® coating system fulfilling the criteria specified above. Besides the acrylate siloxane component, the resulting compound contains only methylsiloxane, meaning that it is entirely fluoropolymer and free of silicone. A uniform coating was achieved on a variety of types of papers and, at both the pilot plant and industrial pilot testing stages, the coating could be processed and UV cured at conveyor speeds of up to 150 m/min. In the course of four-week endurance testing, the coating proved to be completely impermeable to oil when applied to pure paper. The paper/ ORMOCER® coating bond is therefore just as stable as conventional paper-plastic laminates.

A substantial and problematic factor in the use of UV-hardening coatings and printing inks in packaging technology is the danger that unreacted photoinitiators – or fragments of them – will migrate to the packaged commodity, in particular food products. To avoid this danger, a special photoinitiator was developed by a project partner and chemically integrated into the coating system using a sol-gel process. In this way, the danger of migration can be effectively blocked in a way specially tailored to the coating system. Furthermore, initial biodegradability tests indicated a degradation rate of almost 100 %.

The development of a paper coating system to replace the lamination of organic polymers meant it was possible to meet the criteria of the specification in full – both in terms of performance characteristics and industrial application – while also meeting extra requirements in regard to environmental protection and sustainability, resource conservation and material savings.

Sustainable packaging materials

Using petroleum-based plastics to manufacture goods like food packaging does not conform to the environmental standards called for in Germany as part of Research for Sustainable Development (FONA). In the meantime, efforts to bring sustainability to the way we live, work and manufacture has seen the launch of initiatives to develop new materials on the European level, too, with the aim of achieving a new, CO_2-neutral source of raw materials and fully-biodegradable packaging.

Here, Fraunhofer ISC is involved in a big European research project called "DIBBIOPACK" focusing on bio-based and biodegradable packaging. Launched in 2012, it builds on the results yielded by past projects such as "PlasmaNice". The project will bring together five companies, six SMEs and seven research institutes as project partners and pursue two fundamental goals:

1. To develop new, bio-based materials for containers and packaging such as films, to be produced using extrusion lamination or extrusion blow molding. Mechanical and barrier properties of these new packaging materials to be enhanced using innovative, biodegradable functional coatings.

2. To integrate smart technologies into packaging materials in order to provide the consumer with more information about the product and its shelf life and quality.

ENVIRONMENT

Both focal points of the project will involve developing new, environmentally friendly and efficient processes. Fraunhofer ISC will be developing biodegradable functional coatings with barrier and antimicrobial properties.

The project encompasses the design, development, optimization and manufacture of multifunctional, new, and smart packaging materials that respect ecological requirements in the material and production chain. The new packaging materials are directed at the cosmetic, pharmaceutical and foodstuff sectors.

Not only the packaging industry urgently needs the development of new sustainable and environmental friendly materials because of the large quantities of packaging waste. Another sector of similar macroeconomic importance is the protection against corrosion. Corrosion of metals and metal products causes, with 150 billion euros per year, a great loss of material and value within the industrial societies. To face these needs anticorrosive Cr(VI)-coatings were used even though they are known for their ecotoxicological and cancerogenic harms. Since several years, these substances have been forbidden for most of the industrial applications and are about to be forbidden in general.

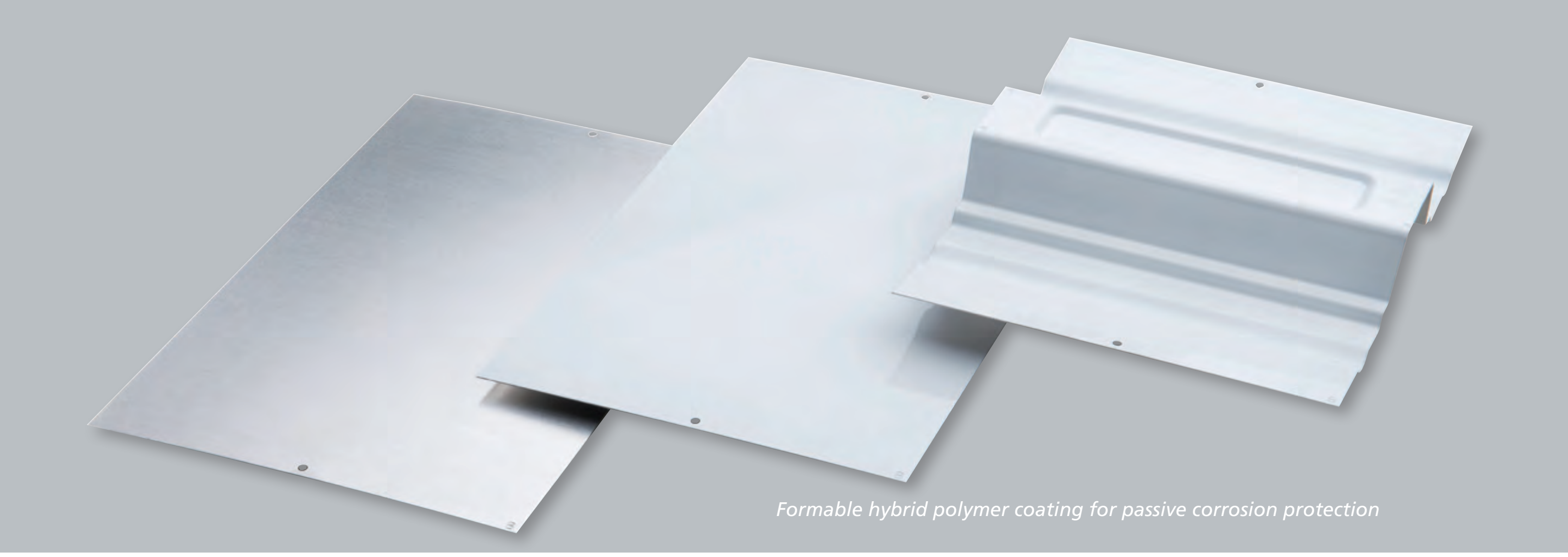
Range of uses for packing materials (Source: www.dibbiopack.eu)

Active coatings for corrosion protection

Galvanized coatings provide steel surfaces with very good protection against corrosion. But the zinc itself is also subject to corrosion when exposed to certain environmental conditions. To prevent this, either the thickness of the zinc coating is increased or an additional conversion coating is applied followed by a further organic coating. The highest corrosion resistance is obtained with a surface treatment known as "chromating", i. e. applying a conversion coating containing hexavalent chromium compounds. However, hexavalent chromium is a toxic substance and a known carcinogen, and so major research efforts are being devoted to finding harmless substitutes to perform the same function.

Fraunhofer ISC is coordinating the ASKORR project in which two Fraunhofer Institutes and two Max Planck Institutes are jointly developing active coatings for smart, sustainable corrosion protection systems. By synergistically combining specific coating materials and new nanocontainers filled with an active agent, it is possible to produce active composites with a selective self-healing effect. In such systems, the encapsulated polymerizable compounds are released exclusively at the site of the damage, and nowhere else.

One of the main problems successfully overcome by the researchers at Fraunhofer ISC was that of embedding the capsules containing the active agent in hybrid polymer corrosion protection coatings without damaging the capsules. They also delivered the proof-of-principle analysis. This involved using ion beam techniques to prepare samples of the hybrid coatings with exposed edges that could then be examined by means of SEM/EDX analysis. As the results depicted in Fig. 1 show, the first experiments proved that it was possible to embed the capsules in the coating, but due to the capsules' fragility, the prepolymers inside them were either partially or completely displaced by the hybrid matrix material during the insertion and coating fabrication process.



Formable hybrid polymer coating for passive corrosion protection

As a result of modifications to the capsule wall material (by the project partners) and to the hybrid polymer matrix (by Fraunhofer ISC), optimization of the insertion process, and not least thanks to efficient collaboration between the Fraunhofer ISC development and analysis teams, it was possible to develop a reliable process that enables microencapsulated polymerizable agents to be incorporated in the hybrid polymer matrix in such a way that both the capsules and their content remain intact, accompanied by the corresponding proof-of-principle analysis (Fig. 2). It was thus possible to establish a complete process, including the appropriate preparation and analysis methods, that is transferable to other active agents. For example, in future the process could be used to encapsulate liquid corrosion inhibitors and integrate them in hybrid corrosion protection coatings.

Managing interior environments with porous glass flakes in building materials and paints

Managing building humidity and temperature levels is an important consideration – and not only in building physics. Aside from the topics of energy consumption and user comfort, the effect of equipping rooms with damp absorbing/desorbing surfaces is now under discussion. In particular, higher building insulation standards and more stringent requirements regarding the ability of building shells to seal off the outside atmosphere, potentially lead to problems associated with mold infestations and high humidity inside the home.

The walls and ceilings of living spaces provide large surface areas that can be used to regulate humidity. Inorganic materials are an obvious choice for this task, as they are suitably

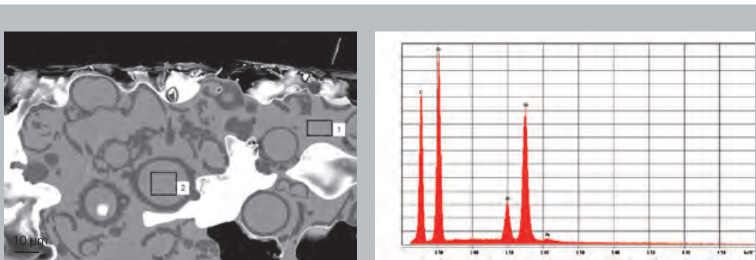


Fig. 1: SEM image of the exposed edge of a sample prepared using a focused ion beam (left) and the EDX spectrum inside a capsule (right), in which strong signals from the hybrid polymer matrix [C, Si, Al, O, (N)] can be observed. Note that the EDX spectra inside and outside the capsule are identical (the latter is not illustrated here).

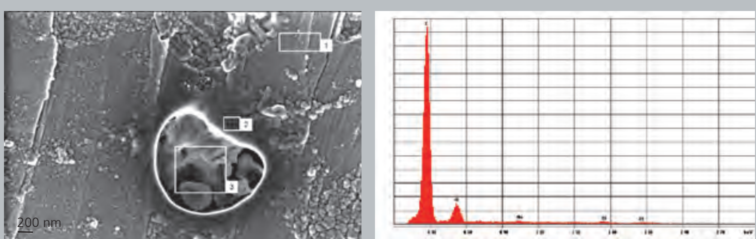


Fig. 2: SEM image of the exposed edge of a sample prepared by means of ion beam thinning (left) and the EDX spectrum (of marked area 3) inside a capsule (right). The carbon signal from the prepolymer is now the dominant feature of the EDX spectrum, rather than the signals from the hybrid polymer matrix (compare Fig. 1). Moreover, the graduated transitions from bright to dark areas in the SEM image suggest the presence of "dried fluid", and are thus a further indicator of the encapsulated prepolymer.

porous and can be incorporated into wallpaper, paints, wall plaster and gypsum. They are then able to absorb the impact of day-to-day or seasonal fluctuations in humidity, significantly reducing the bothersome need to air out the house at regular intervals, for instance. The advantages of water absorbing/desorbing paints, wall plaster and gypsum also include their ability to capture energy as water condensates in the filler substances, as well as enhancing personal comfort through lower air humidity.

Examples of inorganic materials which could be used for this purpose include zeolites (natural or synthetic) or artificially produced porous glasses or ceramics. In contrast to natural materials, specially manufactured materials can be optimized according to specification, including pore volume, pore size and particle shape. Glass and ceramics also raise the possibility of including additional features such as chemicals to stop mold. Glasses and ceramics can be made porous using a targeted sintering process; in the case of glass, this can also be achieved via spinodal decomposition and the isolation of a single phase in what is called the Vycor process.

The advantage of glass as opposed to ceramics is its malleability during the production process, an asset that can be exploited when using the phase separation technique. Compared with isotropic particles, glass flakes produced using this method and employed as filler substances can be incorporated into decorative paints in much higher concentrations. In any case, the material must be affordable and producible in large quantities if it is to be an attractive option for use within construction.

The goal of the project was to develop porous, vitreous filler substances for use in paints, wall plasters and gypsum, with the aim of managing interior environmental factors such as humidity, temperature and air quality in living and work spaces. First of all, it was shown that glass can be produced in batches of several 100 kg in powder or flake form, with a thickness of between 1 and 10 µm. Within the material, pore size can be specifically adjusted to anywhere from a few nm to several µm. The material demonstrates a high capacity for absorbing moisture, even after being embedded in paints or plaster. Model calculations and initial practical testing suggest that building materials modified in this way exercise a considerable influence on a building's energy balance, while improving comfort levels in the process. In addition, there is the possibility of integrating further active functions such as fungicidal or catalytic capabilities.

Using thermo-optical measuring techniques to assess secondary raw materials for use in the building materials sector

The ability to effectively extract and use secondary materials, potentially leading to significant savings in many areas of industry, plays an important role in sustainable economic development. Much of the organic waste produced by farming and forestry activities now goes to biogas plants to generate energy, while other waste products, following appropriate preparation and refinement processes, can be reused in many cases for urgent infrastructure work and in the building materials sector.

In the face of increasingly stringent regulations on work safety and health and environmental protection within the European economic region, the processes used to extract and recycle secondary raw materials must be optimized using new techniques if these materials are to be used at all, particularly in the aforementioned building materials sector. Improving the efficiency of waste-incineration processes, coupled with possible re-use of the residual materials – slag in particular – are the focus of novel concepts and systems now under development. A closer look is also being taken at how secondary raw materials used in construction behave under normal weather conditions, whereby they are to be assessed at alternating

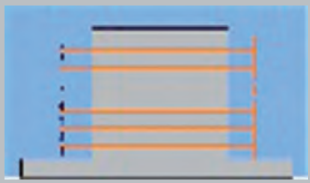


Figure 2 a: Principle of investigation – concrete sample in a water bath. Changes in the expansion of the sample are investigated simultaneously, splitting the sample into layers in order to define the various stress zones.

Figure 2 b: Profile of the sample during testing. Bubbling can be seen on the surface.

Figure 2 c: Set concrete following testing. The pores formed by escaping gas bubbles can be seen on the surface of the material. This sort of porosity is to be avoided as it means a reduction in quality.

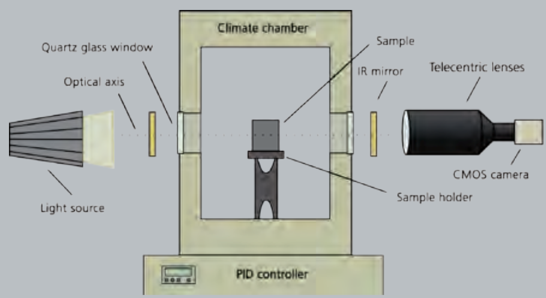
temperatures ranging from - 70 °C to + 180 °C and varying humidity levels of between 0 and 100 %.

Fraunhofer ISC has been working for over 20 years on developing new measuring techniques capable of analyzing thermal processes in situ while materials are under development, as well as helping to evaluate and optimize them. Known as thermo-optical measuring techniques (TOM), these processes have now been refined to the point that they are industrially applicable for a variety of uses within the development departments of numerous companies and universities. At the moment, a tailored technique called KLIMA-TOM is being developed to evaluate primary and secondary raw materials. Figure 1 illustrates the principle of the thermo-optical measuring techniques.

The main component of the measuring system is a furnace, in the case of KLIMA-TOM a controlled-environment chamber fitted with a heating element and a humidifier, allowing the chamber to be set to specified temperatures and levels of humidity. In order to evaluate the behavior of specific materials – including various building materials and concretes – two openings fitted with viewing panes are added on either side of the furnace, running along the horizontal axis. In the course of the thermal process, complex optics use image analysis to precisely record and measure changes in the contours of the sample, which is placed in line with the optical axis. The optical resolution is 0.4 µm.

In the following instance, illustrated in Figures 2 a,b,c, careful setting of the temperature and humidity levels can reconstruct the drying of the material under industrial conditions, allowing its behavior to be investigated. These data are used to modify and optimize production processes. This saves vast quantities of energy, guarantees an optimal and time-efficient drying process and, once the material has been treated, can help to avoid instances of mold in places such as the interiors of homes.

Schematic diagram of the new KLIMA-TOM measuring equipment

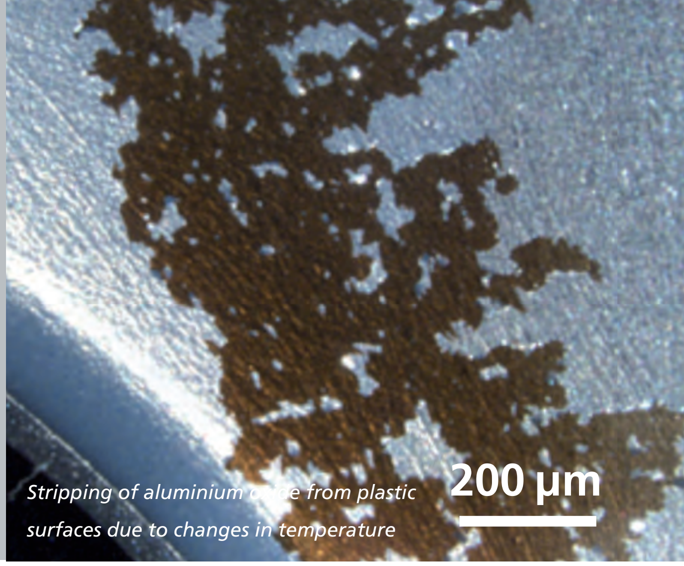


Analytics and the environment

Any substance or material under development will ultimately be subjected to a variety of environmental conditions when put to use, including temperatures that can range from - 40 °C to + 120 °C in direct sunlight or changes in humidity that range from very dry in the summertime to wet once the dew point is reached. Oxidative attacks from exposure to air, or even attacks from fungi and bacteria in what is known as biofouling, must also be considered. If the material is to be used near the sea, the impact of salt must also be considered as this can accelerate corrosion. Salt is not only a problem close to the sea, however, since salt is also used to prevent the formation of ice on roads in winter. If a material is porous or cracked, it can be permeated by water, which can expand when frozen at low temperatures, causing damage to the material or even structural failure.

Building materials and materials for the automotive industry and transport in general – namely those used across the world – must find a way to withstand these strains, whether induced by corrosion, heat or UV rays. Fraunhofer ISC reconstructs the effect of each environmental factor and analyzes its impact on the materials employed.

ENVIRONMENT



Stripping of aluminium oxide from plastic surfaces due to changes in temperature

On the macroscopic level, this involves exposing the aterials to artificial weathering in climate chambers and observing them throughout the weathering process using the KLIMA-TOM equipment currently under development. Subsequently, the materials are also examined on the microscopic level using a wide range of analytical tools. Here, the aim is to elucidate the relationship between environmental factors and changes in microstructure and material properties.

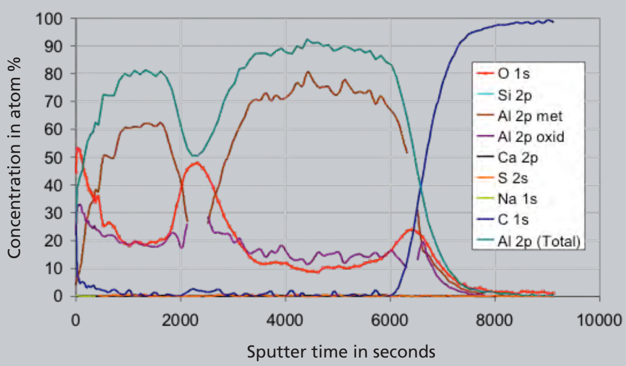
This precise analysis, which reaches the nanometer scale, means that the impact of environmental factors on materials can be investigated and the results used to develop appropriate solutions.

Aluminium coated plastics can serve here as an example of how environmental factors on materials are analyzed. In this specific instance, it was shown that the combination of materials used in the production process could not cope with the frequent changes in temperature, causing the observed patterns of damage (see figure 1).

On the microscopic level, oxidation of the aluminium was observed around the surface area. The resulting aluminium oxide, even though only nanometers in thickness, reacted to heat-induced expansion differently than the rest of the materials, causing the top aluminium coating to strip from the underlying plastic.

Figure 2 shows an XPS concentration depth-profile through the aluminium coating and into the plastic substrate.

The aluminium coating was applied in two steps of sputtering. The red curve shows oxygen concentration. Both directly at the interface with the plastic base material and between the two aluminium coatings, the levels of oxygen concentration increase significantly. The results of the measurements indicate the chemical bonding of the observed elements. The brown curve shows aluminium metal and the violet curve aluminium oxide. The increase in oxygen levels correlates with an increase in the concentration of aluminium oxide. This discovery allows conclusions to be drawn about the production process (what is known as process analysis). In the instance described, it is clear that the sputtering process is extremely vulnerable to leftover oxygen. This knowledge led to two possible solutions: either the purity of the production process had to be improved or a new coating material more tolerant to oxygen had to be found and applied to the process. Scientists chose to design a new material and were successful in doing so.



XPS concentration depth-profile of aluminium coating sputtered onto plastic substrate

As the above example demonstrates, environmental factors can lead to damage as early as in the production stage – in this case caused by tiny amounts of residual gases from the air, combined with another contributory factor, here a subsequent change in temperature. The only way to avoid this is to intervene in the manufacturing process. In-depth analysis of the damage plus a detailed knowledge of production techniques provide the basis for finding a workable solution. This is where the array of measurement techniques and experience on offer within Fraunhofer ISC's Center for Applied Analytics can really make a difference. These are backed up by a wealth of expertise in material design and optimization derived from related materials development activities. However, it is equally possible to come up with new material designs from molecular sources using a bottom-up approach. Systematically applying the principles of nanotechnology gives us access to multifunctional materials with new sets of properties.

