Fraunhofer ISC

FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH ISC

ANNUAL REPORT 2010/11

HEALTH

Encapsulation techniques are used to enclose solid particles, liquids or gases in a coating that enables liquids to be converted into powder form, volatile substances to be stabilized, reactive components of a compound material to be kept apart, sensitive materials to be protected against environmental factors or drug ingredients to be released in a controlled manner. The encapsulation of active substances is a topic of widening interest in many industrial sectors, including pharmaceuticals, medicine, cosmetics, food processing, textiles, chemical engineering, agriculture, and environmental protection.

The Fraunhofer ISC has developed a novel encapsulation technique. This solution promises a particularly non-destructive and clean method of encapsulation that minimizes temperature gradients, works without the use of solvents, and prevents all contamination or damage by foreign substances, such as the unwanted infiltration of monomers.

As can be seen on the front cover, we even succeeded in encapsulating a fresh apple cut into decorative slices to honour the 2011 Year of Health.

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PREFACE

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

2010 was an eventful and very successful year for the Fraunhofer Institute for Silicate Research ISC, in which the Institute made significant progress toward its future goals. Following the sharp decrease in industrial revenues in the wake of the global economic downturn in 2009, the Institute posted record-breaking revenues in 2010. Indeed, the relative proportion of industrial revenues increased by five percentage points from 31.4 (2009) to 36.4 % (2010) of total revenues. The operating budget increased in the same period from 16.6 million euros to 17.6 million euros (+ 5.5 %). The headcount was around 303 on average in 2010, with an annual average of 170 permanent employees. Overall, performance was particularly pleasing for the 2010 financial year.

In 2010, two major expansion projects entered the construction phase: the foundation stone was laid for the Institute's new pilot plant building, Technikum III, at Neunerplatz in Würzburg, and reconstruction work began on the historic coach house, located on the premises of the Bronnbach Abbey, to turn it into a test workshop for plants and devices developed at the Bronnbach Branch in the areas of measuring and process engineering or glass and sintered materials.

The planning and preparation work for the construction of the new pilot plant building (Technikum III) based on the design by the prominent London architectural office Zaha Hadid Architects Ltd. had already been completed in 2009. Construction work commenced officially on July 16, 2010 with the foundation laying ceremony. The new building, which is scheduled for completion by the end of 2012, will first and foremost enable the Institute to reinforce its activities in the fields of electrochemical energy storage and conversion, health, construction and environment, and glass.

The Main-Tauber regional administration had the historic coach house, adjacent to the Bronnach Branch facility, carefully restored in keeping with its status as a historic monument while still enabling the Fraunhofer ISC to set up a new test center in the ground floor that also accommodates a fully automated glass screening plant for the characterization of new glass-forming melts. The renovation project is remarkable testimony to the successful combination of conserving architectural heritage and implementing a state-of-the-art test facility.

The recent spate of reports concerning shortages of key raw materials has led to growing concern on the part of industrial enterprises and governments alike, who are increasingly calling for measures to assure the long-term, secure supply of critical metals and minerals for German and European industry. Prompted by related inquiries from numerous industrial enterprises in the Rhine-Main area, it was decided in 2010 to push forward with setting up a new Fraunhofer project group devoted to materials recycling and materials substitution under the provisional title of Fraunhofer IWKS.

Demand for metals and compounds of rare elements is constantly increasing for all state-of-the-art products that contain electronic components, be it from the energy, IT, medical engineering or security technology sectors, consumer electronics or even in transportation. Elements where a long-term supply is deemed critical include gold, silver, copper, gallium and rare earth metals used in semiconductor manufacturing along with the platinum group metals for catalysis. Even the frontline theme of electromobility is affected, given that the mass production of electrical energy storage devices essentially depends on having an adequate supply of elements such as lithium, cobalt and manganese. In Europe, none of the aforementioned commodities are available in any notable quantities, making manufacturing industry in Germany and throughout Europe almost entirely dependent on imports of raw materials. Closed-loop materials management for critical elements should help reduce dependency on the availability of primary raw materials, with increasing use being made of sources of secondary raw materials or substitute materials. Hence, rare or critical raw materials can be used more efficiently while improving product sustainability.

The planned new project group will focus on precisely these issues. The shortlist of potential sites includes locations in Hanau and to the north of Aschaffenburg. The Bavarian State Ministry for Economics, Infrastructure, Transport and Technology has already approved start-up funding of 5 million euros for the period 2011-2013, which should make it possible to set up the project group in 2011. The state of Hesse is also expected to grant funding for this research area – an area that is particularly important for industrial companies based in the region. Prof. Dr. Armin Reller, Chair of Resource Strategy at the University of Augsburg, has been asked to lead the project group.

In addition to start-up funding for the Fraunhofer IWKS project group, the Bavarian State Ministry for Economics, Infrastructure, Transport and Technology has approved 8 million euros to set up a Center for Applied Electrochemistry at Fraunhofer ISC in Würzburg. This center will form part of the Electromobility Research and Development Center, Bavaria, and cooperate with a Fraunhofer ICT project group to be set up on the TUM university campus in Garching near Munich. This will provide a permanent basis for the activities of the competence unit led by Dr. Kai-Christian Moeller, which has successfully acquired funding for several important projects in the field of electrochemical energy storage and conversion in the past. At present, high-performance storage devices for applications in renewable energy supplies, for mobile onboard networks and for traction applications (EnergyCap) are being developed alongside new materials for Li-ion batteries.

The Project Group Ceramic Composites in Bayreuth, led by Prof. Walter Krenkel, is to be enlarged and transformed into a Fraunhofer Center for High-Temperature Lightweight Construction. In 2010, a concept was devised to speed up growth and intensify the expansion of its activities. A separate section of this annual report is devoted to the project group. To implement the new Fraunhofer Center, the Bavarian State Ministry for Economics, Infrastructure, Transport and Technology has pledged additional investment grants amounting to 7 million euros. One highlight for the project group in 2010 was organizing HT-CMC 7, the internationally acclaimed industry conference devoted to high-temperature ceramics which attracted some 350 delegates.

May I take the opportunity at this point to express my thanks to all staff of the Fraunhofer ISC at Würzburg, Bronnbach and Bayreuth as well as to all staff at the Chair of Chemical Technology of Materials Synthesis for their untiring efforts, without which the successes described would not have been possible. I would also like to thank the Fraunhofer-Gesellschaft, all industrial and institutional project partners, customers and advisors, the members of the Advisory Board, and the Federal Ministry of Education and Research for the trust and confidence they have placed in us.

My special thanks go to the Bavarian State Ministry for Economics, Infrastructure, Transport and Technology for its generous support for the Fraunhofer ISC expansion projects.

I hope you will enjoy reading this annual report.

Prof. Dr. Gerhard Sextl

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In its role as a materials research institute, Fraunhofer ISC opens up the potential of innovative materials for the products of tomorrow, focusing in particular on efficient and safe energy use, sustainable utilization of resources, and affordable, personalized health care.

The Institute's customers are major industrial companies and small and medium-sized enterprises who seek to transfer new materials and processes into production and to implement quality assurance methods in existing production processes. Among the services rendered by the Institute is not only the development of new materials, but also the development of entire technologies and the design of manufacturing processes tailored to specific production environments. Where required, Fraunhofer ISC also develops functional models and demonstrators and optimize manufacturing processes using advanced test and measurement techniques that closely simulate real-life conditions.

Locations

Fraunhofer ISC has four locations in two different German federal states. Its headquarters and one branch office are conveniently situated in the Bavarian city of Würzburg, which is easily accessible by various modes of transport. Since 1995, the Institute has also operated a facility in the town of Bronnbach, some 35 kilometers from Würzburg in the neighboring federal state of Baden-Württemberg. The Fraunhofer Project Group Ceramic Composites, which was established in 2006, is located 160 kilometers away in the city of Bayreuth and maintains close ties to the University of Bayreuth.

Fraunhofer ISC has more than 3,500 m^2 of laboratory space and pilot plant facilities equipped on a semi-industrial scale, ranging from a synthesis plant for inorganic polymers and a spinning pilot plant for high-temperature-resistant ceramic fibers (both located at the Würzburg site) to process monitoring and 3-D failure analysis systems based on high-resolution computed tomography (CT) for components with diameters up to 700 millimeters (Bayreuth site). The accredited Center for Applied Analytics in Würzburg offers more than 50 well-established measurement and analysis techniques as well as virtually artifact-free preparation methods and high-resolution electron microscopy.

Work is in progress on an extension building that will provide some 2,500 m^2 of additional space for the Institute's activities. Scheduled for completion by the start of 2013, the new building will be equipped with advanced technical facilities that will enable the Institute to build up its research capacity in the new focal areas of energy efficiency, environmental protection and human health.

The Institute in figures

Under the terms of the Fraunhofer funding model, Fraunhofer ISC is allowed to cover around one third of its operating expenses by means of government grants. Two thirds of the budget must be generated through industrial contracts and publicly sponsored research projects. In 2010, ISC's operating budget increased to 17.6 million euros (2009: 16.6 million euros).

Revenue from industrial projects climbed to 6.4 million euros (2009: 4.8 million euros) while public sector contract revenue rose to 5.5 million euros (2009: 4.6 million euros). Base funding was supplemented by 1.0 million euros in EU project revenue (2009: 1.3 million euros) while revenue from other projects amounted to 0.6 million euros. Base funding from the federal and Laender governments amounted to 4.1 million euros (2009: 5.6 million euros) including German research programs totaling 1.2 million euros (2009: 0.9 million euros). Total capital expenditure in 2010 came to 1.7 million euros.

Averaged over the year, the Institute employed a total of 303 staff at its sites in Würzburg, Bronnbach and Bayreuth. The permanent staff is supported by external specialists, mainly for technical and administrative tasks. Fraunhofer ISC also plays an important role in the tertiary education sector, offering many students enrolled on materials science courses an opportunity to work on their postgraduate thesis and diploma projects at the Institute or to gain work experience while studying for an academic degree.

Structure

Since the beginning of 2011, Fraunhofer ISC has been operating under a new organizational structure which differs from the previous arrangement on which this Annual Report for 2010 was based.

The activities that were previously spread over six business units are now concentrated in three thematic focal areas: Energy, Environment, and Health. The number of competence units has been reduced to five, each responsible for research projects related to specific applications: Applied Electrochemistry, Dental and Micromedicine, Glass and High-Temperature Materials, Optics and Electronics, and Materials Chemistry. At the same time, the ISC International was established to coordinate the Institute's worldwide activities.

Independently run facilities that are operated under the umbrella of the Institute include the Center for Applied Analytics, the Center Smart Materials CeSMa, the Center of Device Development CeDeD and the International Convention Center for Cultural Heritage Preservation IZKK. Contact details for our various administrative departments, competence units and centers are given on the following pages.