NANOMATCH – Architectural restoration with nanomaterials

Global levels of greenhouse gas emissions are rising dramatically because highly populated, newly industrialized countries such as China, India and Brazil are meeting the energy needs of their expanding economies by burning increasing amounts of fossil fuels. The resulting climate change effects, including more frequent extreme weather events, are beginning to take their toll on historic buildings and ancient monuments in the countries of the northern hemisphere. It only takes an increase of a few degrees in average temperatures to accelerate the chemical processes responsible for corrosion, and thus endanger our centuries-old cultural heritage, which constitutes a significant economic factor for the tourism industry.

The process of degradation caused by airborne pollutants, which started at the time of the industrial revolution, is thus advancing at an ever faster rate. Efforts to repair the damage before it is too late require new materials that can be used as soon as the first signs of degradation appear (micro-fissures, local defects, surface erosion). In such cases, wet-chemical repair methods are far superior to other technologies because the low viscosity of the materials employed enables them to fill even the finest capillary cracks, and they can be applied to the structure on-site. The sol-gel process offers a versatile means of producing inorganic and hybrid materials which, as field tests have confirmed, can withstand many years of exposure with hardly any alteration.

As part of a European collaborative research project involving 15 partners from eight different countries, new inorganic materials systems are being developed for the conservation of glass and stonework, and the associated sol-gel process scaled up for industrial application. The aim is to develop materials that heal defects at an early stage, stabilize surfaces, and are environmentally friendly to use. The suitability of the new materials for application in restoration work on priceless historic buildings has been demonstrated in case studies conducted at Cologne Cathedral (glass, wood), the Cathedral of San Salvador in Oviedo (limestone), the Opera di Santa Croce in Florence (frescos), and Stavropoleos Monastery in Bucharest (stucco, frescos).

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HEALTH

Business unit HEALTH

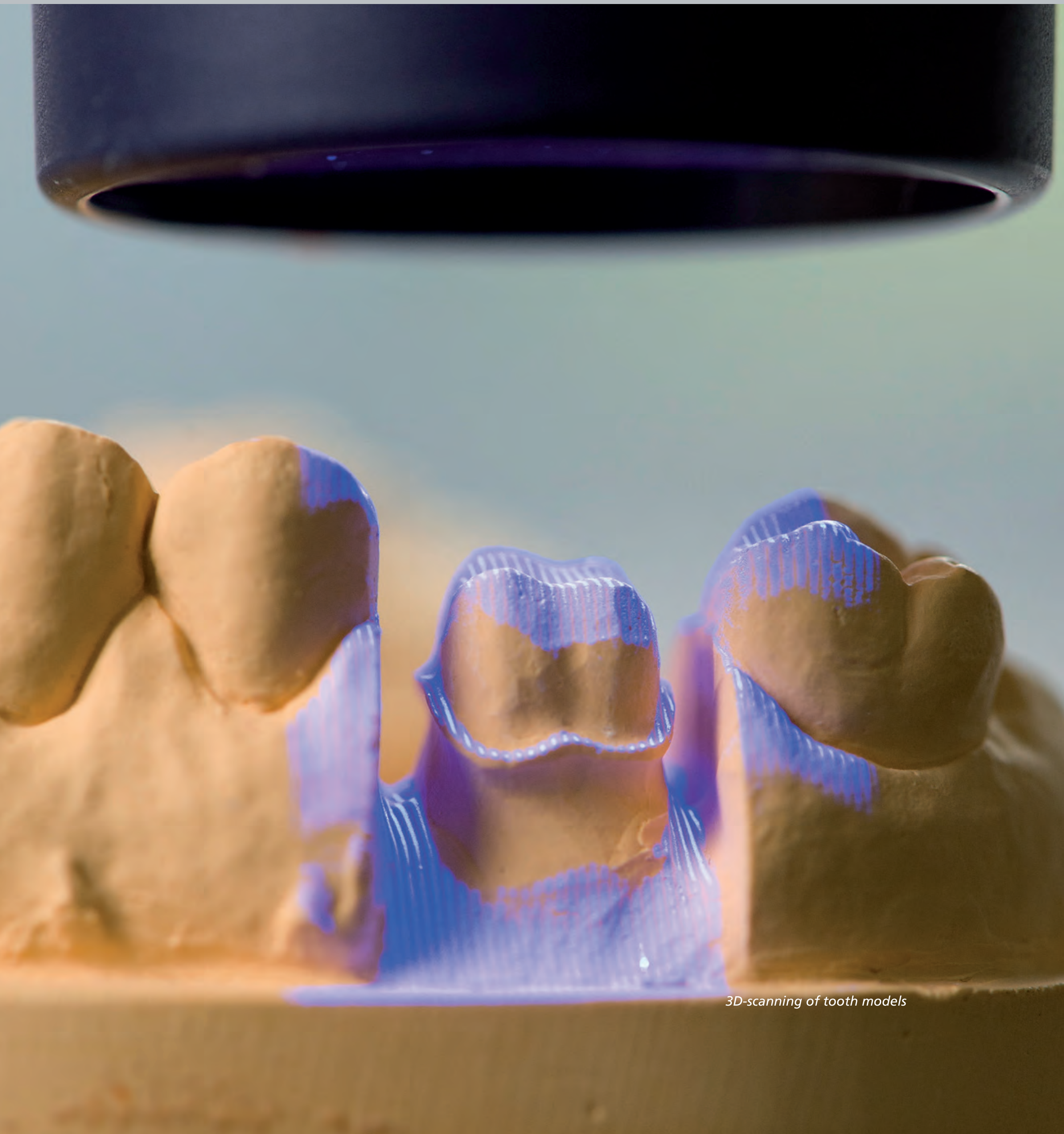
"In the first half of our lives we sacrifice our health for money; in the second we sacrifice our money to regain our health."
Voltaire, French author and Enlightenment philosopher (1694-1778)

Entirely new diagnostic tools and treatment methods will be needed if medical care is to successfully overcome the challenges presented by demographic developments and the impact of major endemic diseases. At the same time, the affordability of new high-tech treatments must be guaranteed – since we assume that every individual has the right to receive the best possible treatment, even in the face of growing pressure to hold down health care costs. This sort of balancing act can only succeed if we tread new paths, opened up to us by close cooperation among different disciplines. And this is where the development of innovative and multifunctional materials becomes a key link in the value creation chain. These materials are what make high-quality, affordable products a reality in diagnosis, treatment and healthcare monitoring. But tailor-made materials only offer a solution if the enduring aim of the applied basic research behind them is to transfer results into general medical care quickly, effectively and cost-efficiently, in collaboration with companies and clinics in the healthcare sector. The business unit Health concentrates its efforts in this context on the following applications:

- Regenerative medicine
- Dentistry
- Diagnostics

The materials developed within these areas can often be transferred to other areas, including applications involving high-tech medical devices ("smart" implants, endoscopic instruments for minimal-invasive surgery MIS, orthoses, ophthalmology), biophotonics (wellness, "healthy light", healthy living, biochips, biosensors) and pharmaceutical packaging (barriers against water vapor and oxygen, protection against light, desorption). These transfers can be traced to the fact that material research at Fraunhofer ISC deals with interdisciplinary technologies which have the potential to be used in nearly every area of health research. Maintaining a certain degree of flexibility is what counts here, also in the long term, since this enables the ISC to deliver an appropriate and quick response to new and urgent market requirements.

Once the new laboratory building (Technikum III) has been completed in mid-2013, particularly the new biology and GMP laboratories, increased laboratory capacity will allow the business unit Health to develop new types of functional materials. Here, the already close cooperation enjoyed to date with external cell and microbiologists will be built up further. Subjects such as theranostics, biohybrid materials and smart biointeractions are all due to be investigated in the coming years in collaboration with the Chair of Regenerative Medicine and Tissue Engineering at the University of Würzburg (Prof. Heike Walles, in-vitro and cell systems), and with the Fraunhofer Institute for Molecular Biology and Applied Ecology IME (Prof. Stefan Barth, biopharmaceuticals and animal models).



3D-scanning of tooth models

HEALTH

An in-vitro method for diagnostic of prostate cancer based on nanoparticles

The prostate carcinoma is the most commonly diagnosed cancer in men. In all, 40 % of the male population runs the risk of developing prostate cancer at some point during their lives. However, only around 10 % develop symptoms and only 3 % die of the disease. The introduction of a screening test for tumor marker PSA at the end of the 1980s led to a steady increase in prostate cancer being diagnosed. However, an increasing number of medical professionals have called the validity of the test into doubt, since in many cases it leads to a false positive diagnosis – with dire consequences. From 1986 to 2005, one million men were treated by resection and/or radiotherapy solely on the basis of a positive PSA test; at least 5000 of these patients died shortly after surgery, between 10,000 and 70,000 suffered from severe complications, while between 20,000 and 30,000 experienced side-effects such as impotence or incontinence. The U.S. Preventive Services Task Force, an independent panel set up by the U.S. Department of Health and Human Services, responded at the beginning of October 2011 with a recommendation to abolish routine PSA screening tests.

Significant importance will accordingly be attached to reliably characterizing the prostate carcinoma in future – both in clinical practice and on a molecular scale. New biomarkers and improved, targeted treatments are urgently needed to avoid over-treatment and to improve the way advanced prostate cancers are treated within an individually-tailored program of therapy. Because of their regulatory function in proliferation, differentiation, apoptosis and migration, miRNAs have attracted the attention of researchers in regard to their role in tumorigenesis and progression. In 2008, Mitchell et al. first showed that the cells of epithelial tumors and prostate cancer cells in particular, secrete miRNAs into the bloodstream. Here, significantly higher levels of miRNA-141 were found in the serum of patients with metastatic prostate carcinomata when compared to healthy test subjects.

Multifunctional nanoparticle systems and new, highly-sensitive detection methods play a central role in the development of cutting-edge, highly-efficient diagnostic methods at Fraunhofer ISC. In particular, they allow disease-specific miRNA biomarkers contained in the minutest concentrations in body fluids and tumor tissue to be identified and validated. This prompted the establishment of the new "Nanoparticle-based Diagnostics" working group, which focuses on developing new, high-efficiency in vitro assays for molecular diagnostics. These assays are to be compatible with the current analytical techniques in mainstream clinical laboratory use. The working group has been set up to be interdisciplinary, and thus covers all key topic areas and expertise required to successfully develop innovative diagnostic techniques.

In particular, work will focus on the following sub-disciplines, in close cooperation with specialist hospitals and other research institutions where appropriate:

- Validating any biomarkers identified in order to determine disease-specific parameters and boundary values for early diagnosis and monitoring of disease progression.

- Development of assay specific, multifunctional nano-particles for physiological system is used as a base for later oupling of biomolecules and adaptation to sensor systems. Due to their size-dependent properties, these materials open up new possibilities for further developing personalized diagnostics. They are able to bind biomarkers, encapsulate signal-emitting substances and make these visible through various imaging techniques during in vitro applications.

Functionalized nanoparticles

- Developing a method for the functional testing of assays by analyzing the relevant constraints of nanoparticle-based in vitro diagnostics, deducing requirements for developing the test, constructing a test platform, testing and subsequently verifying the method.

The vision for the future is to take advantage of pooling competencies to establish a technology platform that can serve as the basis for the accelerated development of diagnostic techniques based on nanoparticles.

ATTRACT research group "Cell-based assays of 3D-bottom-up-nanostructured surfaces for regenerative limplants and scaffolds" (3D-NanoCell)

Fraunhofer’s internal ATTRACT program has been successful in bringing on board Dr. Doris Heinrich, previously head of a biophysics working group at the Ludwig Maximilian University in Munich. She will be working on what is initially a 5 year project dealing with "The interaction of human cells and structured surfaces". Specifically, the six-person research group will be assisted by other Fraunhofer ISC competence units in three-dimensional structuring of material surfaces which allow cells to grow close to that of natural tissue.

A combination of cell tissue and high-tech materials aims to accelerate the process of integration into the biological environment. To achieve optimum cell colonization over the long term, an individually customizable 3D structure is being combined with a nanostructured, biochemically functionalized surface to ensure that cells interconnect with sufficient stability and are always supplied with sufficient nutrients.

This research could in the medium term stimulate a new generation of implants, in which nanostructured surfaces not only improve antibacterial properties but also encourage an adequately strong connection to surrounding tissue (in the case of joint prosthetics, for example, the physiological connection between bone tissue and the prosthesis stem of the implant). In the longer term, scaffolds could be nanostructured for use in tissue engineering, allowing cell functions such as adhesion, proliferation or differentiation to be specifically stimulated. However, being in a position to control and individually regulate cell functions still calls for a more detailed understanding of cytoskeleton regulation in living cells. This aim of the project is to be accompanied by the development of standardized diagnostic assays that could make this sort of regulation and control a reality by systematically modifying 3D-bottom-up surface structures in tandem with nanoscale structuring.

The ATTRACT research group will be working in close collaboration with material scientists from Fraunhofer ISC, as well as numerous departments of the University of Würzburg.

HEALTH

Glass ceramics in dentistry

Glass ceramics have proven their worth in many cases as a tooth replacement material. Their crystalline part – which can be set both in terms of the size of the crystals and the extent of the crystalline phases – allows mechanical attributes such as the strength and polish properties of the material and its translucency (limited light transmission) to be modified as required. Furthermore, the material's chemical resistance is better than pure glass – an important consideration, particularly in the mouth.

Where CAD/CAM applications are involved, the material demonstrates another very useful property, since it can quickly and easily be worked on mechanically during an intermediary step in crystallization. This takes place before a short tempering step transforms the material into the final, highly durable glass ceramic. The CAD/CAM process is carried out at the dental surgery itself or in a dental laboratory, depending on the needs of the individual patient. Often, this technique eliminates the need for time-consuming and costly temporary dental prosthesis.

Between 2009 and 2012, Fraunhofer ISC worked together with VITA Zahnfabrik H. Rauter GmbH & Co. KG (Bad Säckingen, Germany) and DeguDent GmbH (Hanau, Germany) to develop an innovative glass ceramic material as well as the equipment required to produce blocks for dental restorations. A glass ceramic material was successfully developed and patented; this material is characterized by its exemplary translucence, excellent chemical resistance and exceptional durability. There is an extremely large window during the crystallization process in which the material can be processed using standard dental CAM systems, before it is transformed very rapidly into the final material without losing its shape. The material can be very closely matched for color and given its polished finish by the dentist.

A prototype facility for manufacturing dental restoration blocks from this material was designed, set up and run in at Fraunhofer ISC. The facility already allows a monthly production in a variety of colors. The development of the material and construction of the facility were both undertaken by the certified competence team Glass and Mineral Materials, respecting guidelines in force for medical products as well as QM regulations.The material was presented by both industrial partners at the International Dental Show (IDS, March 2013 in Cologne) and should reach the market in September 2013.

Sulfonic acid functionalized ORMOCER® hybrid polymers for use as all-in-one adhesives

In adhesive dentistry, clinical effectiveness is decisively influenced by the long-term bond achieved between the restorative material (filling composite) and the hard tissue of the tooth (dentin, enamel). The adhesive systems employed play a key role alongside the high-quality restorative materials (filling composites) themselves. These systems should be easy to apply within a short space of time and be tolerant of possible error by the dentist while meeting the stringent requirements of biocompatibility.

Standard monomer-based self-etching adhesive systems have not yet been able to fulfill these requirements entirely. A significant shortcoming, apart from instances of discoloring and allergic reactions, is the formation of marginal gaps in which secondary caries can spread, so that restoration work must be redone. Innovative all-in-one adhesives based on

Milling of a chairside crown

sulfonic acid functionalized ORMOCER® hybrid polymers offer an excellent solution to these problems. These adhesives significantly cut down on treatment time– the most expensive part of the process – by reducing the number of steps in the application process. The time saved on treatment is equivalent to a reduction of around 30 – 50 %.

The fact that the all-in-one adhesives allow for error during application and are more stably rooted thanks to optimal etching of the cavity surface – resulting in improved micro-mechanical bonding mechanisms – ultimately increases the lifespan of restorative work and avoids expensive follow-up treatment caused by secondary caries or loss of filling etc.

Thanks to ORMOCER®s' very good solubility in water the need for further solvents such as acetone is eliminated, minimizing cases of allergic reactions. In addition, the monomer-free concept does without traditional methacrylate monomers, particularly HEMA, and employs structures that are hydrolytically insensitive. These factors noticeably improve biocompatibility, which leads to enhanced benefits to patients. These ORMOCER®s can therefore be seen to represent an ideal material basis for high-quality yet simple and affordable all-in-one adhesives.

Chairside crown

ORMOCER®-based composites have already been on the market for several years as straightforward tooth restoration and disease preventing materials. Now, an innovative treatment concept, the "Chairside Crown", is to use an optimized base material to offer a high-quality yet affordable crown material. Taking impressions digitally with an oral scanner, producing an aesthetically high-quality crown (through a multiple coating system and coloring tools tailored to the individual patient, for instance), followed by the subsequent fitting, are all completed "chairside" – during one consultation and without any dental laboratory services.

ORMOCER®-based chairside crowns also offer the advantage of eliminating the need for costly follow-up treatment, while allowing repair work inside the mouth, unlike ceramic crowns. In the latter case, repairs normally involve expensive after-treatment and the need to make a new crown.

In contrast to traditional ceramic crowns, the ORMOCER®-based composites of the chairside method minimize both the work involved and the strain placed on patients (only a one-off local anesthetic is required), as well as significantly reducing the costs of treatment. Accordingly, ORMOCER®-based composites amount to an excellent base material for a high-quality, aesthetically sophisticated and comparatively affordable tooth replacement.

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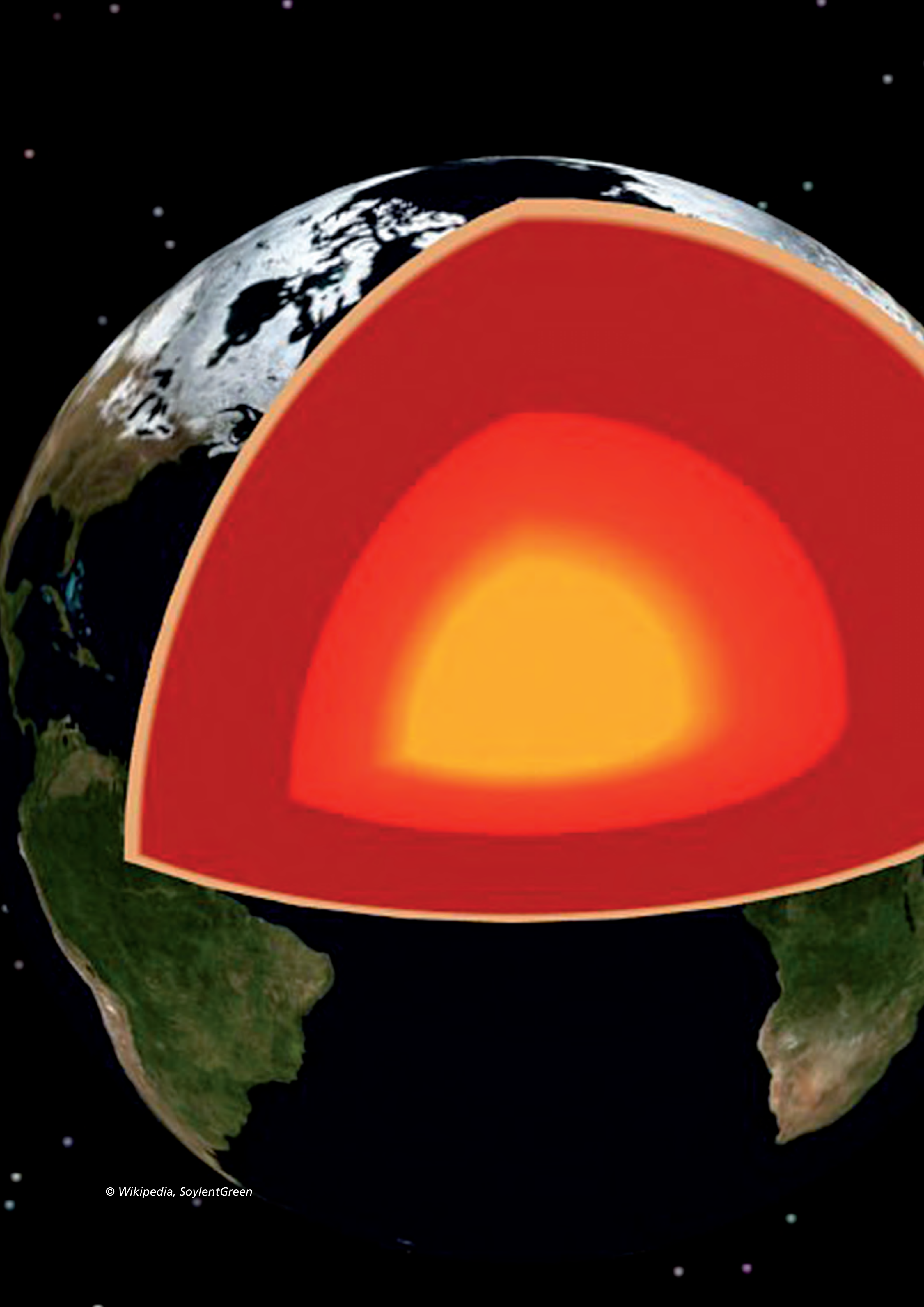


ENERGY

ENERGY

POWERING THE SHIFT TOWARD GREENER ENERGY

Energy is crucial to how we live. The only way for modern industrial nations to prosper in the future is by ensuring a secure energy supply and a responsible use of natural resources.