Key areas of research

- Ceramic fibers
- Inherently safe fabrication of ceramics
- Customized speciality glass
- Energy storage
- Mobile energy supplies
- Smart materials
- Micro and polymer electronics
- Packaging of optical components
- Coating technology
- Environmental monitoring and preventive conservation
- Functional fillers
- Nanotechnology
- Porous and nanoporous materials
- Sustainable use of resources
- Diagnostics
- Regenerative medicine
- Dental medicine
- Micromedicine

ISC INTERNATIONAL

The Idea behind ISC International

As a developer of materials for international markets in the fields of energy efficiency, environmental protection and human health with a particular focus on microsystems technology, the Institute faces global competition. The ISC International was established in 2011 to enhance the co-ordination of the Institute's activities on a global scale and to address the following issues:

› Industries are moving to other countries or are evolving from component suppliers into system providers. Research and development is increasingly carried out by the companies themselves or commissioned from internationally renowned institutions.

› The R&D departments of German and European companies are increasingly drawing on the services of laboratories at Asian universities in countries such as China, India and Singapore for their materials development needs. This is a result of the significant investment these countries are making in young people's education (the 2010 PISA study saw 15-year-olds from the Shanghai region and Korea ranked a long way ahead) and of the return of well-trained scientists to their countries of origin. German and European universities and institutions are steadily slipping further and further down the global league tables and are no longer among the best in many areas.

› The trade fair circuit in Europe is increasingly dominated by systems trade shows rather than the specialized exhibitions of the past. As a result, ISC is forced to look further afield for the kinds of exhibitions and conferences where it can acquire key partners for its materials development projects, including those held in regions whose economies are booming. The idea of China as the workshop of the world has become a cliché of the past. The microsystems technology industries – to which Fraunhofer ISC can offer materials and technologies for applications such as display technology – have long since shifted their core focus to Korea and China, and even traditional European industries such as the glass industry are now holding major fairs in China.

› Key decisions that concern Fraunhofer ISC are no longer being made on an exclusively national level. International contacts and networks are now essential when it comes to staying at the cutting edge of development, exerting a timely influence on unfolding events and responding to changes quickly and flexibly. Playing a role in international markets requires organizations to have networks in Asia and Europe.

In light of this development and the need to ensure an international focus – particularly in the realm of acquisitions – Fraunhofer ISC has created a new role for Dr. Michael Popall, the former head of the Microsystems business unit: His new job is to represent the ISC and the Institute's management on a worldwide basis, establishing international networks, making useful contacts and identifying local development trends. The goal is to achieve greater presence on the international R&D market.

Tasks of ISC International

- To represent the Fraunhofer ISC on a worldwide basis
- To act as direct point of contact for any questions relating to international business
- To serve as a link to Fraunhofer International
- To establish international networks
- To foster the strategic development of the Fraunhofer ISC by identifying local development trends of international markets
- To acquire international projects
- To set preliminary focus on Asia (Japan, Korea, China) and Europe

Current Activities

In 2008, the virtual institute EMMI (European Multifunctional Materials Institute) was established from a network of excellence (FAME) with the status of a non-profit organization domiciled in Brussels. Fraunhofer ISC played an important part in the founding of FAME and EMMI by the Fraunhofer-Gesellschaft and other partners, focusing in particular on materials research in the fields of hybrid materials and ceramics.

Goals of EMMI

- To promote research and teaching in the field of multifunctional materials
- To achieve enough critical mass to present a common front in the competitive international environment as a group of European world-class teams
- To support international cooperation projects through joint research contracts and by exchanging information, data and know-how using a specially created database
- To foster long-term cooperation with selected, like-minded industry partners through methods such as the Industrial Support Group led by Merck KgaA which includes the companies integrated in the EMMI as well as specific institutes of applied research such as Fraunhofer ISC. The task of the Industrial Support Group is to harvest market data, identify target materials and develop appropriate specifications
- To achieve the optimum alignment of basic and applied research and training

EMMI currently comprises 12 universities (BE, ES, DE, FR, PT; UK), Fraunhofer (ISC), CNRS (13 French laboratories), CSIC (two Spanish laboratories) and 30 industry representatives.

One example of a current EMMI project is the EU project METACHEM, in which researchers are investigating the development of meta-materials on the basis of chemical technology. Fraunhofer ISC is heavily involved in this project – which stemmed directly from the EMMI – with its ORMOCER®-based assembly and packaging technologies for optical and electronic components and TPA-based photonic structures.

First memoranda of understanding with Asian partners

In September 2008, Fraunhofer ISC signed a Memorandum of Understanding (MOU) with the globally renowned Japanese Advanced Manufacturing Research Institute, which is based at the National Institute of Advanced Industrial Science and Technology (AIST) in Nagoya. This MOU paved the way for an initial cooperation project at the end of 2008 which gives PhD students from Fraunhofer ISC an opportunity to work on nanocomposites and their technology for microelectronic applications. A further MOU was signed with the prestigious Korea University (Sejong Campus) in 2009 in the field of materials research with a particular focus on the areas of energy production and storage and on surface, electronics and microsystems engineering. Several major applications have since been made to the Korean government to cooperate with Korean industrial partners on the basis of this MOU.

NanoTech Tokyo

Since 2003, Fraunhofer ISC has travelled to Tokyo for every edition of NanoTech, the world's biggest fair and trade show for chemical and physical nanotechnologies. What started out as a small, almost improvised stand has gradually evolved into the biggest stand operated by Fraunhofer at any international industry event. Even though the fair takes place in Asia, it offers an excellent opportunity to find European partners and has already channeled industry-related revenues totaling more than 1.5 million euros to Fraunhofer ISC. The NanoTech fair has also given rise to a number of trade fair seminar programs by the Fraunhofer Nanotechnology Alliance – an example of how Fraunhofer ISC's many years of experience in Japan also benefits other institutes.

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THE ADVISORY BOARD

The Institute's management team is supported by an advisory body made up of prominent figures from the realms of industry, research and politics. In 2010/11, the Advisory Board consisted of the following members:

Prof. Dr. Martin Bastian, Süddeutsches Kunststoff-Zentrum SKZ, Würzburg

Prof. Dr. Peter Behrens, University of Hannover

Dr. Hans Dolhaine, Henkel AG & Co.KGaA, Düsseldorf

Dipl.-Ing. Hans-Michael Güther, SGL Brakes GmbH, Meitingen

Prof. Dr. Martin Jansen, Max Planck Institute for Solid State Research, Stuttgart

Dr. Roland Langfeld (Chairman), Schott Glas, Mainz

Henry Rauter, VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen

Dr. Georg Ried, Bavarian State Ministry of Economic Affairs, Infrastructure, Transport and Technology, Munich

Prof. Dr. Martin Winter, CeNTech GmbH, Münster

Dr. Detlef Wollweber, Bayer Innovation GmbH, Düsseldorf

The main focus of Fraunhofer ISC's work is on the application-oriented development of non-metallic materials – from precursors to functional models. The Institute's core skills are developed and enhanced in five competence units and applied in the course of its project work.

- Synthesis of non-metallic, inorganic and hybrid functional materials on the basis of chemical nanotechnology
- Process development: material manufacture and processing to produce powders, fibers, thin films and coatings, suspensions, composites and microstructures; implementation in industrial production processes
- Material cycles, material substitution and resource efficiency
- Development of speciality glass and manufacture of glasses and preforms
- Material characterization, analysis and optimization
- Material and process optimization for industrial manufacturing methods

ORMOCER®s

One of the Institute's key areas of research and development is the ORMOCER®* class of materials. These inorganic-organic hybrid polymers developed by the Fraunhofer ISC are manufactured using chemical nanotechnology processes. The Institute's expertise in the sol-gel synthesis, functionalization and further processing of ORMOCER®s has steadily improved over the 25 years since this class of materials was first introduced. ORMOCER®s have now been implemented in a wide range of industrial applications.

By selecting the appropriate monomer or polymer starting components, it is possible to create materials and surfaces with a multifunctional property profile. 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 range of applications for hybrid polymer materials is correspondingly diverse.

Many products have already been successfully launched in close collaboration with industry partners, including scratch-proof coatings for plastic magnifying glasses and lenses, dental filling materials, fissure sealants, bonding agents and protective coatings, as well as high-quality decorative coatings for household glassware. Light-sensitive hybrid coatings are used in dosimeters to determine the levels of light to which works of art and other objects of cultural significance are exposed. Hybrid materials are also used in the packaging and integration of electronic and optoelectronic components on printed circuit boards: Waveguides made from ORMOCER®s make it possible to produce highly sophisticated electro-optical circuits at a reasonable cost. Microlenses made from ORMOCER®s already feature in numerous electronic devices.

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TECHNICAL SPECIALITY GLASS

Special types of glass with customized properties for engineering and optical applications are used in a variety of fields including metrology, microscopy, electronics, medical engineering, the automotive industry and the construction industry. The development and characterization of specialty glasses and glass ceramics has long been one of the Fraunhofer ISC's core areas of expertise.

Properties such as homogeneity, viscosity, bending strength and chemical resistance are painstakingly optimized to meet specific industrial requirements. For instance, in order to use glass as a highly temperature-resistant and chemical-resistant joining material, the melting point, expansion characteristics and wetting behavior must be adapted to suit the materials being joined.

The scientists use ultramodern, in-situ measuring techniques to characterize glass-forming melts as well as an automated glass screening system which is the only one of its kind in Europe.

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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 Fraunhofer ISC has amassed extensive experience and considerable expertise in developing and designing magnetorheological and electrorheological fluids (MRFs and ERFs) and magneto-rheological elastomers (MREs). These materials quickly and reversibly change their viscosity and elasticity if an electric or magnetic field is applied, making them the perfect choice for adaptive vibration damping or impact absorption and for haptic control systems.

Researchers are also working on materials which can be used to convert electrical signals into mechanical movements and vice versa. These materials – which include piezoceramics, electroactive polymers (EAP) and carbon nanotube composites (CNT) – are suitable for use as actuator and sensor components, including ultrasonic transducers for online structural health monitoring and for energy conversion (microenergy harvesting). Scientists select and combine the best materials based on the field of application and specified requirements in each case.

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CERAMIC PROCESS ENGINEERING

Optimizing the production of premium high-performance ceramics while keeping energy consumption to a minimum can only be achieved by tailoring process parameters to suit individual processes. Fraunhofer ISC investigates and models key process steps such as shaping, debinding and sintering with the aim of achieving inherently reliable, low-cost production.

Homogenous structuring of the unfired blanks or »green bodies« plays a crucial role in the quality and reliability of the high-tech ceramics they are subsequently used to produce. State-of-the-art testing and measuring procedures are employed in order to determine and steadily improve the homogeneity of green bodies – for example creating high-resolution SEM images using terahertz-wave scattering, and measuring and modeling thermal conductivity and the Young's modulus to suit the respective application.

Thermo-optical measuring (TOM) methods developed at Fraunhofer ISC are used for non-contact in-situ monitoring of the debinding and sintering processes applied to the green bodies. By incorporating special evaluation software, the course of the ceramic manufacturing process can be accurately tracked and predicted for any desired temperature cycles under a variety of atmospheric conditions. The combination of modeling and in-situ measurement makes it possible to optimize the properties of ceramic materials and develop suitable process parameters.