By conducting research into innovative materials, applications and new technologies, we can help to maintain our high living standards over the medium to long-term by developing affordable and reliable energy supply systems. Working in close collaboration with our customers, our goal is to identify sustainable, economical and eco-friendly methods of generating, storing and making more efficient use of energy across a broad range of target applications

Current research is understandably focused on the move towards a greener, more sustainable energy economy based on the expansion of renewable energy sources. However, many of the technologies that are currently available in the fields of wind power, hydro power, solar energy, bioenergy and geothermal energy are still in their developmental infancy and will require considerable efforts to reach technically optimized maturity. What's more, an energy supply that is primarily founded on renewable energy sources will be far more decentralized than has ever been necessary in the past. That will require new infrastructure, new storage technologies and new methods of transmission and control.

The sustainable provision of energy from renewable sources must be accompanied by energy conservation measures and more efficient energy use. The technological leaps required for this can only be achieved through close collaboration between research institutes and industry. With its broad materials science background, Fraunhofer ISC offers the ability to explore a range of exciting opportunities for short- and medium-term solutions. For example, conventional energy conversion systems based on fossil fuels still offer significant potential for efficiency improvements. The efficient utilization of lignite and bituminous coal depends to a significant degree on modern power plant technology. It is therefore important to focus on optimizing combustion processes and cleaning furnaces to remove waste products, especially bottom ash, when considering the development of novel concepts and systems. Thermo-optical measurement (TOM) systems developed at Fraunhofer ISC's Center of Device Development (CeDeD) enable researchers to conduct precise analyses of combustion and cleaning processes on a laboratory scale and develop techniques for their optimization. The results can help to substantially reduce the quantity of coal required to obtain the same amount of usable energy, thereby cutting CO_2 emissions.

One of the key components of the business unit ENERGY is the Center for Applied Electrochemistry ZfAE, which was founded in October 2011. The Center's work primarily focuses on new materials and components for electrochemical energy storage systems. It is increasingly difficult to imagine how modern society could function without electrochemical energy storage systems: They are used millions of times a day in every portable electronic device, in every car and in countless other areas of our lives. As well as various types of batteries, these storage systems also include electrochemical double-layer capacitors (supercaps) which are used to temporarily store small amounts of electrical energy, primarily in order to reduce battery drain. As part of its research into achieving reliable energy supplies from renewable sources, the ZfAE focuses on the potential of both electromobility and stationery energy storage


Switchable window colours with electrochromic coatings

systems. The Center is currently studying the development of materials for safer and more powerful lithium-ion batteries and for hybrid systems comprising double-layer capacitors and batteries.

One of the most promising methods of improving the safety of lithium-ion batteries involves the use of non-combustible polymer electrolytes. The Center has drawn on Fraunhofer ISC's many years of experience in the field of inorganic-organic hybrid polymers (ORMOCER®s) to develop a replacement for current highly flammable organic liquid electrolytes. The inorganic polysiloxane matrix of the hybrid polymers used for this purpose provides high thermal, mechanical and electrochemical stability, thereby offering a particularly high degree of safety. The molecule design can easily be functionalized and tailored to specific requirements. This has already led to the production of stable electrolytes with conductivities of almost 1 mS/cm.

Based on Fraunhofer ISC's synthesis expertise, the Center is also developing new electrode materials for lithium-ion batteries and electrochemical double-layer capacitors. This process involves synthesizing materials with high specific capacity that allow batteries to operate at high voltages and high energy densities, provide rapid charge/discharge capabilities thanks to nanostructuring, and ensure high power density in energy storage systems.

Encapsulation of latent heat storage materials

Efficient energy use can be achieved not only by storing electrical energy, but also by storing heat. Latent heat storage materials, also known as phase change materials (PCMs), store the heat energy that is released or absorbed when changing from one state to another. Fraunhofer ISC is working on hybrid polymer meso-encapsulations of PCMs which are easier to integrate in other materials and which enable the rapid transfer of heat between the storage material and its surroundings. This development could significantly increase the potential commercial applications of PCMs.

Thermal energy is usually stored as sensible heat, i. e. heat that we can feel or see. An advantageous alternative to this form of storage is to store the thermal energy as latent ("hidden") heat. In this case, the thermal energy is contained in a phase transition, generally the transition between liquid and solid phase. Hand warmers containing sodium acetate are a well-known example of this phenomenon: They can be activated by bending a metal tab to release the heat and can be recharged by heating. Energy storage of this type can take place without thermal insulation and in a small space.

When it comes to technical applications, a multitude of different storage substances and container geometries are currently under discussion. Fraunhofer ISC has been working on the microencapsulation of inorganic latent heat storage materials for a number of years. Encapsulation enables the materials to be integrated in other materials and promotes a rapid transfer of heat between the storage material and its surroundings. By encapsulating the materials in small spheres, it is possible to create a much larger accessible surface area for heat transfer while maintaining the same overall volume. This know-how is currently being applied to the fabrication of meso-encapsulated sugar alcohols. These offer a number of highly promising characteristics related to the adjustment of the desired conversion temperature, the quantity of stored energy per volume, and requirements regarding safe operation (toxicity, fire load).Preliminary trials conducted as part of an EU-funded project have resulted in the successful encapsulation of a sugar alcohol in capsules measuring approx. 2 mm.

Dust repellent coatings for a more efficient use of solar energy

Resource-efficient air conditioning using smart shading technology

A significant proportion of the energy consumed by buildings and vehicles is used for air conditioning. One innovative solution involves electrochromic windows, also known as "smart windows", which change their light transmittance when a low voltage is applied. This can reduce energy consumption by up to 30 %. Fraunhofer ISC has developed several new material systems for this purpose which offer levels of functionality that are far superior to commercially available products. A new type of smart window based on metallo-supramolecular polyelectrolytes (MEPEs) makes it possible to utilize a wide spectrum of colors. Fraunhofer ISC researchers have also been working on an additional cost and energy-efficient smart shading technology based on conductive polymers, which they have successfully scaled up to a pilot plant level. The project was conducted by a consortium of 17 partners from 10 countries under the leadership of Fraunhofer ISC and was completed in 2012. In the future, the installation or retrofitting of electrochromic windows for low-energy shading in vehicles and buildings will make an important contribution toward the goal of efficient energy use.

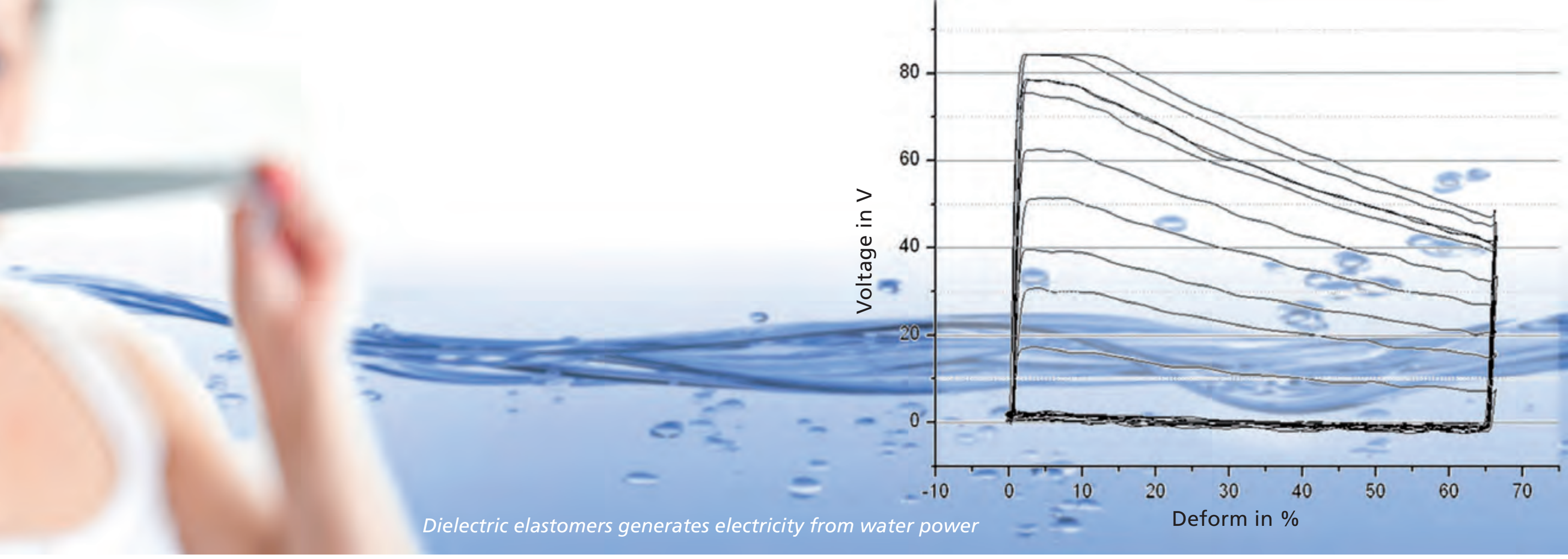
Efficient use of solar energy

In conventional photovoltaic cells and thermal solar collectors, 10 % of the incident solar radiation cannot be used to generate energy, with the majority of this (8 %) being reflected from the surface. Anti-reflective coatings successfully commercialized by Fraunhofer ISC significantly reduce the amount of reflectance, thereby increasing the energy yield. This can increase the annual performance of photovoltaic modules by between 3.5 and 4 %, a figure that jumps to between 7 and 8 % for solar thermal systems. The new dust-repelling coatings also provide photovoltaic modules with lasting self-cleaning effects. For the first time, this means that solar installations can be used efficiently in dusty desert regions and arid areas of southern Europe.

Research by the competence team Materials Chemistry is also playing a key role in the latest generations of photovoltaic systems. For example, light-scattering layers are helping to improve the efficiency of silicon-based thin-film solar cells. Transparent barrier coatings on films for organic photovoltaics are essential for protecting the organic solar cells from the effects of environmental exposure. Known as ultra-barrier films, these coatings were developed within the Fraunhofer POLO Alliance, which is coordinated by Fraunhofer ISC. These high-density films are also important in the manufacturing of durable energy-saving organic light-emitting diodes (OLEDs).

Smart methods of energy conversion

The increasing use of microtechnical systems with power requirements of between 1 and 100 mW – for example in the fields of sensor systems, communication devices, positioning and monitoring systems – requires the development of special solutions to achieve a reliable and autonomous supply of energy. Based on the many years of experience acquired by the Center Smart Materials CeSMa, researchers working in a joint project have developed "Energy Harvesters" based on piezoelectric generators. These smart energy conversion devices have already been used in a number of applications, including supplying power to a sensor system used to monitor the structure of a highway bridge. In this case the power was generated by the piezo-generators from the vibrations caused by traffic crossing the bridge.



Dielectric elastomers generates electricity from water power

DEGREEN – Pioneering technologies for harnessing wind and hydro power

Fraunhofer ISC is exploring entirely new grounds in power generation in its DEGREEN project. Researchers are studying special dielectric elastomer films which can work as variable capacitors to convert mechanical energy into electrical energy. This approach will be used as a basis for the development of decentralized systems for harnessing wind and hydro power which will be capable of efficiently generating power even in quantities as small as just a few kilowatts. Currently, harnessing wind and water to generate energy requires the use of wind turbines, waterwheels, dams, etc., which are increasingly coming under criticism for their visual, acoustic and biological impact. New solutions are therefore needed.

In the DEGREEN project, the Center Smart Materials CeSMa is using dielectric elastomer generators (DEGs) to develop new technologies for effective, environmentally-friendly energy conversion which avoid the unwanted side-effects of conventional techniques. The high elasticity of the dielectric elastomer films – the surfaces of which are coated with highly distensible electrodes which allow them to work as a capacitor – makes it possible to utilize a new principle of converting mechanical energy into electrical energy. When the film is mechanically deformed by wind or water, its electrical capacitance changes. This charges a temporary storage device implemented on an integrated circuit. The aim is to develop modular DEGs with an electrical output of up to 1 kW.

This will enable the development of energy supply concepts which can be used to create effective, eco-friendly and decentralized energy supplies for rural regions. Decentralized energy supply concepts are of particular interest in these regions because they eliminate the need to install new power lines. Potential areas of application include charge spots for electric cars which could be installed far from transmission grids. Elastomer materials are the key to a new generation of generator systems for energy conversion. By supporting the DEGREEN research project, the Bavarian State Government is showing its support for the innovative technologies required to move towards a greener, more sustainable energy economy.

The services offered by the business unit ENERGY are not only aimed at major industrial enterprises, but also expressly at small and medium-sized enterprises, as some of the selected project examples show. We value the opportunity to collaborate with our partners on constructive, exciting and inspiring projects. By working together to tackle short and medium-term challenges, we can play a key part in helping to shape living conditions in the future.

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CENTER FOR APPLIED ELECTROCHEMISTRY

DR. VICTOR TRAPP, HENNING LORRMANN

Electric vehicles are the future! Very few would question this assertion in light of rising fuel costs and ever more advanced storage technologies. Contrary to all forecasts and targets, however, the term "electric vehicle" is now no longer applies solely to electric cars. We are increasingly becoming (electro-) mobile from a wholly unexpected quarter: while only around 4,500 electric cars were registered in Germany by the start of 2012, more than 300,000 electric bicycles, also known as pedelecs, were already on roads, in parks, and on cycle paths at the same point in time. In China there are now over 150 million electric bicycles. And the market continues to grow rapidly – by just under 30 % year-on-year. While the target of bringing to market one million electric cars by 2020 is proving to be a herculean task for government and the automotive industry, a two-wheeler market running into millions has sprung up almost by itself.

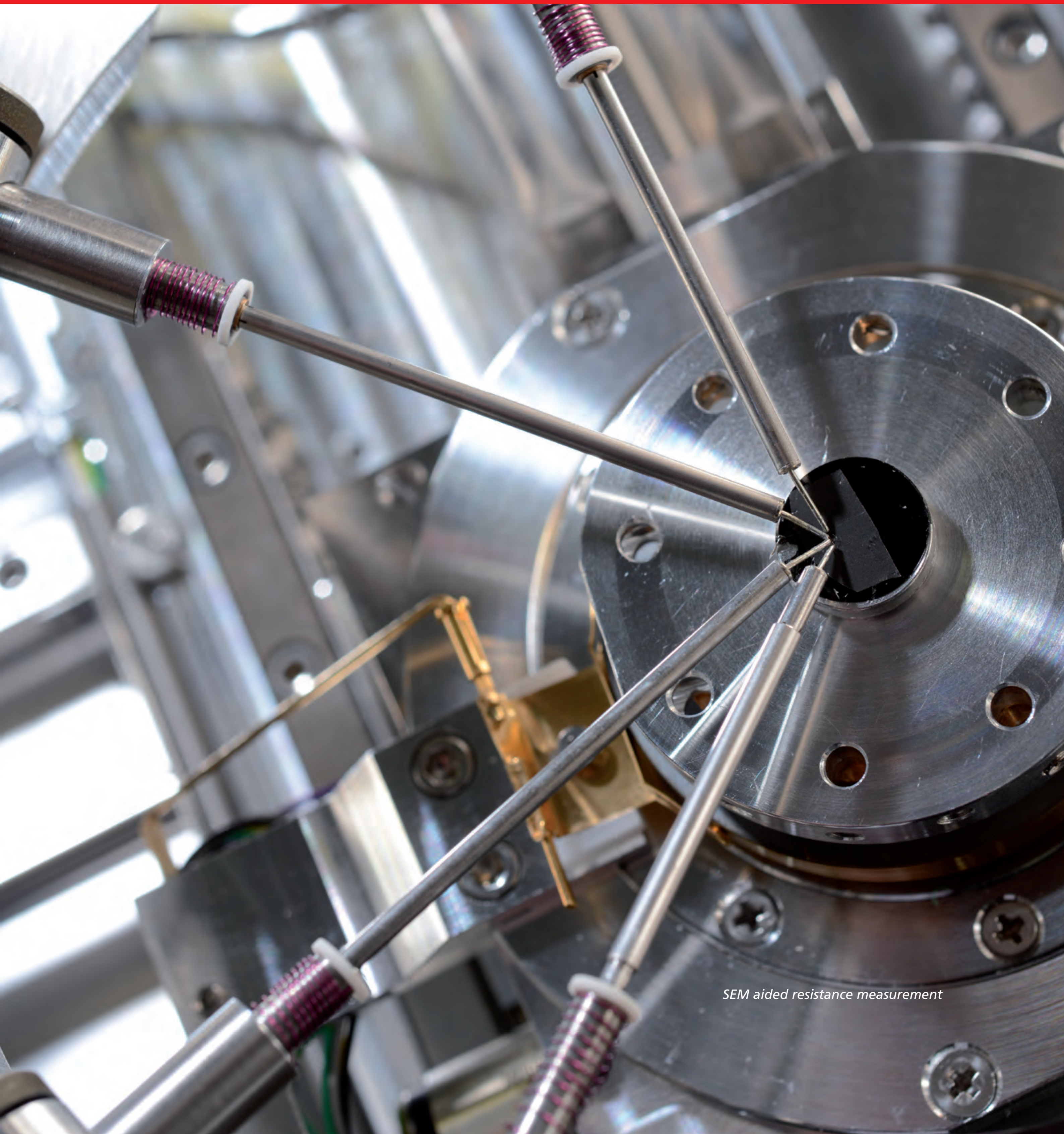
Stationary energy storage devices offer just as much potential. Power utilities are facing new challenges all the time thanks to the growth of renewable energy sources such as wind, hydroelectric and solar power. The need for stationary storage devices is driven by a need for local energy storage at the decentralized point of generation. According to a forecast from strategy consultants Roland Berger, the combined market for stationary storage devices based on lithium-ion technology, leisure vehicles and mobile machinery (e. g. electrically powered forklift trucks) will be worth 4 billion euros by 2020.

The Center for Applied Electrochemistry is tasked with promoting these developments through materials and process development, analytical studies and lifecycle analysis. Besides novel anode and cathode materials with increased storage and power densities, research is also focusing on safe hybrid electrolytes. The materials are analyzed and qualified in-house using a wide range of methods. At the same time the Center is also working closely with industry and research partners to develop the various cell components as well as developing a measurement cycle for the actual representation of the load profiles of pedelecs. Manufacturing processes are tailored precisely to the particular requirements in order to ensure maximum performance of all components.

The work of the Center for Applied Electrochemistry is divided into three complementary areas: materials development, process development, and electrochemical characterization and post-mortem analysis.

Electrodes

It was possible to apply the production technique for phosphates and oxides as electrode materials using hydrothermal synthesis to a wide range of transition metals. This means electrode characteristics such as energy density and voltage range can now be customized. High crystallinity with good access of the lithium ions to the interior of the particles provides higher power density than conventional compact particles.



SEM aided resistance measurement

ENERGY

Processes that cause damage at the electrode/electrolyte interface, due to the development of high redox potential and leaching of the materials, are important causes of premature cell ageing. In order to combat this process, a method was developed of sheathing active materials with an artificial protective layer (solid electrolyte interface, SEI). The results of this research were transferred successfully to a patent application. Industrial implementation is being prepared in a Fraunhofer-internal project with Fraunhofer ISIT.

Electrolytes

Work involving inorganic/organic hybrid polymers aims to produce inherently safe electrolytes. The integration of functionalized particles and various additives allows the properties to be controlled and balanced very effectively. Consequently, it is important to use highly stable components for systems with high conductivity in the range of 1 mS/cm. Electrolytes with an increased voltage range were developed by Fraunhofer ISC last year using special high-voltage spinels and olivines. This return to the Fraunhofer Institute for Silicate Research's roots – the chemistry of silicates and glasses – laid the foundation for the development of inorganic solid-state electrolytes, which combine outstanding electrochemical stability and high ionic conductivity with virtually all the industry and user requirements for non-flammable electrolytes. A fully automatic glass screening plant developed in-house is facilitating this research. The robot-controlled plant allows up to 16 different glass modifications to be manufactured and analyzed for use as solid-state ionic conductors. In combination with the hybrid polymers, remaining questions regarding mechanical flexibility and the interface between electrode and electrolyte are being investigated. Together with an industry partner, a project has been initiated that involves connecting the hybrid polymers to the electrochromic layers with high optical transparency. The aim is to develop electrolytes for use in electrochromic windows.

Process development

It takes a great number of successive process steps to manufacture lithium-ion batteries and supercapacitors, from the precursors through electrode coating to the complete cell. High-performance products demand appropriate coating and manufacturing processes. This is why these process steps were analyzed in detail last year (e. g. by measuring the paste rheology) and also incrementally improved (e. g. by modifying the mixing techniques). New processes were developed to this end, while customary solvents replaced with harmless materials or dispensed with entirely by going down the dry route. Parameter modifications often require partial or complete conversion of the process chain. An entirely new binder system needs to be devised and tested for the dry coating of new active materials. Semiautomatic manufacturing of multilayer pouch bag cells up to a size of DIN A5 was set up so that the materials could also be offered to prospective customers and project partners from industry and research.

Ageing and post-mortem analysis – quality control for batteries

Mobile devices with lithium-ion batteries have become an integral part of everyday life. Some product segments boast growth rates in the double-digit percentage range. Many manufacturers see the potential of this technology (e. g. for electrically powered bicycles, battery-powered garden tools, etc.), but often have neither the necessary resources nor the insight into the complicated cell chemistry to inspect the characteristics of large volumes of cells sourced from external suppliers. The Center for Applied Electrochemistry is the ideal partner in this respect. Sound knowledge of every battery component, combined with the necessary metrology, enables it to test component characteristics thoroughly before the decision is taken to invest in a given manufacturer's battery cells and packs. Testing can be limited to an independent compari-

Synthesis of electrode materials

Electrode materials

Mini calender

son of the nominal and measured capacity. Where necessary, the cell can also be broken down into its constituent parts in an inert atmosphere and the respective components compared with the data-sheet specifications or the expected lifecycle checked by means of realistic test processes. Detailed cell benchmarking can thus prevent a mistaken investment in cells with poor quality or the wrong characteristics. Even the best battery pack can be prone to defects. In the case of a customer complaint, the Center for Applied Electrochemistry can pinpoint the cause of the defect through non-invasive methods (computer tomograph, impedance spectroscopy analysis) or opening the cell to examine the individual components.

Electrochromics

The ability to switch windows from transparent to blue (or to virtually any other color) at the push of a button paves the way not only for a wider range of design options but also for major energy savings. Shading the windows in the summer can achieve substantial energy savings. In collaboration with the Center Smart Materials, the University of Würzburg, the Karlsruhe Institute of Technology and the Federal Institute for Materials Research and Testing in Berlin, two projects funded by Germany's Federal Ministry of Education and Research (BMBF) and the EU were successfully completed last year. The results of each project were so outstanding that they form the basis of new government- and industry-funded projects. In addition to application-oriented basic research on metallo-polyelectrolytes and other conducting polymers, these projects essentially entail transferring the results from the lab to a pilot-plant scale and, ultimately, to an industrial application. To this end, a system is being planned at the new pilot-plant building at the Neunerplatz location that can provide fully automatic coating on transparent, conducting films using the roll-to-roll process. The applications for this "transparent battery" are extremely wide-ranging and go far beyond conventional façade glazing: since neither their switched nor their unswitched state requires an energy supply, and since conventional float glass or flexible films can be used as a substrate, the systems are suitable in an architectural context not just for use in new buildings but also for retrofitting existing windows. Thanks to their flexibility, they can also be used for curved window surfaces, such as aircraft cabin windows, in cars, in visors for motorcycle helmets or as viewing windows in refrigerators.

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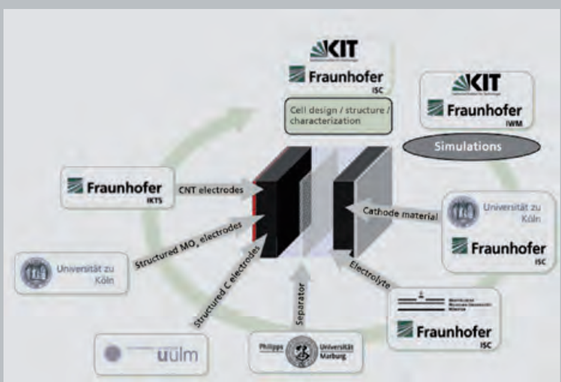
CONCEPT STUDIES FOR NOVEL LITHIUM-ION CELLS

HANNE ANDERSEN

The "Concept studies for novel Lithium-ion cells based on Materials Innovations" (KoLiWIn) project was run in conjunction with two Fraunhofer institutes and five university partners. Funded by Germany's Federal Ministry of Education and Research (BMBF), the project focused on developing innovative anode materials. The material- and structure-dependent properties were analyzed using not only electrochemical methods but also multiscale simulations. The goal was to make lithium-ion batteries faster, safer and smaller. This included increasing the energy and power density compared with the state of the art and bolstering safety by using noncritical electrolyte and electrode active materials.

Concept studies for novel lithium-ion cells based on material innovations (KoLiWIn)



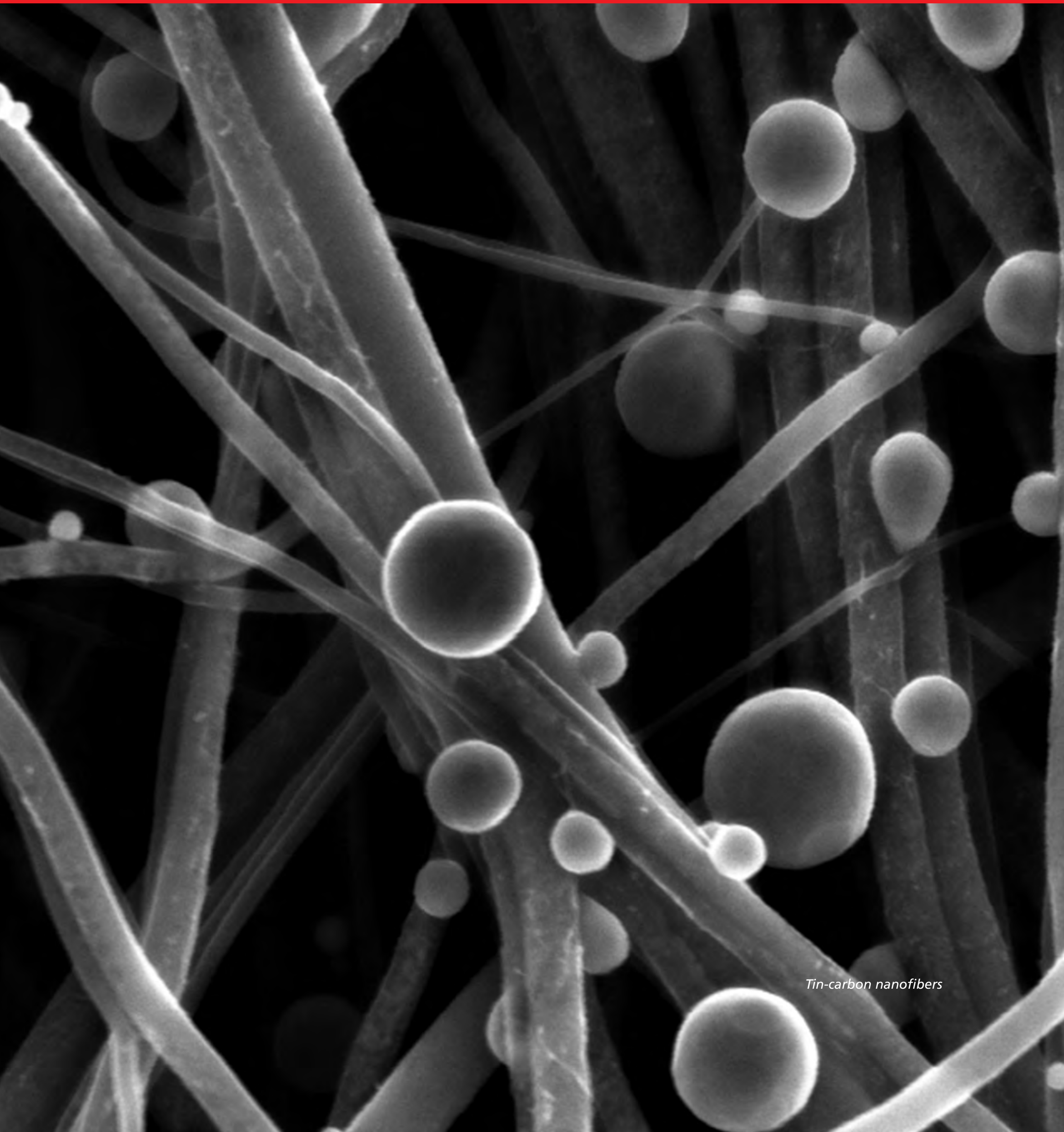
Structure of the KoLiWIn project

A battery's individual components – the anode, cathode, separator and electrolyte – are important factors in the battery's performance, along with the manner in which these components are finely tuned to each other. This demands in-depth materials expertise and precise knowledge of the electrochemical processes that determine interaction of all components in a battery cell's various load states. The starting point for KoLiWIn was to conduct basic research into these areas.

Ten years' experience in materials development for lithium-ion batteries made Fraunhofer ISC the ideal candidate to coordinate the project. The main aims were to develop and implement a new cell structure, its characterization possibilities and other optimization strategies for more powerful, safer components in future lithium-ion batteries.

As regards functional electrodes, the focus was on developing "nanostructured anodes". Here, the project partners (Fraunhofer IKTS, University of Cologne and University of Ulm) adopted various approaches and these were evaluated during the course of the project.

New approaches for innovative separators with aligned porosity were developed at the University of Marburg. Electrolytes and conducting salts were selected and the interaction with the electrodes investigated at Fraunhofer ISC and the University of Münster. The work was based on multiscale simulations



Tin-carbon nanofibers

(Fraunhofer IWM) and on electrochemical characterization and modeling (Karlsruhe Institute of Technology). The entire lithium-ion cell was examined and the partners' complementary expertise leveraged to the full. The consortium was actively supported by industry thanks to the involvement of Varta Microbatteries GmbH.

New anode materials deliver more power

In collaboration with the University of Cologne, various developments were made on the nanowire anode with elements such as tin, germanium and silicon. Vapor deposition was used to manufacture nanowire SnO_2 with a very high output charge. Using metallic foams instead of flat films for the current collector permitted a substantial increase in the material's charge and stability. A carbon matrix was created to reduce the negative impact of the known volume changes of anode materials containing Sn during charging and discharging. Electrospinning was used to manufacture flexible tin-carbon nanofibers whose electrochemical properties substantially exceed the state of the art.

The University of Münster pursued a second approach to resolving the volume change issue by using polymer coatings on the anode materials. The stability of the Sn anodes was improved by means of an external protective layer, thus substantially increasing service life.

Anodes based on nanocarbons were manufactured at Fraunhofer IKTS and at the University of Ulm. On the one hand, CNT lawns were deposited onto various substrates using vapor deposition. On the other, porous carbon monoliths with very high conductivity were synthesized on the basis of silica templates. Both anode materials were successfully doped with silicon, making it possible to achieve the desired increase in charge capacity required for more powerful battery cells.

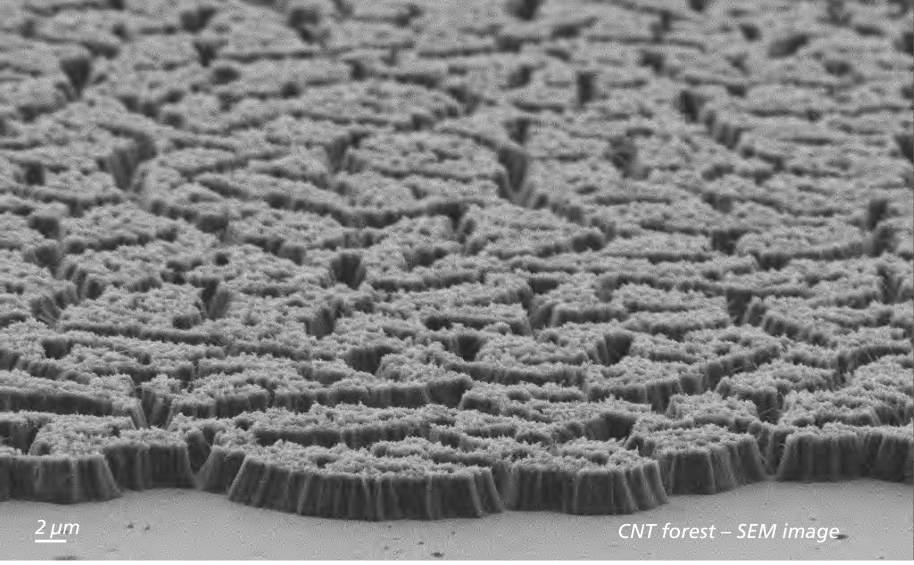
At the University of Marburg the quaternary lithium chalcogenidometallates $Li_4MnSn_2Se_7$ and $Li_4MnGe_2S_7$ were manufactured for the first time as an innovative electrode material and electrochemically characterized. They exhibited promising properties compared with the state of the art, especially as regards specific charge and stability during cycling.

Corresponding functional cathodes

$LiCoO_2$ tends to be used as a commercial cathode material in lithium-ion batteries. A substitute is necessary to make the batteries safer – and not reliant on the availability of cobalt. For this reason $LiMn_2O_4$ cathodes were manufactured at Fraunhofer ISC. The material improves the state of the art thanks to higher theoretical charging, energy density and safety. Optimized adhesion to the substrate was achieved with a metallic, porous current collector. The porous substrate also allowed for higher loading of the cathode material. Other cathode materials were manufactured at the University of Cologne using electrospinning. The advantage of the process lies in the self-supporting, binder-free electrode and good scalability. $LiFe_{1-y}Mn_yPO_4$ with a carbon coating to increase the electron conductivity exhibited improved electrochemical properties.

Improving safety – nonflammable electrolytes

An important aspect in the KoLiWIn safety concept was, however, the substitution of electrolytes containing solvents (and hence flammable) with solid-state ion conductors. The inorganic-organic hybrid polymers developed at Fraunhofer ISC are fundamentally well suited to accepting and transporting lithium ions. As part of the project, the Fraunhofer ISC research scientists managed to modify the chemical composition and structure of the hybrid polymers for optimum



CNT forest – SEM image

tailoring of essential properties such as conductivity and electrochemical stability to the requirements of the charge and discharge cycles. A design with standard electrode materials proved compelling thanks to its highly stable behavior and good material compatibility.

The battery cell is more than the sum of its parts

The innovative materials and structures developed in the project were tested at Fraunhofer ISC in half cells (cells where the cathode/anode are examined separately). This allowed the electrochemical properties of the novel anode and cathode materials to be assessed and suitable pairs selected. As part of this research, it became clear that the doping process for the new anode materials in particular provides a very good balance between charge capacity and cycle stability.

Finally, the selected combinations were electrochemically analyzed and tested in full cells and characterized with constant charge/discharge currents using cyclic voltammetry and cycling. This approach allowed the outstanding issues in terms of cell design and surface geometry to be defined more accurately, thus paving the way for a new lithium-ion cell prototype. A follow-up project will start at this point and provide the basis for technological implementation.

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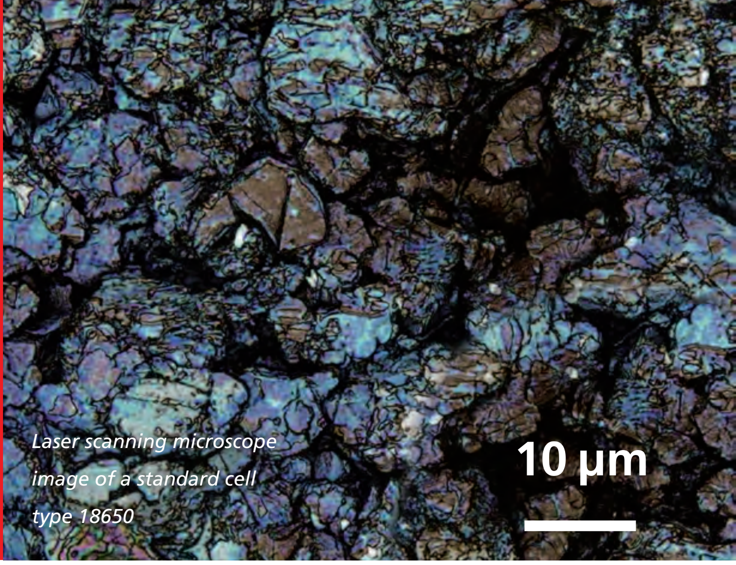
ENERGY



Laser scanning microscope image of a standard cell type 18650

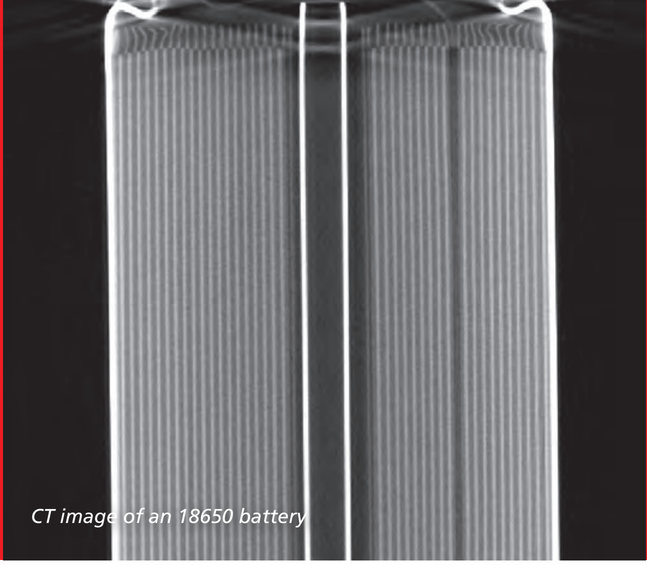
AGEING AND POST-MORTEM ANALYSIS

JANA MÜLLER

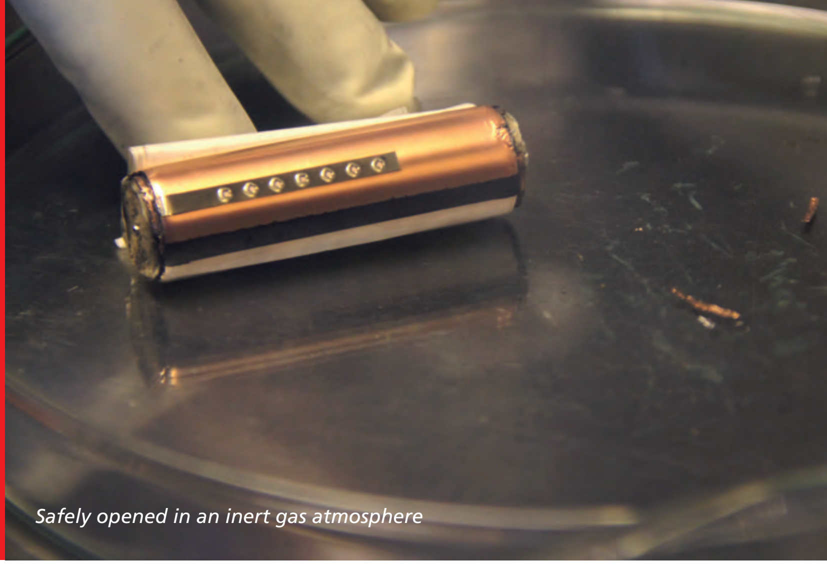
It will only be possible to continue increasing the energy storage density of lithium-based batteries, while at the same time guaranteeing high levels of reliability and safety, if we first gain a better understanding of the ageing processes and wear mechanisms that shorten battery life. The way forward lies in the continuous improvement of the individual components that make up the battery system. By introducing an ageing and post-mortem analysis, it is possible to deliberately age batteries of different configurations in a targeted manner. This provides an efficient and reliable means of studying degradation mechanisms, for instance under extreme climatic conditions to test the resistance of the cell technologies being investigated. The aged batteries are disassembled into their constituent subsystems for analysis and then each component is examined separately. This allows the results of the analysis to be directly incorporated in the materials development process, which is conducted in parallel.

As well as requiring a broad spectrum of testing methods, this type of analysis also imposes strict requirements on the test environment, because batteries contain a considerable number of highly reactive materials. Specially designed workstations were set up for this purpose, which allow the batteries to be manipulated in airtight and watertight containers known as glove boxes. One of the milestones of this project was the successful establishment of a safe method for opening different types of batteries. A preparation technique was also developed to avoid the risk of false analysis results as far as possible. Validated analysis methods include computed tomography and impedance spectroscopy. The use of computed tomography as an imaging technique permits the detection of manufacturing defects such as short circuits, delamination and poor contacts, while impedance spectroscopy provides an interface between the electrical characterization and materials testing of discrete components. This method has been successfully applied to obtain impedance measurements at targeted points on key elements of lithium-ion batteries in an inert gas atmosphere. The measurement results acquired in this way provide far more detailed information than when using conventional methods. Additional information on the condition of the battery cell can be obtained by supplementing the above techniques with physical and chemical methods. For example, various chemical analysis methods can be used to detect local alterations in the material and the associated degradation products. The combination of these different methods makes it possible to reliably identify the mechanisms responsible for ageing, both those specific to the material and those attributable to environmental factors. The applied test methodologies are guaranteed to the highest standard through close collaboration with the accredited laboratories of Fraunhofer ISC's Center for Applied Analytics ZAA.

The resulting knowledge can be used to advance the development of improved battery designs and materials, and also contribute to future recycling initiatives, which depend on the availability of reliable data concerning reclaimable components and materials. The described methods offer a potential means of addressing these unmet data needs. Recycling is also the main focus of the "Automotive Battery Recycling and 2nd Life (ABattReLife)" project sponsored by the German Federal Ministry of Economics and Technology, in which Fraunhofer ISC is participating in collaboration with international partners



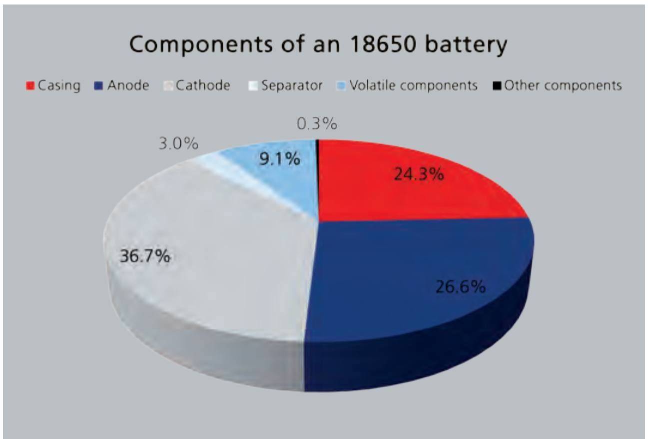
CT image of an 18650 battery



Safely opened in an inert gas atmosphere

from industry and research. Fraunhofer ISC's role is this project is to deliver insights into the chemical processes in battery cells and the degradation of battery materials. This project thus represents the ideal proving ground for applications of ageing and post-mortem analysis, because it not only looks at the interrelationship between battery ageing and recyclability in terms of technical synergies but also considers how these dual aspects can be combined in sustainable marketing concepts.