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COMPOSITE MATERIALS

Originally developed by the aerospace industry as an alternative to metallic materials, ceramic matrix composites (CMC) are lightweight, high-performance materials with excellent temperature stability which are increasingly finding their way into everyday applications – for example lightweight and highly wear-resistant CMC brake disks.

Fraunhofer ISC in Würzburg develops novel ceramic fibers with high temperature stability based on the Si-B-N-C and Si-C materials systems. Since SiC fibers reach their performance limits at very high temperatures, researchers are working on a SiBNC high-temperature ceramic designed for use at temperatures above 1,300 °C as well as developing economical manufacturing processes for SiC. For both systems, the team's work spans the entire process chain on a pilot plant scale, from the manufacture of ceramic precursors and the synthesis of spinnable polymers right through to fiber production.

Founded in 2006, the Fraunhofer Project Group Ceramic Composites in Bayreuth designs, manufactures and tests CMC materials. Thanks to the expansion of its facilities over the last few years, the Group is now able to carry out all the key processes from component forming and high-temperature treatment through to final quality inspection. Particular emphasis is placed on the application-specific development of structural components with high temperature stability made from oxide and non-oxide fiber composites. The team also devises simulation models based on detailed fault-analysis data, which can be used to produce reliable predictions concerning the expected lifetime of fiber-composite ceramics under real-life operating conditions.

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NEWLY STRUCTURED COMPETENCE UNITS AND COMPETENCE TEAMS AS OF 2011

Competence Unit Glass and High-Temperature Materials

Non-metallic inorganic materials which are produced and/or used at high temperatures are the key focus of the Glass and High Temperature Materials competence unit, which covers all the development steps from the model-based development of new materials through to process engineering and the manufacture of prototype components. Particular emphasis is placed on the development of speciality glasses and ceramics in the form of bulk materials, fibers and coatings. By using a combination of simulation-based material development, in-situ characterization of high-temperature processes and upscaling of manufacturing techniques, a broad range of customer-specific requirements relating to high-temperature materials can be fulfilled.

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Competence Team Glass

This competence team specializes in the modeling, development and manufacture of speciality glasses and glass ceramics. Both the composition of the glass and the melting and processing techniques used in its manufacture are tailored to the profile of properties required for each specific application. An automated glass screening system – the only one of its kind anywhere in the world – is used to accelerate test melting processes. Glasses and preforms can be manufactured on request in quantities of up to 100 kilograms per year.

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Competence Team Process Engineering

This competence team focuses on the manufacturing and systems engineering processes required to develop ceramic precursors and to convert these precursors into ceramic fibers, bulk materials and coatings. From laboratory scale to pilot scale, the team also operates facilities for sampling on behalf of its cooperation partners. In addition, customers are supported in the industrial, process-based implementation of fiber-material production systems.

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Competence Team High-Temperature Materials

This competence team specializes in high-temperature materials, in particular the development of novel ceramic precursors, the processing of these precursors into ceramic products and the optimization of the required thermal process management. By drawing on the department's expertise in computer simulation, thermo-optical in-situ measuring methods and modern material analysis techniques, the researchers are able to focus on developing materials and the corresponding manufacturing processes in accordance with specific customer requirements and correlating the structure-property relations with the process parameters. This enables reliable predictions to be made to support optimization of the ceramic processes.

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Competence Unit Applied Electrochemistry

This competence unit focuses on the development and characterization of nanostructured materials for rechargeable batteries and electrochemical double-layer capacitors. Examples include the development of lithium-ion conducting hybrid polymers, in particular for use as non-combustible solid electrolytes. Electrodes for hybrid capacitors combine the high power density of electrochemical double-layer capacitors with the high energy density of lithium-ion batteries.

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Competence Unit 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 the development of coating, shaping and two-dimensional and three-dimensional structuring processes, including their adaptation to the production environment, with a particular focus on material classes developed at the Fraunhofer ISC such as (hybrid) polymers, glasses and ceramics. The competence unit also specializes in developing directly structurable hybrid polymers for optical and electronic packaging technologies and for micromedical applications.

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Competence Unit 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. Its core competencies include the 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 competence unit employs a wide variety of processes for structuring solutions and for filler synthesis and application.

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Competence Unit Materials Chemistry

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

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Competence Team Sol-Gel Materials and Products

Researchers in this department synthesize precursors for non-metallic, inorganic materials using the classic sol-gel chemistry route. These precursors serve as the basis for the 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 the field of regenerative medicine. Key areas of research include products for affordable health care in future markets and tailor-made technical solutions designed to enable the efficient use of solar installations in desert regions and other dust-laden environments.

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Competence Team Hybrid Coatings and Coating Technology

Chemical nanotechnology processes are used to synthesize multifunctional hybrid coating materials. This involves the use of substrate-specific, material-specific and component-specific application and processing techniques tailored to specific production environments and processes, as well as modern curing methods for coatings. The team of researchers works on an array of properties and applications including a broad range of protective effects, adjustable permeability and migration barriers, catalytic effects, special chemical sensitivity, variable optical properties and switchable, active functions.

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Competence Team Conservation Sciences

Backed by many years of experience in the effects of corrosion on metal and glass, this competence team investigates the impact of environmental factors on endangered cultural heritage, especially made of glass, metals and ceramics. Measurements of environmental impact using specially designed glass and light dosimeters enable preventive measures to be taken to better protect artworks and items of cultural significance in situ, in display cases and in museum storage facilities. The team's services also include the development of new conservation methods and materials designed to protect historical and industrial monuments. Projects include the development of a special glass-in-glass solidifying agent designed to enable the gradual, gentle repair of micro-cracks in corrosion-damaged church windows, a project that was carried out in cooperation with the competence team on sol-gel materials and products.