The interdisciplinary working group on ageing and post-mortem analysis offers its services to industrial customers as well as to other research institutions.



Proportion by weight of the components in a standard battery cell

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ELECTRODES FOR HYBRID ENERGY STORAGE DEVICES

DR. UWE GUNTOW, DR. JOCHEN UEBE

Lithium-ion batteries are already in use to power modern cell phones, MP3 players and laptops, but these energy storage systems also offer tremendous future potential for applications in the fields of electromobility, mobile power supplies, mechanical engineering, automation engineering and stationary energy storage systems. In each case, the ideal solution must be customized to meet the application-specific requirements. Customized active materials with optimized properties are the key to developing energy storage devices that offer enhanced energy and power densities and greater stability. At Fraunhofer ISC, researchers have developed a technique that can be used to produce electrodes for customized energy storage devices – hybrid energy storage systems that combine the advantages of batteries (high energy density) with those of electrochemical double-layer capacitors (high power density, fast charge/discharge cycles, longer service life).

Energy storage systems to suit every situation

The use of current electrical energy storage devices is restricted by the limitations of available storage technologies. These technologies can essentially be divided into two groups: Faradaic storage (batteries, e. g. lithium-ion batteries) and electrostatic storage (electrochemical double-layer capacitors, EDLCs). Lithium-ion batteries offer high energy densities (> 100 kW/kg) but suffer from limitations in terms of their capacity, cycle life and temperature range. Double-layer capacitors offer significantly longer cycle lives and can be used across a wider range of temperatures, but their energy densities are too low for many applications.

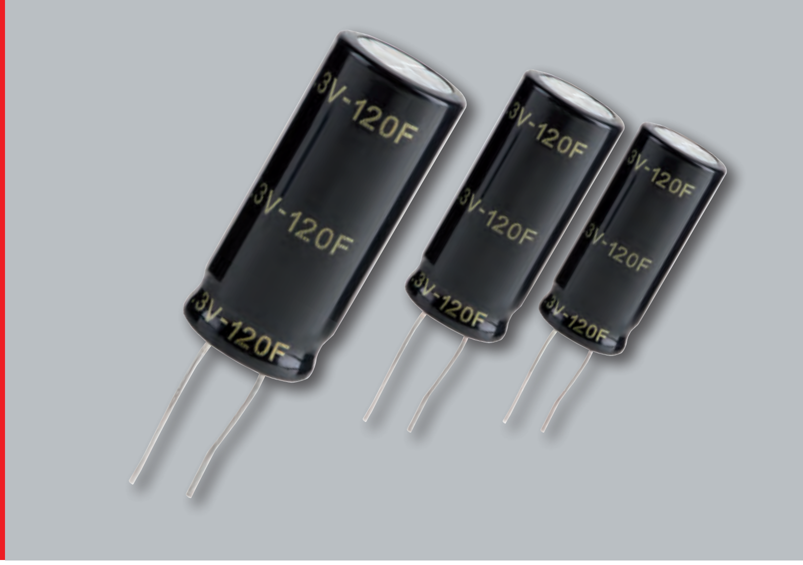
Active material – the key to new energy storage concepts

Electrodes for lithium-ion batteries and double-layer capacitors typically consist of the active material, conductive additives, a polymer binder and the current collector. The actual energy storage processes – the storage of the electrical charge – take place in the active material.

In the case of lithium-ion batteries, lithium ions in the electrode are integrated in the mesh structure of the active material as reversibly as possible in the processes of intercalation/deintercalation. These processes run very slowly and are not always completely reversible. They also lead to volumetric expansion and contraction of the active material. This limits the number of times the battery can be charged and discharged and thus reduces the battery's service life. In summary, lithium-ion batteries offer high energy densities over a longer period of time yet exhibit considerably lower power densities than double-layer capacitors.

In contrast, double-layer capacitors feature an electrostatic charge storage mechanism which takes place on the surface of the active material. Compared to lithium-ion batteries, these charge storage processes are significantly faster. As well as having the largest possible surface area (> 2000 m^2/g), the active material also needs to have a suitable pore structure which is accessible to the cations and anions of the electrolytes. Nowadays, scientists primarily use activated carbon as the active material in order to achieve the required mechanical, chemical and electrochemical stabilities. Since the charge is electrostatically stored on the surface, this does not


Small series production of electrodes

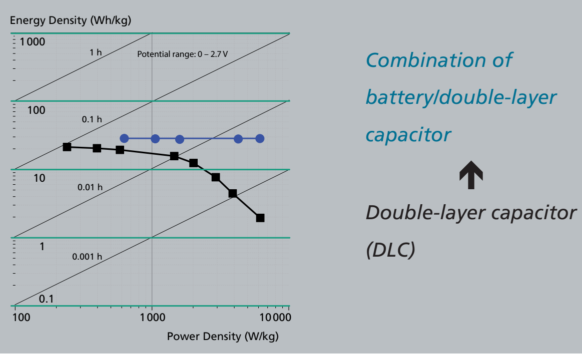


involve any volumetric expansion or contraction of the active material. As a result, the number of possible charge/discharge cycles is significantly higher than in the case of lithium-ion batteries, and the system's service life is consequently longer. In summary, double-layer capacitors offer high power densities when used for short-term storage, but provide low energy densities.

The solution: Hybrid electrodes for customized energy storage systems

To solve this dilemma, scientists have developed a hybrid storage system based on lithium-ion batteries and double-layer capacitors which combines the benefits of lithium-ion batteries (high energy density) with the advantages of double-layer capacitors (rapid charge/discharge capabilities, long cycle life, high power density). This system is based on an innovative manufacturing method for the active materials in the electrodes, which was developed at Fraunhofer ISC. The technique works by combining battery materials and activated carbon (double-layer capacitors) in the active material. In an ideal scenario, virtually all of the large surface area created by the pores in the activated carbon can be used for charge storage, thereby simultaneously achieving high energy density as well as high power density. In this scenario, the charge/discharge cycles are very fast. By increasing the battery component in the active material, it is possible to shift the properties further toward those of lithium-ion batteries (high energy density) should this be required. Compared to state-of-the-art systems, the new solutions that use the active materials modified by Fraunhofer ISC researchers have been shown to achieve significant increases in energy density while maintaining the same level of power density (see diagram).

Comparison between the state of the art system (double-layer capacitor, DLC) and the solution developed by Fraunhofer ISC



Applications and uses

Energy storage systems containing the improved active materials open up a wide range of potential applications:

- Electromobility (cars, trucks, e-bikes, motorboats, forklift trucks and cleaning machines)
- Regenerative braking in cars, trams and trains
- Mobile power supplies
- Uninterruptible power supplies
- Mechanical engineering
- Automation technology
- Stationary energy supply systems (for balancing out fluctuations in supply and demand)
- Temporarily storing electricity generated by renewable energy sources (wind turbines and photovoltaic plants) and feeding it into the grid

and many other applications.

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ENERGY HARVESTING – A CONCEPT FOR HARNESSING RENEWABLE ENERGY

DIETER SPORN, DR. BERNHARD BRUNNER

In the context of converting energy from one form into another, methods for arriving at electrical energy go beyond conventional, technologically refined methods, such as generators, to include a range of other possibilities. Ambient temperature (thermoelectrics), vibrations, or air currents are particularly good at producing small amounts of electricity from their immediate environment, in what is collectively referred to as Energy Harvesting. A great deal of effort is going into employing them in the field of autonomous operation of low-power mobile devices. In the case of wireless technologies, Energy Harvesting can avoid the limitations that a cable-based power supply would impose.

Innovative Energy Harvesters (EH) provide a technological basis for the long-term, secure and autonomous supply of power primarily to microtechnology systems with moderate power demand of between 1 and 100 mW. These autonomous concepts are suited to a great number of applications in the field of mobile or hard-to-access systems. Examples include implants and emergency transponders, but power can also be supplied to communications and multimedia devices, sensor networks, onboard positioning and surveillance systems in aircraft, offshore wind farms, security systems, etc. In these settings, the economic advantages of having an efficient, autonomous supply of energy (e.g. no need for maintenance) are also obvious.

"Piezo-EN", a joint project funded by Germany's Federal Ministry of Education and Research BMBF to develop and test piezoelectric generators for an EH, builds on earlier CeSMa developments in the field of piezoelectric thin-film materials and components made from them. The piezoelectric transducers developed by the project boast high electromechanical coupling factors as well as simple, mechanically robust and extremely flexible system designs, at affordable prices and with low weight. These transducers are not dependent on sunlight or temperature and have a very long service life. In gathering electromechanical energy, these transducers also act favorably to dampen vibrations in the fundamental mechanical structure.

As part of the project, the results of the development work were put to the test in a variety of demonstration applications. One of these was structural health monitoring for bridges.

Piezoelectric patch transducers

Certain crystalline materials react to mechanical deformation by altering their electrical potential. The deformation causes a charge separation at the crystal level, in what is known as the piezoelectric effect. This means voltage impulses arise during deformation that can be collected by a suitable electrical connection called an electromechanical voltage transducer. The project used thin films of the piezoelectric material developed by Fraunhofer ISC to produce large (100 cm^2) patch transducers for transducing electromechanical energy.

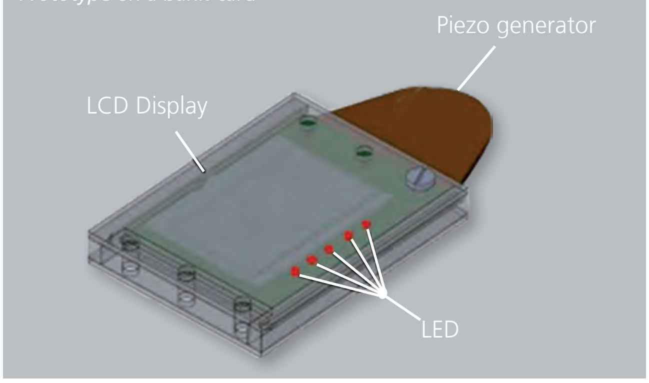
Energy harvester demonstrator, powered by vibrations in the freeway bridge

These were then electroded and subsequently evaluated. The demonstrators' layer thickness, geometry and electrical contacting were optimized for maximum energy yield, and electrical matching to the transducer electronics was investigated. Life-cycle analyses showed that these transducer assemblies are suited even to extreme cyclical deformation loads of up to 0.2 % in up to 100 million cycles. Test assemblies were used to determine the energy yield. For a piezoceramic thin-film layer with an area of approx. 100 cm^2 the yield is around 10 µW, at an output voltage of 0.6 V. This voltage is not sufficient to directly actuate rectifier diodes in the energy-transducing circuit. However, series arrays of several piezo layers operating jointly in phase on a mechanical demonstrator did achieve higher output voltages and hence generate a few mW of power in a frequency range of 1 – 10 Hz.

Working together with project partners INVENT, Fraunhofer IIS and Fraunhofer IZM, a prototype of an energy harvester on a bank card was developed to show what possibilities exist for mobile electricity supply. Fraunhofer ISC's role in this was to develop the circuit for the low-power sensor that shows information on temperature and degree of movement on a display. (Figure 2)

An EH demonstrator fitted with the piezo transducers described above was built and tested by Wölfel Beratende Ingenieure & Co. KG for use in a freeway bridge (Figure 3). Project partner Wölfel Beratende Ingenieure sees excellent commercial prospects for applying the microsystem for autonomous energy supply with smart piezo generators in structural health monitoring for bridges. Putting it to use in other autonomous structural health monitoring tasks, such as in rotor blades for wind power or in chemical and power plants, would considerably reduce the efforts presently involved in monitoring those facilities. Of these applications, development work is furthest advanced on integrating monitoring technology into wind turbine rotor blades. Wind farm manufacturers and operators have shown a great deal of interest in installing the system in a test facility. Once this test installation is successfully completed, follow-on orders can be expected in coming years, especially for further development of energy-optimized sensor nodes.

Prototype on a bank-card



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INCREASED RESOURCE EFFICIENCY THROUGH OPTIMIZED PROCESSES IN POWER PLANT TECHNOLOGY

DR. ANDREAS DIEGELER

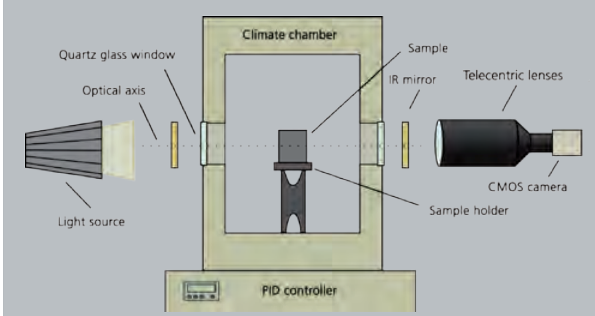
Use of thermo-optical measurement processes for evaluating brown and hard coal slag

In the wake of the transition toward a new energy economy and the move away from nuclear power, alternative energy sources are becoming increasingly important. However, the fact that these energy sources are unable on their own to cover all our energy needs has led to a resurgence in conventional energy sources based on fossil fuels, first and foremost crude oil, natural gas, and brown and hard coal. In 2011, brown coal accounted for 24.5 % of the energy mix in Germany, while hard coal made up 18.3 % (source: AG Energiebilanzen). Estimated reserves of brown coal in particular total approximately 40 billion tons, which can be mined using state-of-the-art technologies. These reserves will last several generations provided they are used effectively.

Effective use of brown and hard coal depends especially on cutting-edge power station technology. In developing innovative concepts and plant, the focus is on optimizing combustion and cleaning processes and on recycling waste materials, especially the slag produced.

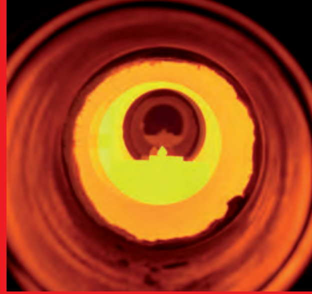
Fraunhofer ISC has for over 20 years been developing new processes for analyzing, evaluating and optimizing thermal processes during materials development. These include thermo-optical measurement processes, TOM for short. These processes have now been refined to the point where they can be used industrially for a wide range of applications in the development departments of businesses and universities. Users include power utility RWE in the area of brown coal and the Technical University Bergakademie Freiberg in the area of hard coal.

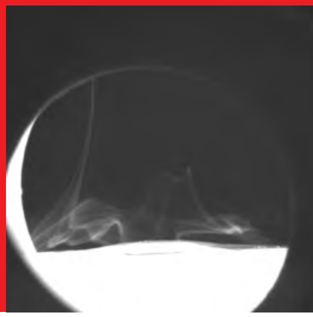
Principle of the thermo-optical measurement processes



TOMMI TLF

Thermal processing of lignite slag at 1100 °C





Thermal processing of hard coal liquefying at 1950 °C

TOM processes are used by these cooperation partners for slag evaluation and the analysis of combustion processes in order to gain insights at the laboratory scale into the processes involved and the scope for optimization. The figure below (Figure 1) illustrates the principle of the thermo-optical measurement processes.

The main component of the measurement system is a furnace that can be equipped with various heater inserts depending on the sample material, the required ambient atmosphere and the experimental temperature. The system can be run up to 2400 °C under a controlled atmosphere. In order to analyze the material's behavior, in this case slag, two viewing windows are positioned on either side of the furnace along a horizontal axis. The left viewing window is used as an illumination aperture; the right window serves as an observation window. A strong LED light source and sophisticated optics with a CMOS camera provide image analysis of the contour change of a sample placed in the optical axis as the thermal processes are completed. This contour change is recorded with a resolution of up to 0.4 µm. In the case of slag, the atmosphere in the furnace can be precisely set to study behavior during softening and melting under industrial conditions. This data is required to adjust and optimize heating processes, or to save very large amounts of energy. In the case of brown coal, it is temperatures in the range of 800 °C – 1300 °C that are of interest, while the range can extend to 2000 °C for hard coal depending on the proportion of SiO_2 in the sample.

The process is currently being used successfully with both material groups. During the combustion of brown coal, the cleaning process in the furnace was optimized by reducing the temperature and adding mixed gases. As regards the quantities of brown coal that are burned in a thermal power plant, which amounts to several thousand tons in operation, a temperature reduction of just 50 °C leads to an energy saving of several thousand kilowatt hours. The above Figure (top, right) shows the inside of the furnace when brown coal residual slag is heated at 1100 °C.

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ENERGY

INNOVATIVE SHADING APPLIANCES

DR. UWE POSSET

Funded by the European Commission under its Seventh Framework Programme (FP7), the "INNOSHADE – Innovative Shading Appliances" project targeted to scale up a previously developed cost and energy-efficient smart shading technology based on electrochromic (EC) devices from laboratory to pilot line production in order to validate it. Conducted by a consortium of 17 partners from 10 countries under the leadership of Fraunhofer ISC, the project yielded promising results when it was completed in mid-2012.

EC devices normally consist of a color-active working electrode and a suitably engineered ion storage layer (counter electrode), connected to each other by means of an electrically insulating yet ion conductive layer. When an electrical voltage is applied, redox processes occurring in the electrode layers produce changes in the color-active material's optical absorption behavior. A color change technology based on this phenomenon can be used to produce switchable or "smart" windows, by means of which air conditioning efforts can drastically be reduced in buildings and vehicles. In addition to the convenience of individualized lighting control, the technology thus also offers huge potential for saving energy. Current commercially available EC systems present a number of disadvantages and marketing hurdles, in particular high prices, slow switching times and – perhaps most importantly – the significant weight of the glass-based designs, which excludes many applications from consideration. There is, however, considerable demand for a cost-effective, plastic-based EC technology.

Electrochromic film laminates

The key focus of the INNOSHADE development process was a novel nanocomposite of electrically conductive electrochromic polymers and polysiloxanes which is characterized by remarkable electro-optical properties. Applied as a thin coating on a transparent plastic electrode, the material is capable of changing its color intensity and thus its light transmittance within a matter of seconds when a low voltage is applied, exhibiting high optical contrast. The electro-optical active polymer is made of specially modified EDOT units (3,4-ethylenedioxythiophene) and offers high coloration efficiency, resulting in low energy consumption during the color change process. The material is applied using a proprietary polymerization technique at low temperatures in a roll-to-roll process. The thin films produced in this process are mechanically flexible and can be applied to any surface desired or integrated (retrofitted) within existing window systems.

Potential applications

This technology is particularly suitable for applications that require electrical modulation of light transmittance, either for reasons of comfort and convenience or to enhance safety and save energy. During the INNOSHADE project, the EC films were put to the test in a number of different applications to determine the technology's capabilities. The primary applications contemplated in the initial stage were ophthalmic lenses (sunglasses), household appliances (refrigerator and oven doors) as well as vehicle and aircraft cabin windows.

Possible application for innovative shading systems
© Knud Dobberke

ENERGY

Application example – aircraft cabin windows (A320)

Advantages of the new material properties

- Scalable, cost and resource-efficient EC technology, compatible with plastic substrates
- Can be processed using wet-chemical roll-to-roll techniques
- Electrically controlled, continuous color change between colorless and deep blue
- Rapid response over large surface areas with minimal energy consumption
- Novel transparent hybrid electrodes with low surface resistance

Key steps successfully taken

- Scaling up the preliminary stage chemical syntheses to pilot line production
- Determining the key structure-property relationships in the roll-to-roll processing of EC coatings
- Optimizing the total primary energy consumption by incorporating life cycle assessment data
- Adaptation of coating and lamination technologies (including the manufacture of high precision machine components, application systems and pumps)
- Development of viable assembly methods
- Development of electrical control units (ECUs)
- Extensive application testing
- Manufacturing demonstrators for the target applications

Life cycle assessment for eco-friendly production

A number of different manufacturing options were explored in an effort to develop an economical and energy-efficient solution for EC devices. The feasibility of high-throughput production of EC device components was demonstrated in the form of continuous and semi-automatic coating processes. High precision nozzle and pump technologies were successfully used to achieve the required homogeneity of the coating thicknesses, with white light interferometry being used for in-line quality control. The results of a comprehensive life cycle assessment including benchmarking confirmed the technology's eco-friendly credentials and highlighted considerable potential for energy savings.

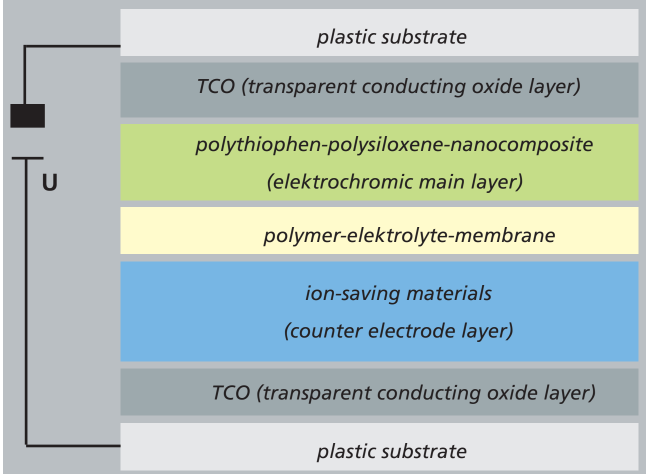
- Optical contrast: approx. 60 %, switching response: approx. 20 s per switching operation for 30 x 45 cm^2
- Power consumption: 160 mA per switching operation for 30 x 45 cm^2; voltage: -1.5 to +1.5 V_{cc}
- Cycle life >120,000 cycles under laboratory conditions (equivalent to 20 switching operations a day for 20 years)
- Thermal stability: Operation -25 – 80 °C (survival -50 – 120 °C).

Production of demonstrators © EADS

INNOSHADE paves the way for new product line

In short, the INNOSHADE technology offers a new concept for intelligent shading solutions featuring unique perspectives for improved switching times and cycle stability, less weight and production costs, but more flexibility due to continuous manufacturing processes. The high number of industry partners involved (> 50 %, five SME, four global players) reflects the attractive business potential. Presently, implementation options are being investigated with the aim to establish a prototype production in Europe, so that interested customers can easily be provided with samples and demonstrators.

INNHOSHADE base equipment



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Details of a winding system for CMC preforms

FRAUNHOFER-CENTER HTL

THE FRAUNHOFER CENTER HTL

DR. FRIEDRICH RAETHER

Around 7 % of the primary energy consumed in Germany is used for heat-treating materials at temperatures over 1000 °C. This amounts to a total energy consumption of 1000 petajoules per year, equivalent to the amount of power generated by 30 power plants with an average output of 1GW. The iron and steel industries consume the most energy, with the pit and quarry industry and glass and ceramic industries also making up a significant chunk of the large amounts of energy consumed by high-temperature applications. The way energy is obtained from fossil fuels can also be made more efficient, with scope for improvement at higher temperatures. The effectiveness of gas turbines increases significantly with the temperature of the gases entering the turbine, a principle that holds true for both stationary gas turbines and aircraft gas turbines. Improving the energy efficiency of high-temperature processes would thus have a long-term impact on the CO_2 footprint, and what's more, this improvement could be implemented relatively quickly, without the need to first create the sorts of new infrastructure for distributing and storing energy demanded by renewable energy generation.

The Center for High Temperature Materials and Design contributes to improving the energy efficiency of high-temperature processes in industry in the following three areas:

- Materials resistant to high temperatures
- Components and systems for high-temperature applications
- Characterization and optimization of high-temperature processes

Materials that are resistant to high temperatures are developed as ceramic composites, fibers and coatings. The Center's expertise includes the chemical synthesis of the precursors, up-scaling to pilot scale production and computer-based material design. One of the focal areas of activity is the development of ceramic fibers and relevant fiber-coating processes. The Center HTL produces oxidic ceramic fibers from aluminum oxide, zirconium oxide and mullite, for example, as well as non-oxidic fibers made of silicon carbide.

Ceramic Matrix Composites (CMC) components up to approximately 700 mm in size are designed and produced as prototypes or in small series production. All manner of fibers can be processed: endless fibers or short fibers, oxidic or non-oxidic fibers, fabric or fiber rovings. The matrix is built up over ceramic slurry, polymers or silicon melt. The components are designed with the aid of computer simulations that show how they will perform, and testing of the components is carried out using non-destructive testing methods such as computer tomography.

Experts at the Center HTL are developing special thermo-optical testing methods that allow them to characterize materials at high temperatures. These tests are used to determine the thermal and mechanical characteristics of small components or large samples, at temperatures of up to 2 100 °C. They also measure any changes that materials undergo during heat-treatment processes in situ. The measured data that are used to simulate heat-treatment processes and optimize energy efficiency on a computer.

Producing insulation fibers from environment-friendly raw materials

Ceramic fibers are used as high-grade insulation materials for high-temperature applications. E. g., theycan save up to 30 % of the energy consumed by intermittent kilns. The fibers currently available on the market are based on chlorinated precursor compounds, so that the manufacturing process generates large amounts of hydrochloric acid (HCl) and also some highly toxic dioxins. Experts at the Center HTL are developing an alternative, chlorine-free raw material for the production of insulation fibers. Whilst still taking cost-factors into account, the scientists modify the chemistry of the precursor compounds in such a way that absolutely no HCl and dioxins are produced during the fiber-making process. Using a centrifugal spinning process, the newly-developed raw materials can be made into ceramic fibers with the necessary diameter and desired composition.

These new developments are due to be transferred to customer production in the near future. As neither HCl nor dioxine are generated during manufacture, the energy-intensive processes that are currently necessary to treat exhaust gases and recover HCl become obsolete, all of which is reckoned to save a near 25 % of the electricity used in fiber manufacture. By further adapting the processing properties and production process, newly-developed raw materials can also be used to make ceramic reinforcement fibers, which are in turn used in high-performance composite materials.

Increasing the energy efficiency of firing processes using fiber-reinforced kiln furniture

Kiln furniture is an indispensable part of the heat-treatment process for products made of glass, ceramic or metal. Its function is to support, attach or contain items being fired in the kiln. Kiln furniture has to be heated up together with the material being fired, which increases the overall amount of energy required. Reducing the mass and thereby also the heat absorption capacity of kiln furniture lowers the amount of energy consumed during the heat-treatment process. One way of achieving this is to design kiln furniture with thinner walls and/or greater porosity, provided its mechanical properties remain unaltered. A joint research project between the Center HTL and Rauschert GmbH's site at Steinbach am Wald aims to improve the mechanical and thermal properties of kiln furniture by reinforcing fibers and optimizing the microstructure of the material. Near-net-shape kiln furniture "green bodies" (unfired blanks) will be produced using injection molding techniques. The advantages of fiber-reinforcement when compared to monolithic ceramics include higher damage tolerance, resistance to temperature fluctuations and thermal shock resistance.

Low-pressure turbine (source: MTU Aero Engines)

Intrinsically safer and more energy-efficient LSI process

Silicon carbide is used for components in a number of different fields, including fluidics (gaskets and slide bearings), heat technology (kiln furniture, crucibles, heating filaments, heat exchangers) and friction technology (brakes and clutches). Its strengths come into play when surrounding conditions are unfavorable, such as when materials are subject to abrasive wear, high temperatures or aggressive media. Silicon carbide can be densified via solid or liquid phase sintering. Sintering takes place at very high temperatures between 1700 °C and 2100 °C, with correspondingly high energy-consumption rates. Alternatively, it is also possible to produce a non-porous SiC material by infiltrating silicon melt into a porous preform made of carbon and silicon carbide, in a process known as liquid silicon infiltration (LSI). The LSI process is used to make near-net-shape SiC ceramics at relatively low temperatures (melting point of silicon: 1410 °C). The joint research project ISE-LSI aims to provide a more in-depth understanding of the kinetics of the process, via in situ measurements of the LSI process at the HTL center's thermo-optical measuring facilities. The process will then be simulated using a computer in order to significantly reduce the energy it requires.

Ceramic high-temperature lightweight construction material for use in aircraft gas turbines

Oxidic ceramic composites for use in aircraft gas turbines were developed in collaboration with MTU Aero Engines as part of the aviation research program IV conducted by the German Federal Ministry of Economics and Technology (BMWi). The materials, which are based upon a zirconium oxide matrix, were produced from Nextel™ 610 fibers using a winding process. The matrix material was chosen on the basis of zirconium oxide's superior resistance to hot gas corrosion.

The ceramic composites were formed into flat, wound structures made up of several layers with 0 °/90 ° fiber orientation, suitable for comparison with laminated OFC materials. The newly-developed ZrO_2 composite materials were subjected to bending tests conducted at room temperature, which proved that they shared the same mechanical properties as commercially available OFC materials. The new materials also underwent high-temperature bend testing at temperatures as high as 1000 °C. Hot gas corrosion tests conducted by MTU Aero Engines proved that the material samples remained stable for several hundred hours while subject to cyclic temperature fluctuations.


TOMMI TLF


Heat treatment device up to 2400 °C

Redevelopment of thermo-optical measuring facilities

The high performance capacity of the thermo-optical facilities has been markedly increased by targeted optimization of the components and a number of new measurement options has been added. The basic components – kiln, optical beam path and measuring software – were redesigned. The aim was to significantly improve the temperature homogeneity of the kiln, to make the imaging process more robust, with the very best optical resolution possible, and to enhance user friendliness. The following new measurement options were evaluated:

- Hermal diffusivity and conductivity
- Elastic modulus
- Thermal expansion
- Specific heat
- Resistance to thermal shock
- Thermal cyclability
- Emissivity
- Friction at crack boundaries

These will be integrated into TOM-wave, a new thermo-optical measuring instrument currently being developed as a prototype. In TOM-wave, samples are preheated to temperatures of up to 1800 °C within a controlled atmosphere. A CO_2 laser is used to generate the measuring signals and heat the samples. The laser optic is adjusted to suit the different measurement types. The measuring signals are detected acoustically or pyrometrically.

In consequence, the TOM instruments now offer an even greater range of measurement options for developing and optimizing high-temperature materials.

Making roller kilns more energy-efficient

Many heat-treatment processes take place in continuous kilns. These kilns have high throughput and are highly energy-efficient because, unlike intermittently heated ovens, their parts remain at a constant temperature without having to be reheated for each cycle. Roller kilns are gaining importance among the various types of continuous ovens. The material being fired passes through the kiln on numerous rotating transport rollers arranged in parallel. The rollers protrude out of the sides of the kiln, and are powered by a motor. Roller kilns are built to be quite flat, as keeping the height of the firing stacks low minimizes temperature gradients in the material being fired and loss of radiation inside the kiln. Throughput and energy-efficiency are determined by the width of the kiln, which is in turn limited by the width of the transport rollers. The project simulates the energy flow in roller kilns using finite element methods. The performance of suitable high-temperature materials is examined using thermo-optical measuring processes, and the results used to generate concepts for improving the energy-efficiency of roller kilns.

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Wound CMC components

CREEP-RESISTANT METAL-CERAMIC HYBRID PIPES FOR SUPERHEATED STEAM APPLICATIONS IN POWER STATIONS

DR. JENS SCHMIDT

Using resources efficiently in energy production

In view of increasing energy demands worldwide, and the simultaneous depletion of raw materials, using resources more efficiently in energy production is an absolute must. Active pursuit of the science and research behind related objectives is therefore a priority. In power stations, increasing operating temperature leads to a direct improvement in efficiency, and therefore a more efficient utilisation of the energy source.

Upper-temperature limits of pipes used in current systems to transfer superheated steam are dictated by the heat tolerance of steel. Creep deformation, which leads to the failure of pipework, caps the upper operating temperature of steel setups below 600 °C, at a pressure of 250 bar. The aim is to prevent the creep deformation of steel pipework, and reinforcement with ceramic matrix composite materials (CMC) could allow an increase in operating temperature, while extending service life.

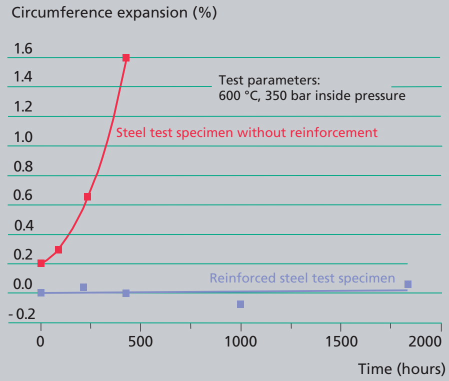
Under the BMBF funded WING program – "Materials Innovation for Industry and Society", the Center HTL of the Fraunhofer ISC is working on an joint project entitled "Compound-Pipes" with industry and research partners to develop fundamental concepts and processes to insulate superheated steam pipework with CMC. The objective is to demonstrate that creep-deformation of superheated steam ducts under hypercritical conditions can be effectively hampered through ceramic reinforcement.

Functional separation of components

A fundamental principle of CMC-reinforced superheated steam ducts is the functional separation of components. The inner steel pipe takes on the role of a gas-sealed, corrosion-resistant transfer pathway. The heatproof CMC coating restricts the creep-deformation of the inner pipe. To account for the difference in the heat expansion properties of the inner steel pipe and the CMC coating, an integrated interphase material is located between the two principal materials.

During the attempts to manufacture such a compound pipe, different types of fiber were used in conjunction with a precursor-based matrix to process a reinforcing material that can be made to form a ceramic coating in the open air, without

Tests to ascertain creep deformation of a steel test specimen with and without reinforcement at 600 C and 350 bar inside pressure.



Test specimen made of steel (above) and with CMC reinforcement (below)

the use of an oven. To determine creep resistance and fiber stability, specimens were subjected to creep-deformation and tensile strength tests under relevant power-station conditions. This ascertained the most suitable type of fiber. The degree to which the stability of the fiber-wound body depended on the helix angle was determined by means of a split-ring test on cylindrical test specimens. Carrying out creep rupture tests in open air, the creep characteristics of reinforced steel pipes were measured.

From the laboratory to long-term power-station testing

The feasibility of the metal-ceramic hybrid-pipe concept was established using oxide ceramic fibers which are similarly resistant to tensile load at high operating temperatures. A wet-winding process using a four-axis coiling machine was devised at the Center HTL to manufacture the fiber reinforcement. The production process was also demonstrated using fiber roving and, at a later project stage, with woven fibers, whereby a unidirectional reinforcement was proved, to reduce tensile stresses of the metal pipe most effectively. Employing commercially available precursors as a matrix and a polymer infiltration process, it was shown that the production of a composite ceramic could also be achieved at lower temperatures. Using this technique, several specimens could be reinforced with ceramic, and made available for testing.

In creep rupture tests, partners at the University of Stuttgart's Materials Testing Facility were able to establish that the CMC-reinforcement of steel test specimens significantly minimized creep distortion at hypercritical conditions, i. e. maximum temperature 600 °C and 350 bar inside pressure. The lifespan of the steel test specimens increased fourfold as a result. The coil macrostructure of these sample specimens (L ~ 380 mm, D ~ 34 mm), along with the interphase material, was characterized non-destructively using high-definition computer tomography imaging, before and after creep rupture testing. This process showed that even after long test periods extending up to 2 000 hours, there was no detectable damage to the material forming the ceramic coating. That the compound-pipe concept could be transferred to practical trials was demonstrated by moving from the laboratory to a field test at Mannheim's high-output power station. Here, a superheated steam duct with reinforcing ceramic coating thickness of 14 mm, totaling approximately 300 mm in width, was installed along with thermal elements and expansion sensors. The CMC-reinforcement in this applied test will be evaluated over the coming months. The test period will extend initially to a year, and the condition of the ceramic fiber coating will be assessed at the next revision in 2013.

A transferable technology

The intention is to transfer knowledge gained from the development of CMC-reinforced steel pipes, and quality testing of the hybrid structure, to larger pipe dimensions, including an adaptation to the complex geometric requirements of a power station, such as pipe bends and outflows. This hybrid material technology can be transferred to other applications requiring vessels to operate at high temperature and pressure. However, special effort must be made to reduce manufacturing costs. To this end, an automation of at least some of the individual manufacturing steps and further optimization of processing parameters are required.

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Details of a winding system for CMC preforms

LOW COST TECHNOLOGIES FOR PRODUCING CERAMIC MATRIX COMPOSITES

DR. LIVIU DAN TOMA, DR. ANDREAS NÖTH

Are CMCs much too expensive for the mass market?

Ceramic Matrix Composites (CMCs) consist of ceramic fibers embedded in a ceramic matrix. In contrast to monolithic ceramics, these sorts of materials have shown themselves to be damage-tolerant given a suitable fiber-matrix interface, and consequently free of brittle fracture. There are also advantages over metals when it comes to weight, resistance to corrosion and mechanical properties at high temperatures.

The high production costs of CMCs, however, have limited their use to high-end applications such as aerospace engineering or motorsport. An internal Fraunhofer research project focusing on preliminary, market-orientated strategic basic research is now underway at the Center for High Temperature Materials and Design HTL, in collaboration with other Fraunhofer institutes, to developa technology that will significantly reduce CMC production costs – by at least 25% – so that this type of material can find more widespread use in machine and plant construction, car manufacture, and conveyor and energy technology.

New approaches to an affordable production

The Center HTL is working on implementing an idea that adapts production methods from plastics technology to manufacture semi-finished CMC products. These methods should allow components to be produced in bulk and facilitate complex geometries closely approximating the contours of the finished product. The process involves developing special silicon polymers and then mixing them with short ceramic fibers, allowing the polymers to be processed using forming process technologies such as pressing and injection molding. Following the forming process, pyrolysis is used to transform the silicon polymers into a SiC matrix containing evenly distributed ceramic fibers. Alternatively, the CMC component can also be compacted using Liquid Silicon Infiltration (LSI).

To make the CMC materials damage-tolerant, it is essential to find a way to weakly bind the fibers to the surrounding matrix. This prompted the development of a fiber coating in the course of the project, allowing what is known as fiber pull-out effect when components are subjected to mechanical tensile loading, giving the material quasi-ductile properties. For the fiber coating technology, a wet-chemical approach was preferred due to cost considerations. Production of the ceramic fiber and silicon polymer base compounds occurred in collaboration with colleagues from the Fraunhofer Pilot Plant Center PAZ.


Continuous fiber coating facility


Polymer coating of textiles fabrics

The silicon polymers were dissolved and compounded with the ceramic fibers in a double-screw extruder. The fibers, meanwhile, were fed from a reel as continuous fibers and crushed by shear forces in the extruder. This enabled production of silicon polymer substances with evenly distributed short ceramic fibers.

The forming process involved hot pressing at temperatures of around 300 °C and pressures of around 20 MPa. One of the main areas of potential cost savings arises from producing CMC components that closely approximate the contours of the finished product while in the pressing machine, thus minimizing the expenditure on the expensive finishing process. Pressing cycles were optimized accordingly.

By way of alternative, Fraunhofer IKTS is testing a forming process using injection molding methods. When applied to forming, the LSI process is a good way of achieving full compaction in CMC preforms. To aid the process, a barrier coating was developed, effectively protecting short carbon fibers from exposure to liquid silicon during the liquid silicon infiltration process. At the same time, scientists were able to verify that the coating allowed the weak bond required between fibers and the matrix, resulting in the desired attribute of damage tolerance.

Optimizing process parameters

At present, work is continuing to investigate the impact of process parameters during forming and heat treatment on material properties such as density, porosity, microstructure, and bending strength. Results to date have been very promising. If the project succeeds in its aim to significantly reduce manufacturing costs while turning out materials boasting state-of-the-art properties, it is expected that the CMC components could reach new markets and find new applications within the areas of machine and plant construction, car manufacture or energy technology.

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ENERGY EFFICIENCY IN THE HEAT TREATMENT OF CERAMICS

PD DR. FRIEDRICH RAETHER, RALF HERBORN

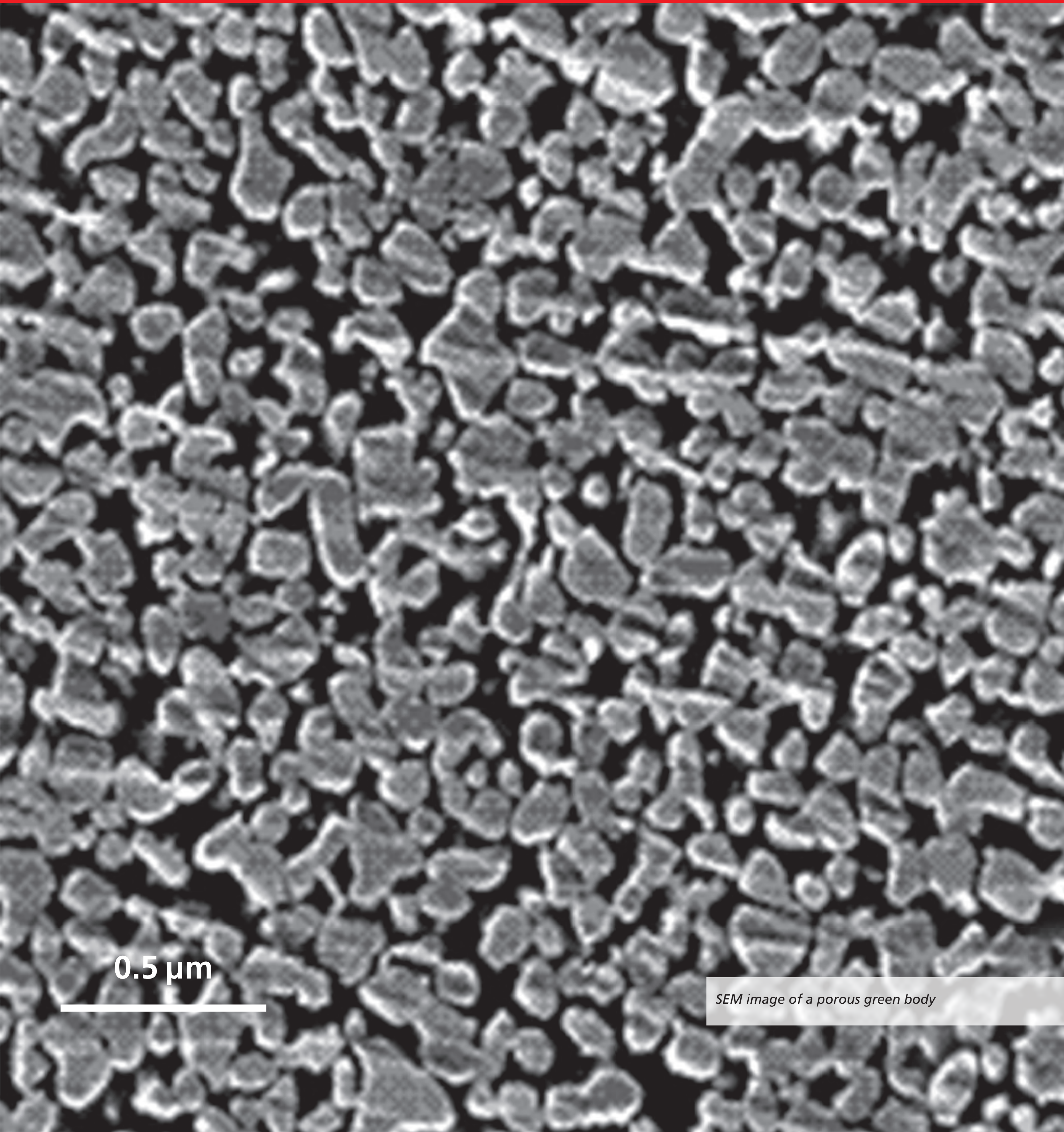
Energy consumption in debinding, sintering and finishing

Eco labels, which explain to consumers just how much energy a given technological product consumes when in operation, are being used ever more widely. It is only a question of time before the assessment also covers the energy used in manufacturing the product. This will then give manufacturers an incentive to ensure all components have been produced using as little energy as possible. As a result, the CO_2 footprint will play an ever more important role for materials to gain acceptance.