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Competence Team Particle Technology and Interfaces

With the growing functionality and complexity of materials and components, interfacial phenomena gain more and more importance. Wherever large surfaces come into play – for example in particle systems for diagnostics or in composite materials – the chemistry at the interfaces and boundaries is likely to determine their quality and even their key properties. Based on many years of experience in the field of wet-chemical synthesis of multifunctional particles for dental applications, surface functionalization and composite manufacturing, the team's expertise has steadily been expanded to include areas such as medical diagnostics/theranostics, drug encapsulation, targeted release and self-healing.

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Center for Applied Analytics

In-depth materials analysis is a key stage in the development of many materials and processes. The Fraunhofer ISC's Center for Applied Analytics is an accredited test laboratory certified to DIN EN ISO/IEC 17025 and equipped with an extensive range of cutting-edge scientific instruments and analysis systems. As well as providing its services in-house, the Center provides external parties with a central point of contact for all questions relating to materials analysis in connection with industrial product development and optimization.

The Center's main expertise lies in chemical analysis methods for nonmetallic materials, nano-scale analysis, failure analysis, characterization of structural properties and coatings, product testing (including RAL and EUCEB testing of mineral insulation fibers), and 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 (AAS) are capable of analyzing even a few millionths of a gram of a material in solution.

High-resolution scanning electron microscopes allow researchers to analyze microstructural properties such as the surface topography and surface properties of specimens. The Center also uses an advanced ion-beam cross-section polisher that enables even porous specimens to be prepared without artifacts. A transmission electron microscope (TEM) is used to analyze microstructural features down to the nanometer scale. The specimens are obtained by preparing ultra-thin slices of the material under test using a focused ion beam (FIB). Other techniques employed include X-ray photoelectron spectroscopy (XPS) for the chemical analysis of surfaces, and scanning force microscopy for mapping the surface topography of solid materials.

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CeDeD – Center of Device Development

The principal task of CeDeD is to develop scientific research systems and devices 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 the scientific development, planning, design, and construction of research systems. This covers the entire line of development of the Institute's own research systems – from the concept and design stages based on the 3-D modeling program AUTOCAD Inventor right through to computer-based component production in the workshop. CeDeD is a central point of contact for internal and external research groups and also acts as a direct partner to industry. CeDeD develops prototypes, demonstrators and pilot plants for the manufacture and processing of newly developed materials and of research instruments used for process control at the end of the value added chain.

Particular emphasis is placed on the development of thermo-optical measurement systems 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 and 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. Thermo-optical measurement methods are an excellent choice for all groups of materials that undergo heat treatment during their manufacture, such as materials used in powder metallurgy and injection molding processes.

Certified under ISO 9001:2008, CeDeD guarantees full reproduction of the process chain and is annually audited for its quality management system. It is a reliable partner for organizations seeking to develop new technologies.

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Center Smart Materials CeSMa

»Intelligent« or adaptive materials whose properties can be changed by electric or magnetic stimuli are generally referred to as »smart materials«. Established at the Fraunhofer ISC in 2009, the Center Smart Materials CeSMa has the task of systematically exploring the potential of various smart materials for its primarily industrial clients with the goal of generating new products.

Smart materials can be used to simplify complex mechanical systems and equip them with entirely new functions and properties, opening up the possibility of simpler designs and combined component/system monitoring. Examples include high-precision positioning systems, semi-active and active damping systems, adaptive clutches, components for self-sufficient power supplies for microelectronic components and intelligent control systems with haptically integrated functions.

Key projects at the CeSMa, which is funded by the federal state of Bavaria, include the application-oriented material development, the customization of material properties for defined applications, the analysis and improvement of materials with regard to their conditions of use and service life, and the fabrication of demonstrators and functional models for customers from industry.

The development projects are run on the basis of interdisciplinary cooperation between Fraunhofer researchers and workgroups from universities, universities of applied science and industry. Other partners include the Bavarian clusters »New Materials« and »Mechatronics and Automation«. CeSMa's resources enable it to provide a broad array of technically sophisticated and scientifically proven materials and technologies for industrial customers from Bavaria and beyond.

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Center Smart Materials
CeSMa
Partner der Wirtschaft

International Convention Center for Cultural Heritage Preservation IZKK

The Fraunhofer ISC has been involved in the development and adaptation of restoration methods and materials designed for use in the conservation of cultural heritage for many years now, with very successful results. The Institute also carries out related work in the field of environmental monitoring by developing products and methods that are designed for tasks such as measuring and evaluating the environmental impact of industrial processes.

Reaffirming Bronnbach's importance in the field of cultural heritage preservation, the ISC decided in 2008 to establish the International Convention Center for Cultural Heritage Preservation IZKK in close collaboration with the Main-Tauber regional administration.

With its focus on promoting knowledge-sharing, research and the pooling of resources, the IZKK defines itself as an educational institute and contributes to the Fraunhofer-Gesellschaft's principles of sustainability. Housed in a living monument, Bronnbach Abbey, the Center aims to revive interest in our cultural heritage, and especially contribute to its preservation by disseminating the results of its research. 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. In 2011, for example, the IZKK was chosen to host the third edition of GLASSAC, an international conference on glass science in art and conservation.

The Center's target audience includes restorers, architects, master craftsmen, plasterers, artists, curators and other professions involved in cultural heritage preservation. In terms of its research activities, it fosters intensive cooperation and dialog with universities of science and applied science, research institutes, museums, and offices and agencies responsible for cultural heritage preservation.