In the manufacturing of technical ceramics, heat treatment tends to be the step that consumes most energy. The process step consists of debinding and subsequent sintering. In the case of debinding, the organic additives needed for forming are burnt or pyrolized at temperatures between 200 °C and 600 °C. The debinding must be performed carefully to prevent the ceramic components from being damaged through excessive pressure or temperature gradients. This means debinding cycles can take several days.

In the case of sintering, the porous green compacts are densified to create a largely pore-free end product. Sintering takes place at temperatures between 1000 °C and 2200 °C, depending on the ceramic material. Heating and cooling the material being fired takes many hours, if not several days. Ceramic components are normally mechanically finished following sintering in order to smooth surfaces or comply precisely with the final dimensions. Finishing also consumes large amounts of energy as the ceramics are extremely hard.

In order to demonstrate that the energy used in the manufacture of technical ceramics can be reduced significantly, the ENITEC project was launched in mid-2009. This collaborative research project was funded by Germany's Federal Ministry of Education and Research (BMBF). Three ceramics manufacturers, two furnace makers and two research institutes joined forces to demonstrate on the basis of very different ceramics that a minimum 40 % reduction in energy use is possible compared with the state of the art, without compromising the quality of the ceramics. By way of example, various ceramics such as dental implants made of zirconium oxide, sliding rings made of silicon carbide and high-voltage insulators made of porcelain were investigated.

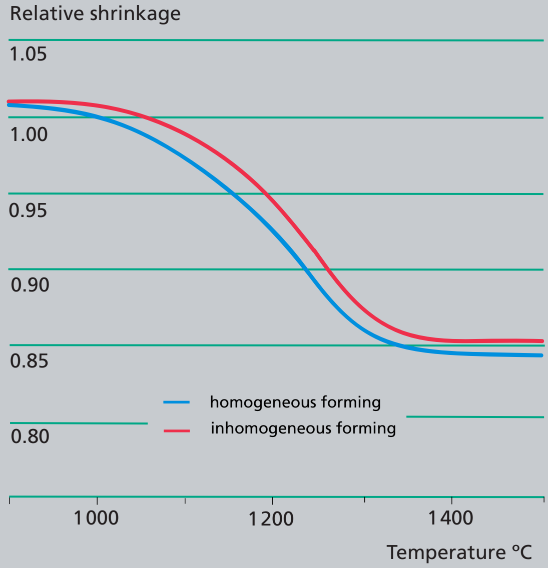


SEM image of a porous green body

Heat treatment devices at the Center HTL (© T. Köhler für Fraunhofer-Zentrum HTL).

Assessment of green compacts

At the Center HTL, the ENITEC project developed three methods which were used to measure the quality of the green compact at various size scales from the submicrometer range through to a few centimeters.

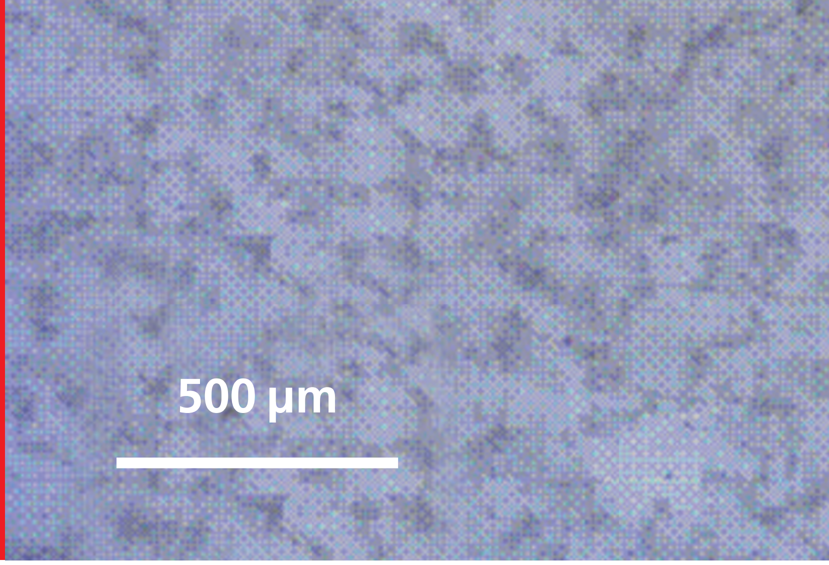


Sinter behavior of green bodies following different forming

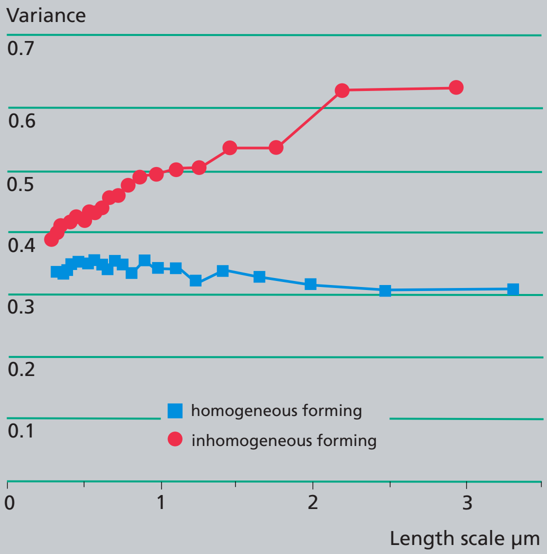
For experiments at the submicrometer scale, the sensitive green bodies are prepared with virtually zero artifacts using ion beam technology (cross section polishing). They are then imaged at high contrast using a scanning electron microscope. The homogeneity of the pore distribution is determined using software developed in-house. Improvements in homogeneity go hand-in-hand with a substantial reduction in the required sinter temperature. At the medium size scale, immersion methods have been developed to assess the green bodies.

As part of this process, liquids were identified that have the same refractive index as the ceramics. These liquids are infiltrated into the green bodies so that pores and ceramic particles can no longer be distinguished optically, thus making the green bodies transparent. Under a light microscope, individual flaws in the size range of approx. 20 µm up to a few millimeters can then be identified. These are revealed and studied by means of a target preparation, allowing the causes of the flaws in the process to be eliminated and failure rates reduced. Larger pores are identified by partially removing the liquid. In the example, the green body was manufactured from a spray granulate using dry pressing. Once the liquid was removed, the gaps between the individual granules became visible, allowing the researchers to determine whether the compaction pressure had to be increased and/or the granulate strength reduced.

The homogeneity of the pore distribution at the component scale is a crucial factor in distortion during sintering and, in turn, in the near-net-shape manufacturing of ceramic parts. Various X-ray processes were investigated to measure pore distribution. The most accurate measurement results were, however, achieved by removing cylindrical drilled cores from the green bodies and then sintering them in the thermo-optical measuring device at Fraunhofer HTL. The radial shrinkage of the drilled cores during sintering could be measured with an accuracy of approximately 10 µm through numerous measurement windows positioned along their axis. This allowed porosity variations in the green bodies to be determined in the region of 0.1 %. This accuracy was sufficient to qualify green bodies for a finish-free manufacturing process.



Green sample manufactured using dry pressing seen under a light microscope following infiltration with immersion solution. The gaps between the granules are clearly visible.



Dependency of variance on length scale

Optimization of heat treatment

Another task for the Center HTL in the ENITEC project was to further develop in-situ metrology to investigate what goes on during heat treatment. Here, sound detection was identified as a particularly sensitive measurement technique that allows damage to the green bodies caused by excessively fast heating to be identified. Sound detection allowed the maximum permissible heating rate to be determined at which no cracks appear during the debinding of green bodies. The kinetic field technique, already familiar from earlier experiments, was further qualified in the ENITEC project and employed universally to calculate the reaction kinetics of thermally activated processes. Temperature distribution and energy consumption in stationary furnaces were simulated using FE methods. Combining the kinetic field technique with furnace simulation allowed energy consumption to be specifically minimized without impairing the quality of the sintered ceramics.

The project was successfully completed in 2012. Key success criteria regarding energy savings included: high-quality forming, furnace optimization, minimization of heat losses from the furnaces, well-aimed optimization of temperature cycles and minimization of finishing work.

The insights gained from ENITEC form the basis for a wider-ranging research project at the Center HTL, to be funded by the Bavarian State Ministry for Commerce, Infrastructure, Transport and Technology. The project aims to improve energy efficiency and CO_2 footprints in industrial heat treatment processes generally. This sector alone accounts for 12 % of primary energy use in Germany. High-temperature processes above 1 000 °C account for around 7 %, equivalent to the output of some 30 nuclear power stations. If it can be managed to significantly reduce energy consumption in this area, this will make a significant contribution to promotethe transition towards a new energy economy in Germany and fulfilling the agreed CO_2 emissions targets.

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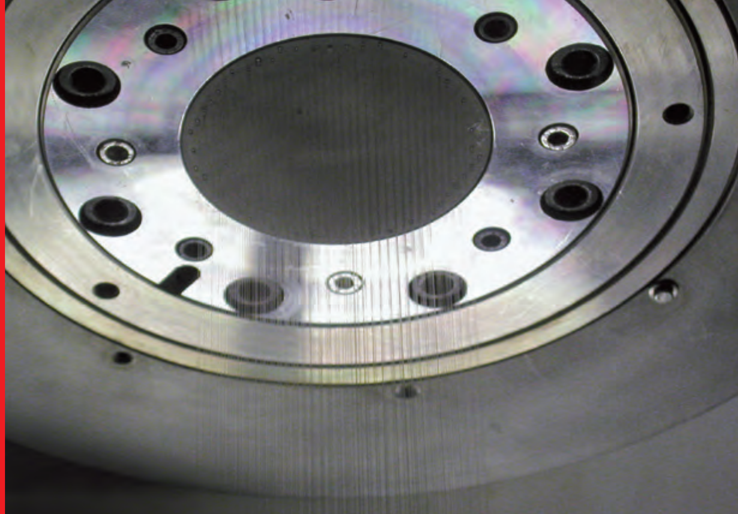

Dry spinning of polymer derived SiC fibers

DEVELOPING A EUROPEAN SiC FIBER PRODUCTION PROCESS

ARNE RÜDINGER

Urgent need for innovation on the European market

For European companies operating in the aerospace and energy sectors, access to high-performance silicon carbide ceramic fibers is of strategic importance. To date, production of this sort of fiber has been limited to three overseas manufacturers. Procuring the fiber is subject to conditions which European manufacturers cannot fulfill, such as the requirement to disclose the development subject of the user. Accordingly, the competitiveness of European companies in the ceramic matrix composites (CMC) market depends on the availability of a cost-efficient SiC fiber of equivalent technical quality that can be obtained from an independent, European source. The prospect of having internationally determined thresholds in the future for pollutant emissions, noise levels and kerosene consumption adds to the pressing need for innovation in the aerospace sector. These requirements can only be met by employing new materials, and ceramic matrix composites are among the most promising. An independent process for producing SiC fibers is now due to be set up at the SGL Group. The development of these fibers forms part of two collaborative projects sponsored by the Free State of Bavaria, SiCTec 1 and SiCTec 2, and will be jointly undertaken by SGL Carbon GmbH, Meitingen, and the Center HTL.

Cost-efficient production and establishing supply chains

The SiCTec 1 project resulted in a fiber production process that advances present technology by introducing two innovative and fundamental improvements:

- The use of a cost-efficient base material to produce spinnable polymers
- Spinning thermally processable green fibers derived from a polymer solution

The current project, SiCTec 2, is looking to upscale fiber production. When targeting manufacturers of aero-engines, successful commercialization relies on integrating these manufacturers at an early stage as the users of SiC/SiC-CMC and building up future supply chains. This gives rise to the following additional aims of the SiCTec 2 project:

- Further processing of the fibers developed (coating, textile preforms)
- Optimization of a matrix polymer for use in SiC/SiC-CMC
- Collaboration with European producers of SiC/SiC-CMC and manufacturers of aero-engines from an early stage in order to establish a supply chain for SiC/SiC-CMC

Coil with SGL-ISC SiC ceramic fibers

Project partners and their tasks

The consortium participating in the SiCTec 2 project encompasses every stage of the value creation chain. In addition to SGL Carbon GmbH in Meitingen, as a future fiber producer, the Würzburg site of the Center HTL is also participating in the project to provide scientific support in the areas of polymer synthesis and fiber development. Research will be primarily oriented around the cross-linking reactor and fiber drawing equipment built during SiCTec 1. MTU Aero Engines GmbH Munich, a worldwide manufacturer and supplier of aircraft engines and components, is partnering the project as a user by providing specifications for a demonstrator component. This demonstrator is to incorporate design details that are characteristic of certain components used in aircraft engines. The demonstrator component will be tested by MTU throughout the course of the project in order to assess the fundamental suitability of SiC fibers developed for such applications. MT Aerospace AG already produces SiC/SiC-CMC parts for use in the aerospace industry and will test the workability of the SiC fibers at certain milestones in the fiber development process.

Material basis and production engineering

Fiber production will be scaled up in two stages to 300 filaments using the existing fiber spinning machine at the Center HTL. The spinning process will have to be optimized accordingly, as well as the drying, pyrolysis and sintering of the fibers. The target fiber properties are summarized in the table.

The fibers must subsequently be coated to protect them against corrosion and control the degree to which they bond to the surrounding matrix. Only then can the pull-out effect be used to achieve the desired increase in fracture resistance. In the next step of the project, tests are done to ascertain how well these coated fibers can be processed as a textile. To this end, they will be wound, or woven to form a fabric, and process parameters will be optimized.

To create the SiC matrix in which the fibers are embedded, scientists will be using a polysilane/polycarbosilane precursor developed and produced at the Center HTL. This will be optimized by varying process parameters during the thermal polymerization reaction and by adding additional polymers or reactive substances to achieve both a level of viscosity suitable for polymer infiltration and a high ceramic yield. The mechanical, thermal and chemical properties of the CMC parts developed in the project will be measured and compared with the properties of the CMC parts produced at MT Aerospace using chemical vapor infiltration.

Target properties for SiC fibers

Property/attribute	
Tensile strength (GPa)	> 1.5
Elastic modulus (GPa)	> 150
Number of fibers in bundle	300
Length of bundle	500 m

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PROJEKTINFORMATIONEN

ENERGIE | ENERGY

Konzeptstudien für neuartige Lithium-Ionen-Zellen auf der Basis von Werkstoff-Innovationen "KoLiWIN"
Teilvorhaben: Elektrodenbeschichtung, hybride Elektrolyte und elektrochemische Charakterisierung
Förderung durch das BMBF
FKZ 03SF0343A
Laufzeit: 1.7.2009 - 30.6.2012

Projekt Piezo_EN, Autarke Energieversorgung über intelligente Piezogenerator / Lithium-Akkumulator-Mikrosysteme
Förderung durch das BMBF
FKZ 16SV3404
Projektpartner: Fraunhofer IIS, Erlangen; Fraunhofer LBF, Darmstadt; Fraunhofer IZM, Berlin; Wölfel Beratende Ingenieure GmbH & Co. KG, Höchberg, VARTA Microbattery GmbH, Ellwangen; OttoBock HealthCare GmbH, Duderstadt; Bayer Material Science AG, Leverkusen; INVENT GmbH, Braunschweig
Laufzeit: 1.4.2008 - 30.9.2011

Innovative Switchable Shading Appliances based on Nanomaterials and Hybrid Electrochromic Device Configurations (INNOSHADE)
Förderung durch Europäische Kommission (FP7), Vertragsnummer 200431
Partner: Centro de Tecnologias Electroquimicas (E), National Institute of Chemistry (SLO), GORENJE Group (SLO), CNRS (F), Institut de Recherche d'HydroQuebec (CN), INSTM c/o Universita Milano-Bicocca (INSTM-UMIB) (I), ESSILOR International (F), MASER Microelectrónica S.L./E, ARCELIK A.S. (TR), SOLEMS S.A. (F), Universidade do Minho c/o Departamento de Fisica (PT), EADS Deutschland GmbH, LCS Life Cycle Simulation GmbH, Coatema Coating Machinery GmbH, Centrum organické chemie s.r.o. (CZ), Hanita Coatings RCA Ltd. (IL).
Laufzeit 1.9.2008 - 31.12.12

Projekt DEGREEN - Dielektrische Elastomer-Generatoren für regenerative Energien
Förderung durch das Bayerische Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie
Laufzeit: 1.6.2012 - 31.5.2017

Entwicklung und Charakteristik nanoskaliger Elektroden-Komposite für EnergyCap: Hochleistungsspeicher für Anwendungen im Bereich der erneuerbaren Energieversorgung, mobiler Bordnetze und Traktionsanwendungen EnergyCap
Förderung durch das BMBWi
FKZ AZ0327822B
Partner: BMW Forschung und Technik GmbH, München; Freudenberg Vliesstoffe KG, Weinheim; Liebherr-Werk Biberach GmbH; Merck KGaA, Darmstadt; RWTH Aachen; Siemens AG, München; SGL Carbon GmbH, Meitingen; WIMA Kondensatoren GmbH & Co. KG, Berlin, ZSW, Ulm
Assoziierter Partner ohne Förderung: ENERCON GmbH, Aurich
Laufzeit 1.7.2009 - 31.3.2012

"Sugar Alcohol based Materials for Seasonal Storage Applications" SAM.SSA,
Förderung durch die EU, Vertragsnummer 296006
Partner: Centre National de la Recherche Scientifique (F); Institut de Mécanique et d'Ingénierie de Bordeaux (F); Institut Jean Lamour (F); RHODIA Operations (F); National R&D Institute for non-ferrous and rare metals (ROM); Technical University of Eindhoven (NL); CIC Energigune (E); AIDICO – Instituto Tecnológico de la Construcción (E); Phase Change Materials Product Limited (UK); EURICE GmbH; Fraunhofer ISE
Laufzeit: 1.4.2012 - 31.3.2015

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HTL

ENITEC - Effiziente Niederenergie Entbinderungs- und Sintertechnik in der Keramikherstellung
Förderung durch das BMBF
FKZ 02P02025
Partner: CeramTec AG (Plochingen), Lapp Insulators GmbH & Co. KG (Wunsiedel), BCE Spezialkeramik (Mannheim), Eisenmann Maschinenbau KG (Böblingen), FCT Systeme GmbH
Laufzeit: 1.7.09 - 30.6.12

LC-CMC: Low-Cost-Technologien für die Herstellung von Bauteilen aus Ceramic Matrix Composites
Förderprojekt der Fraunhofer-Gesellschaft – Marktorientierte Vorlaufforschung – MAVO
Laufzeit: 1.2.2010 - 30.1.2013

SiC-Tec 2
Förderung durch den Freistaat Bayern / PTJ "Neue Werkstoffe in Bayern", Fraunhofer ISC im Unterauftrag,
Partner SGL-Carbon GmbH, Meitingen, MTU Aero Engines GmbH München, MT Aerospace AG Augsburg
Laufzeit 30.6.2010 - 31.12.2013

Compound-Rohre - Ressourceneffiziente faserummantelte Stahlrohre für Höchsttemperaturanwendungen
Förderung durch das BMBF
FKZ: 03X3529
Projektpartner: EnBW Kraftwerke, Großkraftwerk Mannheim AG; Schunk Kohlenstofftechnik GmbH, Heuchelheim; Materialprüfungsanstalt (MPA), Universität Stuttgart; Universität Bayreuth, Lehrstuhl Keramische Werkstoffe (CME); Universität Haifa, Technion Materials Engineering, Haifa, (IL)
Laufzeit 1.06.2009 - 31.12.2012

Herstellung von Isolationsfasern aus umweltfreundlichen Rohstoffen
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Projektpartner Fa. Rath GmbH

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Partner Rauschert GmbH
Laufzeit 1.10.2012 - 30.9.2015

Inhärent sicherer und energieeffizienter LSI-Prozess - ISE-LSI,
Förderung durch die Bayrische Forschungsstiftung,
FKZ AZ-972-11,
Laufzeit: 15.6.2011 - 15.6.2014.

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DIBBIOPACK – Development of injection and blow extrusion molded biodegradable and multifunctional packages by nanotechnology: Improvement of structural and barrier properties, smart features and sustainability
Förderung durch die EU (FP7)
Laufzeit: 1.3.2012 - 29.2.2016
www.dibbiopack.eu

PlasmaNice – Atmospheric Plasmas for Nanoscale Industrial Surface Processing
Förderung durch die EU (FP7)
FKZ 211473
Partner: Tampere University of Technology (FIN); Flemish Institute for Technological Research (B); Technical Research Centre of Finland (FIN); University of Technology Eindhoven

(NL); Jozef Stefan Institute (SL); Stora Enso Oyj (FIN); AFS Entwicklungs- und Vertriebs GmbH; Segers & Balcaen (B); Print 2000 Nyomda Kft (HU); SurA Chemicals GmbH (D); Sappi Netherlands Services B.V. (NL); Technical University of Denmark (DK); 2B Consulenza Ambientale de Leo Breedveld (IT); http://hlab.ee.tut.fi/plasmanice/home

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Fraunhofer-Attract-Projekt:
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Laufzeit: 1.11.2008 - 30.4.2011

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17. Treffen der GCTP Arbeitsgruppe Cultural Heritage,
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- Institute of Photonics and Electronics
- Institute of Chemical Process Fundamentals

Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e.V., Köln

Bundesanstalt für Materialforschung und -prüfung BAM, Berlin

Center for Documentation of Cultural & Natural Heritage, Giza (ET)

Center for Organic Chemistry, Pardubice (CZ)

Centre de la Recherche Scientifique (F)

Centro de Tecnologías Electroquímicas, San Sebastián (E)

Cercle des Partenaires du Patrimoine, Laboratoire de Recherche des Monuments Historiques, Champs sur Marne (F)

Commissariat à l'énergie atomique CEA, Laboratoire d'Électronique des Technologies de l'Information (Leti), Grenoble (F)

Consorzio Venezia Ricerche, Venecia (I)

Deutsche Bundesstiftung Umwelt (DBU)

Deutsches Kunststoff-Institut, Darmstadt

Deutsches Zentrum für Luft- und Raumfahrt DLR, Stuttgart und Köln
- Institut für Technische Thermodynamik

Dombauamt Erfurt, Glaswerkstatt

Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA), Zürich (CH)

Europäische Forschungsgesellschaft Dünne Schichten e.V., Dresden

Europäisches Feuerfestzentrum ECREF, Höhr-Grenzhausen

Flemish Institute for Technological Research (VITO), Mol (B)

Forschungsallianz Kulturerbe (FALKE)

Forschungsgemeinschaft Feuerfest e.V., Bonn

Forschungsgemeinschaft Technik und Glas e.V., Wertheim

Forschungskuratorium Textil e.V., Berlin

Forschungszentrum Jülich
- Ernst-Ruska-Centrum

SCIENTIFIC COOPERATIONS

Fundacion Andaluza para el Desarollo Aerospacial, Sevilla (E)

Fundacion TEKNIKER, Eibar (E)

Glasrestaurierungswerkstatt der Dombauhütte Köln

Gradbeni Institut ZRMK
- Centre for Indoor Environment, Building Physics and Energy, Ljubljana (SLO)

Helmholtz-Zentrum Berlin

Hüttentechnische Vereinigung der Deutschen Glasindustrie HVG, Offenbach

Institut de Chimie de la Matière Condensée de Bordeaux (F)

Institut de Recherche d'HydroQuébec (IREQ), Montreal (CAN)

Institut für Bioprozess- und Analysenmesstechnik e.V., Heiligenstadt

Institut für Diagnostik und Konservierung an Denkmalen in Sachsen und Sachsen-Anhalt, Halle/Saale

Institut für Energie- und Umwelttechnik (IUTA), Duisburg

Institut für Fertigteiltechnik und Fertigbau Weimar e.V.

Institut für Klinische Hygiene und Qualitätssicherung e.V. (IKHQ), Köthen

Institut für Korrosionsschutz Dresden GmbH, Dresden

Institut für Luft- und Kältetechnik gGmbH, Dresden

Institut für Photonische Technologie e.V., Jena

Institut polytechnique de Grenoble (INP), Grenoble (F)

Institute of Inorganic Chemistry and Surface (ICIS) of the Italian National Research Council (CNR), Padova (I)

Instituto di Scienze dell'atmosfera e del Clima, Consiglio Nazionale Delle Ricerche, Rom (I)

Joanneum Research Forschungsgesellschaft mbH, Graz (A)

Jožef Stefan Institute, Ljubljana (SLO)
- Department of Surface Engineering and Optoelectronics

Karlsruher Institut für Technologie (KIT)
- Werkstoffe der Elektrotechnik

Laser Labor Göttingen

Max-Planck-Institut für Eisenforschung, Düsseldorf

Max-Planck-Institut für Meteorologie, Hamburg

Max-Planck-Institut für Plasmaphysik, Garching

Max-Planck-Institut für Polymerforschung, Mainz

MRB - Research Center for Magnetic Resonance Bavaria e.V.

National Institute of Chemistry, Ljubljana (SLO)

Norwegian Institute for Air Research, Kjeller (N)

Research Center on Nanoscience and Nanotechnology, CIN2: CSIC-ICN, Bellaterra-Barcelona (E)

SIMaP (Materials and Processes Science and Engineering Laboratory), Martin d Heres Cedex (F)

MITGLIEDSCHAFTEN

Staatliche Museen Preußischer Kulturbesitz, Berlin

Swiss Research Centre for Stained Glass and Glass Art, Romont (CH)

The Cathedral Studios, The Chapter of Canterbury Cathedral, Canterbury (UK)

VTT Technical Research Centre of Finland, Tampere (FIN)

VTT Technical Research Centre of Finland, Oulu (FIN)

Zentrum für Sonnenenergie- und Wasserstoffforschung, Ulm

Zentrum für Innovationskompetenz "Virtuelle Hochtemperatur-Konservierungsprozesse – Virtuhcon", an der TU Bergakademie Freiberg, Freiberg

Mitgliedschaften und Mitarbeit in Gremien
Activities in associations and committees

Academy of Dental Materials (ADM)

Allianz Bayern Innovativ
- Cluster Chemie
- Cluster Mechatronik & Automation e.V.
- Cluster Medizintechnik
- Cluster Neue Werkstoffe
- Cluster Nanotechnologie

AMA Fachverband für Sensorik e.V.

AGEF Arbeitsgemeinschaft Electrochemischer Forschungsinstitutionen e.V.

American Ceramic Society (ACerS)
- Fellow

Arbeitsgemeinschaft Wirtschaftsnaher Forschungseinrichtungen in Baden-Württemberg

AVN – Automation Valley Nordbayern
Bayern Innovativ GmbH

bayern photonics e.V.
Kompetenznetz optische Technologien

BMBF NanoExperts Working Group Russland-Deutschland

BioMedTec Franken e.V.

BioMST - Arbeitskreis Mikrosysteme für Biotechnologie und Lifesciences e.V.

Bundesanstalt für Materialforschung und -prüfung BAM
- Arbeitsgruppe Glasig-kristalline Multifunktionswerkstoffe

Bundesverband mittelständischer Wirtschaft BVMW

Ceramic Composites im Carbon Composites e.V.

Cluster INNOB – Innovative Oberflächen

Cluster TEMASYS – Technologie und Management intelligenter Systeme

DECHEMA Gesellschaft für chemische Technik und Biotechnologie e.V.
- ConNeCat Kompetenznetzwerk Katalyse
- Fachsektion Nanotechnologie

ACTIVITIES IN ASSOCIATIONS AND COMMITTEES

Deutsche Forschungsgesellschaft für Oberflächenbehandlung e.V.
- Fachausschuss Oberflächenbehandlung von Stahl und Multisubstraten

Deutsche Gesellschaft für Materialkunde e.V. (DGM)
- Arbeitskreis Verstärkung keramischer Werkstoffe
- Arbeitskreis Energiespeicherung
- Arbeitskreis Energiegewinnung
- Fachausschuss Biomaterialien
- Fachausschuss Werkstoffe der Energietechnik

Deutsche Glastechnische Gesellschaft (DGG)
- Fachausschuss I

Deutsches Institut für Bautechnik (DIBt)
- Expertenausschuss Abwassersysteme

Deutsches Institut für Normung (DIN)
Normenausschuss für
- Volumenmessgeräte
- UA Volumenmessgeräte mit Hubkolben
- UA I/ FA I
- NMP 261 (Chemische Analyse von oxidischen Materialien und Rohstoffen)

Deutsche Keramische Gesellschaft (DKG)
- Arbeitsgruppe Keramografie
- Fachausschuss (FA1) Physikalische und chemische Grundlagen
- Arbeitsgruppe Thermoplastische Formgebung von Technischer Keramik

Deutsche Physikalische Gesellschaft e.V. (DPG)

Deutscher Verband für Materialforschung und -prüfung e.V. (DVM)
- Arbeitsgruppe Zuverlässigkeit adaptiver Systeme

Editorial Board of "Dataset Papers in Optics",
Hindawi Publishing Corporation

Electrochemical Society ECS

EU Ad-hoc Advisory Group on Industrial Nanotechnologies for the NMP Program

Europa Nostra

European Multifunctional Materials Institute EMMI

Fachausschuss Biomaterialien der DGM

Firmenausbildungsverbund e.V. Main-Tauber (Fabi)

Förderkreis Kloster Bronnbach

Forschungsgemeinschaft Technik und Glas e.V., Bronnbach (FTG)
- Technischer Ausschuss

Forum Elektromobilität

Forum für Medizin Technik und Pharma in Bayern e.V.

Forum Innovation und Technologie Heilbronn Franken

Fraunhofer-Demonstrationszentrum AdvanCer
- Mitglied des Projektleitungsrats

MITGLIEDSCHAFTEN

Fraunhofer Allianzen und Netzwerke:
- Adaptronik
- Batterien
- Bau
- Energie
- Hochleistungskeramik
- Leichtbau
- Nanotechnologie
- Numerische Simulation von Produkten und Prozessen
- Polymere Oberflächen (POLO)
- Optisch-funktionale Oberflächen
- Photokatalyse
- Qualitätsmanagement

Gemeinschaftsausschuss Hochleistungskeramik der Deutschen Keramischen Gesellschaft DKG und der Deutschen Gesellschaft für Materialkunde DGM
- Arbeitsgruppe Keramische Schichten
- Arbeitsgruppe Verstärkung keramischer Werkstoffe
- Arbeitsgruppe Polymerkeramik
- Arbeitsgruppe Ausgangspulver

Gesellschaft Deutscher Chemiker (GDCh)
- Arbeitsgruppe Chemie am Bau
- Fachgruppe Anstrichstoffe und Pigmente
- Fachgruppe Angewandte Elektrochemie

Gesellschaft für Umweltsimulation e.V. (GUS)

Gesellschaft Mess- und Automatisierungstechnik (GMA)
- Fachausschuss 4.16 Unkonventionelle Aktorik

GfKORR Gesellschaft für Korrosionsschutz e.V.
- Arbeitskreis Korrosionsschutz in der Elektronik und Mikrosystemtechnik

ICOM International Council of Museums
- Committee for Conservation

ICOMOS International

Institute for Environmental Simulation (GUS)

International Advisory Board of Journal of Sol-Gel-Science and Technology

International Conference on Coatings on Glass and Plastics (ICCG)
- Programm-Ausschuss

ISGS International Sol-Gel-Society

Journal of Nano Research (TTP Switzerland, ed.)
- Editorial Board

LEADER-Aktionsgruppe Neckar-Odenwald-Tauber

Materials Research Society
- Program Committee Optical Interconnects

Materials Valley e.V. – Kompetenznetzwerk für Materialforschung und Werkstofftechnik

mst–Netzwerk Rhein5.n
- Kompetenznetzwerk Mikrosystemtechnik

NanoMat – Netzwerk Nanomaterialien

Nanonetz Bayern e.V.
OEA - Organic Electronic Association

Netzwerk Innovative Werkstoffe e.V.

Organisationskomitee DECHEMA-Nanobiotechnologie 2012

Organisationskomitee MSE 2012 (Materials Science and Engineering Conference)

ACTIVITIES IN ASSOCIATIONS AND COMMITTEES

Photonics West
- Programme Committee Optoelectronic Interconnects and Component Integration

Quadriga – Associated Network on Organic and Large Area Electronics

Scientific Committee of the International Symposium on Flexible Organic Electronics (ISFOE)

Technologie-Roadmap LIB 2030

VDMA
- OEA-Plattform (Arbeitsgemeinschaft Organic Electronics Association)

Verein Deutscher Ingenieure (VDI/DIN)
- Kommission Reinhaltung der Luft

Wirtschaftförderung Heilbronn, Industrie und Handelskammer (IHK)

Wirtschaftsförderungszentrum Ruhr für Entsorgungs- und Verwertungstechnik e.V.

Würzburger Forschungsverbund Funktionswerkstoffe

Gastreferenten des ISC-Seminars in Würzburg
Guest speakers at the Fraunhofer ISC

10. Januar 2012
The Origin, Development and Future of Lithium-Ion Batteries.
Dr. Akira Yoshino
Asahi-Kasei Corporation (Inventor of the Lithium-Ion Battery)

13. Januar 2012
Developing functional inorganic materials at Umicore.
Dr. Egbert Lox
Umicore (B), Group Research & Development (Kurator des ISC)

20. Januar 2012
Sensing and actuating with Lamb waves at solid-liquid boundaries.
Prof. Dr. Gerhard Lindner
Hochschule für angewandte Wissenschaften Coburg, Fachbereich Angewandte Naturwissenschaften

23. Januar 2012
Faltlösungen für die Industrie – Minimierung und Maximierung von Flächen und Objekten.
Dipl.-Designerin Kristina Wißling

2. Februar 2012
Verfahrensvarianten und Anwendungen des elektrochemischen Abtragens in der Präzisions- und Mikrofertigung.
Dr.-Ing. Dipl.-Phys. Matthias Hackert-Oschätzchen
TU Chemnitz, Institut für Werkzeugmaschinen und Produktionsprozesse, Professur Mikrofertigungstechnik

28. Februar 2012
Hybrid Inorganic-Organic Ion Conducting Polymer Electrolytes: Synthesis, Structure and Conductivity Mechanism.
Dr. Vito Di Noto
University of Padova, Department of Chemical Sciences, Professor of Chemistry for Energy and Solid State Chemistry

29. Juni 2012
Transparent Organic-Inorganic Hybrids for Different Refractive Index Materials.
Dr. Kimihiro Matsukawa
Osaka Municipal Technical Research Institute (OMTRI)

VERANSTALTUNGEN
CONFERENCES AND EVENTS

5. Juli 2012
Funktion und Innovation – Umsetzung technologischer Anforderungen in chemische Produkte.
Dr. Klaus-Dieter Franz
Ehem. Merck KGaA

23. Oktober 2012
Technologie- und Innovationsmanagement bei Fa. Kärcher GmbH & Co. KG.
Dr. Daniel Heubach
Alfred Kärcher GmbH & Co. KG

12. November 2012
Silizium – Technologie – Funktion – Anwendung: Praxisnahe und anschauliche Beispiele aus der Siliziumchemie der Evonik,
Dr. Harald Hoecker
Evonik Industries AG

Veranstaltungen am Fraunhofer ISC
Conferences and events at the Fraunhofer ISC

Würzburger Wirtschaftstage
Berufsnavigator: Arbeiten in der Forschung für die Produkte von morgen.
Würzburg, 29.2. – 1.3.2012

CeSMa-Workshop:
Industrielle Herausforderungen für Smart Materials.
Würzburg, 8.5.2012

Tag der Offenen Tür in der Fraunhofer-Projektgruppe IWKS.
Alzenau, 4.6.2012

Feierliche Eröffnung des Zweiten Standorts der Fraunhofer-Projektgruppe IWKS.
Hanau, 29. Juni 2012

Ausstellung im Schlösschen Michelbach zum Thema Ressourcen.
Alzenau, 1. – 29. Juli 2012

Feierliche Übergabe des Bewilligungsbescheids für den weiteren Ausbau des Fraunhofer-Zentrums HTL.
Bayreuth, 1.8.2012

Kick-Off-Feier des Projekts DEGREEN.
Würzburg, 19.12.2012

Messen und Ausstellungen 2012
Fairs and exhibitions

Photonics West
San Francisco, CA (USA), 21. – 26.1.2012

NanoTech 2012
Tokyo (JP), 15. – 17.2.2012

Würzburger Wirtschaftstage
Würzburg, 27.2. – 3.3.2012

Energy Storage
Düsseldorf, 13. – 14.3.2012

Symposium Material Innovativ
Rosenheim, 14. März 2012

Entwicklerforum Akkutechnologien
Aschaffenburg, 18. – 19.4.2012

Hannover Messe
Hannover, 23. – 27.4.2012

MESSEN
FAIRS AND EXHIBITIONS

MS Wissenschaft im Dialog
Ausstellung zum "Wissenschaftsjahr 2012 – Zukunftsprojekt ERDE"
30. Mai – 15. Oktober 2012

IFAT ENTSORGA 2012
München, 7. – 11.5.2012

Kongress-Forum Elektromobilität
15. Mai 2012

Ceramitec 2012
München, 22. – 25.5.2012

Sensor + Test 2012
Nürnberg, 22. – 24.5.2012

Wirtschaftsmesse Rothenburg o.d.T.
Rothenburg o.d.T., 15. – 17.6.2012

Industrial Technologies
Aarhus (DK), 19. – 21.6.2012

ACHEMA
Frankfurt, 17. – 22. Juni 2012

Singapore International Water Week/Water Expo.
Singapore, 2. – 4. Juli 2012

Verband Deutscher Glasbläser, Fortbildungsseminar
TU Berlin, 14. – 15.9.2012

Glasstec
Düsseldorf, 23. – 26.10.2012

f-cell
Fraunhofer-Allianz Batterien,
Stuttgart, 10. Oktober 2012

denkmal
Leipzig, 22. – 24.11.2012

Messen 2013
Fairs and exhibitions 2013

Bau 2013
München, 14. – 19. Januar 2013

NanoTech 2013
Tokyo (JP), 30.1.– 1.2.2013

Photonics West 2013
San Francisco (USA), 5. – 7.2.2013

Symposium Holz Innovativ
Rosenheim, 20.2.2013

JEC Europe Composites Show and Conferences
Paris, 12. – 14.3.2013

Material Innovativ
Aschaffenburg, 11.4.2013

Hannover Messe
Hannover, 8. – 12. April 2013

Sensor + Test
Nürnberg, 14. – 16.5.2013

Solar Power International 2013
Chicago (USA), 22. – 24.10.2013

ALLIANZEN UND NETZWERKE

The institute in networks

Fraunhofer ISC is an active member in several national and international research networks. Goal of the cooperation is to support the interdisciplinary exchange of knowledge with industry and other university and non-university research institutions, share own experiences and gain new partners.

Within the Fraunhofer-Gesellschaft one Fraunhofer ISC employee is responsible for the alliance "Nanotechnology". On business units level there are a number of additional close cooperations with Fraunhofer networks for the topics of "Adaptronic", "High-performance ceramics", "Numeric simulation of products and processes", "Optically functional surfaces" and "Photocatalysis" as well as with numerous universities and research institutions outside the Fraunhofer-Gesellschaft.

The institute is member of the "Wilhelm Conrad Röntgen Research Center for Complex Material Systems" (RCCM) at Universität Würzburg, on national level in the competency net for materials of nanotechnology (NanoMat) and in the competency network for materials research and technology, Materials Valley e.V. and on European level in "European Multifunctional Materials Institute" EMMI.

Fraunhofer ISC, being a materials development institute, belongs to the Fraunhofer Materials and Components Group. Chairman is Professor Dr.-Ing. Holger Hanselka who is also Director of Fraunhofer LBF. Other members are the Fraunhofer Institutes EMI, IAP, IBP, ICT, IFAM, IGB, IKTS, ISE, ISI, ITWM, IWM, IZFP and WKI. Furthermore, the institute is represented in the demonstration center alliance "AdvanCer" (System development with high-performance Ceramics – For more information go to www.advancer.fraunhofer.de).

Fraunhofer ISC in more alliances and networks

Fraunhofer Nanotechnology Alliance
Spokesperson and Director of branch:
Dr. Karl-Heinz Haas, Fraunhofer ISC
Phone: +49 931 4100-500
karlheinz.haas@isc.fraunhofer.de
www.nano.fraunhofer.de

Fraunhofer Building Innovation Alliance
Contact
Andreas Kaufmann
Fraunhofer-Institut für Bauphysik
Phone: +49 8024 643-240
andreas.kaufmann@ibp.fraunhofer.de

Research Alliance Cultural Heritage
Contact
Dr. Johanna Leissner
Scientific Representative for Fraunhofer IBP, IAP, ICT, IGB, IST, ISC and MOEZ
Phone: +32 2 506-4243
johanna.leissner@zv.fraunhofer.de

Dr. Stefan Brüggerhoff
Deutsches Bergbau-Museum DBM, Bochum
stefan.brueggerhoff@bergbaumuseum.de

Dr. Stefan Simon
Rathgen-Forschungslabor, Staatliche Museen in Berlin, Stiftung Preußischer Kulturbesitz
s.simon@smb.spk-berlin.de

ALLIANCES AND NETWORKS

Fraunhofer Sustainability Network
Contact
Fraunhofer Office Brussels
Dr. Johanna Leissner
Rue du Commerce 31
B-1000 Brussels, Belgium
Phone: +32 2 506-4243
johanna.leissner@zv.fraunhofer.de

Cluster of Bavarian Research Alliance

Cluster Chemie
Spokesperson:
Professor Dr. Utz-Hellmuth Felcht
hermann@cluster-chemie.de; felcht@cluster-chemie.de
www.cluster-chemie.de

Cluster Mechatronik & Automation
Spokespersons:
Professor Dr.-Ing. Gunther Reinhart and
Professor Dr.-Ing. Klaus Feldmann
gunther.reinhart@cluster-ma.de,
klaus.feldmann@cluster-ma.de
www.cluster-ma.de

Cluster Medizintechnik
Spokesperson:
Professor Dr. med. Michael Nerlich
michael.nerlich@medtech-pharma.de
www.cluster-medizintechnik.de

Cluster Nanotechnologie
Spokesperson:
Professor Dr. Alfred Forchel
info@nanoinitiative-bayern.de
www.nanoinitiative-bayern.de

Cluster Neue Werkstoffe
Spokespersons:
Professor Dr. Rudolf Stauber and
Professor Dr. Robert F. Singer
cluster-neuewerkstoffe@bayern-innovativ.de
www.cluster-neuewerkstoffe.de