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izkk
Internationales Zentrum für Kulturgüterschutz
und Konservierungsforschung

LAYING THE FOUNDATIONS FOR THE NEW INSTITUTE BUILDING

July 16, 2010, was a big day for Fraunhofer ISC: The foundation stone was laid for the latest extension to the Institute, known as Technikum III, marking the culmination of an 18-month period of preparation which began when the site plan and architectural design were approved by the German Federal Ministry of Research and Education. The building will feature two basement levels and four stories above ground and will primarily be used for laboratories and pilot plant facilities. The Fraunhofer campus that surrounds the distinctive brick building on Neunerplatz has been expanded on two previous occasions with the construction of two earlier extensions in 1996 and 2006.

Speaking to an audience of some 150 guests and a similar number of employees, Bavaria's Economics Minister Martin Zeil personally presented the Free State of Bavaria's funding approval for the project, ceremoniously handing over the funding agreement to Institute Director Prof. Dr. Gerhard Sextl together with his very best wishes for the continuing development of the Institute, the Würzburg region's status as a research hub and Bavaria's ongoing appeal as a business location.

Expressing his gratitude for the funding, Prof. Dr. Sextl highlighted the multifaceted requirements of modern research buildings. He emphasized how important it is for research and development work to take the requirements of industrial production into account from an early stage – especially in the field of materials – and he explained how the new building has been designed to apply industrial scale standards to the development of materials and technologies, particularly in the fields of regenerative medicine, energy storage and process optimization. He also pointed out that the building itself is meant to embody progress and cutting-edge research by its unique architectural design.

Board member Professor Alfred Gossner emphasized in his address that the Fraunhofer-Gesellschaft wants its new buildings to be efficient and sustainable: Solar technology is used to provide heating and cooling using adsorption chillers, concrete core temperature control techniques are used in the building components to help regulate the indoor climate, and lighting is controlled by daylight and motion sensors. He said that their stated goal was to build and operate laboratory buildings of this scale in a sustainable fashion, i. e. with a focus on energy efficiency and resource conservation. »We intend the ISC's new pilot plant building to be one of the first of its kind in Germany to be certified in accordance with the criteria laid down by the German Sustainable Building Council.«

Würzburg's mayor Georg Rosenthal echoed these positive sentiments in his address, recalling how he had enthusiastically supported the plans to expand the Fraunhofer ISC right from the start. He stressed how the cooperation and networking with nearby universities of applied science and with Würzburg University are of tremendous importance to Würzburg's status as a research hub.

After hearing the details of the construction project from the architect in charge of the project – Jan Hübener from Zaha Hadid Architects, London – the guests of honor laid the foundation stone, a stainless-steel time capsule containing contemporary documents, in a prepared spot at the base of the wall in the foundation pit.

Some 10,000 cubic meters of soil and rock were moved to create the building's foundations, and the shell of the structure has been gradually taking shape since July 22, 2010. By mid-2011, the builders will have used some 7,000 cubic meters of concrete to construct the new building at Neunerplatz, at which point work can begin on the complex-shaped glass facade. The planning team expects the laboratory and pilot plant facility to be completed by the end of 2012.

CLUSTER FORUM: »NEW FUNCTIONALITIES WITH GLASS«

With support from the Fraunhofer ISC, the Bavarian cluster »New Materials« held its second forum on the topic of glass on November 25, 2010. This year's forum focused on glass applications in architecture, energy technology and lighting systems. Some 80 experts from industry and the research community came together to discuss the opportunities offered by this familiar material and the hidden potential that could be exploited by developing new types of glass and processing technologies.

Prof. Dr. Josef Nassauer, CEO of Bayern Innovativ, and Institute Director Prof. Dr. Gerhard Sextl, the two patrons of the event, expressed their delight with the positive response from industry and emphasized that the cluster will continue to call for and support further activities in Bavaria relating to high-tech glass applications.

MS ENERGIE IN WÜRZBURG

The science ship operated by the German Federal Ministry of Education and Research dropped anchor in Würzburg's old harbour from October 5-7, 2010, on the last leg of its 2010 tour. It included an exhibit from the Fraunhofer ISC: An interactive battery model showing how a lithium-ion battery works. To make the science vessel's stay even more interesting for the citizens of Würzburg, the municipal authorities, Fraunhofer ISC and other partners arranged an energy exhibition in the adjacent Kulturspeicher Museum.

Under the motto »The Future of Energy«, the ISC presented recent examples of its energy research work, including an energy harvester which was used in a highway bridge as part of a project run by the German Federal Ministry of Education and Research. 150 guests turned up at the »Energy Scenario 2050 Forum« to discuss alternative energy supply strategies for the future with Prof. Ernst Ulrich von Weizsäcker and other key figures in this field.

SOL-GEL SYMPOSIUM

Organized by the Technical Academy Wuppertal at the Fraunhofer ISC for the second year in succession, the Sol-Gel Symposium attracted some 30 paying participants. 20 experts presented information on the industrial applications of sol-gel-based materials and processes during the event, which was chaired by Dr. Johanna Kron from the competence team Hybrid Coatings and Coating Technologies of Fraunhofer ISC on September 28 and 29, 2010. The series of presentations was rounded off with a guided tour of the Fraunhofer ISC.

SUSTAINABILITY – A MISSION STATEMENT FOR RESEARCH AND DEVELOPMENT

A term as abstract as »sustainability« inevitably covers a whole range of different aspects. In 1987, the Brundtland Commission defined sustainable development in a global context as »development which meets the needs of current generations without compromising the ability of future generations to meet their own needs«. The mission statement of the federal government's sustainability strategy goes into significantly greater detail, defining the terms intergenerational equity, quality of life, social cohesion and international responsibility as key components of sustainable development.

But what does sustainability mean in the context of applied research? How can sustainability be measured and evaluated objectively in projects and business processes? What can individual members of staff, individual institutes and the Fraunhofer-Gesellschaft as a whole do to promote sustainability throughout all the different areas of the organization?

To answer these questions, the Executive Board has embarked on a project entitled »Strategy for implementing the principles of sustainable development in the Fraunhofer-Gesellschaft«. The Sustainability Network – an amalgamation of approximately 20 institutes of the Fraunhofer-Gesellschaft – is tackling this topic in a project split into three parts. Work began in November 2010 and is scheduled for completion in the fourth quarter of 2011. Fraunhofer ISC is involved in all three parts of the project.

The first part of the project is entitled »Strategy and Mission Statement« and is concerned with the development of a Sustainability Mission Statement specifically tailored to the applied research carried out by the Fraunhofer-Gesellschaft, as well as with the manifestation and dissemination of this statement both internally and externally. One of the fundamental ideas behind this mission statement is to expand Fraunhofer's conception of itself as a leading innovator in the field of science and technology and to encourage it to take on an exemplary, pioneering role in implementing the concept of sustainability in the realm of science and research. The aim is that our research partners should be able to benefit directly from our experience.

The second part of the project, »Sustainable Research and Business Processes«, turns the focus inwards and responds to the question of how sustainable research can be structured and evaluated. The aim is to set standards for responsible research, development and innovation that can be applied to any research topic. One of the key issues is to develop indicators and evaluation tools which will allow for a consistent evaluation of how sustainability is being implemented in our projects. This evaluation provides a benchmark of the current status of sustainability in the processes within the Fraunhofer-Gesellschaft, showing what is already contributing towards sustainability (i .e. which activities) and how the activities are being structured and reviewed (i. e. the process design). From innovation processes to administrative procedures – every single process is measured against the guiding principle of sustainability.

Even during the preparation of the Board's project, it became clear that many institutes have already successfully implemented some of the individual criteria of the federal government's sustainability strategy, but that this had generally happened through sheer good intentions on the part of individuals rather than through actual planning. Enhancing people's awareness that sustainability must be actively designed and implemented

as a central concept in projects and business processes should make it possible to focus even more sharply on the key objectives.

Another goal is to standardize the institutes' reporting procedures for the topic of sustainability. Part of the Board's project involves pilot institutes submitting sustainability reports in accordance with defined criteria. The results of this new approach are being compiled and will be used to set future standards for drawing up the reports. This will make it easier for the institutes and any other interested parties to draw comparisons on how the different institutes are evolving.

The third part of the project, »Research for Sustainability«, is designed to answer three main questions: What are the key, frontline themes of the future? Which contribution will they make to sustainable development? And for which of the global challenges we face do they offer potential solutions? The results of this part of the project are closely interlinked with the Fraunhofer-Gesellschaft's frontline themes and should be incorporated in the Fraunhofer-Gesellschaft's corporate strategy in tandem with these themes.

Sustainability and the Fraunhofer ISC – a preliminary assessment

Fraunhofer ISC's strengths lie in social cohesion and intergenerational equity. The Institute has maintained high rates of vocational training for a number of years, offering apprenticeships and training courses in its chemistry and physics laboratories, mechanical and electrical workshops, and commercial and administrative departments. Having completed their courses, many of those trained at Fraunhofer ISC are taken on in permanent positions. In the field of research, Fraunhofer ISC offers opportunities for diploma and master theses as well as for PhD projects. We also employ interns and research assistants in order to help familiarize students with the field of applied research from an early stage of their education.

To achieve these goals, the Institute works closely with the Chair of Chemical Technology of Functional Materials at the University of Würzburg and the Chair of Ceramic Materials Engineering at the University of Bayreuth. Yet it is essential to awaken interest in scientific and technical professions from an even earlier stage, which is why Fraunhofer ISC regularly welcomes the classes of schoolchildren and groups of teachers who visit our Institute, as well as continuing to develop special activities for the »Girls' Day« event which it has supported for many years. Although the overall proportion of female staff and students at the Institute is exceptionally high compared to other parts of the Fraunhofer-Gesellschaft at almost 50 percent, the proportion of female managers is still too low, totaling just 15 percent.

Another key issue is the employment of people with disabilities, an area in which the Fraunhofer ISC has long exceeded minimum quotas and maintained figures well above the Fraunhofer-Gesellschaft average. However, one area for which Fraunhofer ISC – and indeed the Fraunhofer-Gesellschaft as a whole – is not yet fully prepared is the upcoming increase in retirement age. The number of staff aged more than 60 has been steadily decreasing. A research-based institution with minimal levels of arduous physical work would be a suitable choice to provide a pioneering role in the employment of older members of staff.

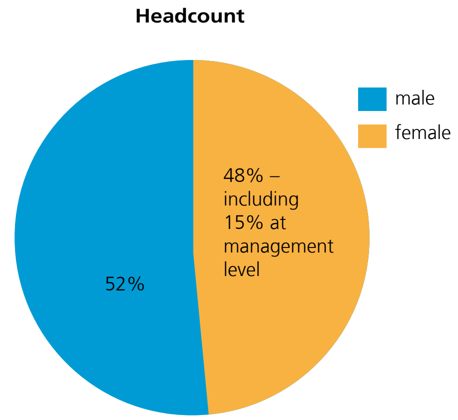
One thing we can take particular pride in is the way in which historical buildings have been preserved and put to good use. Our main building dating from 1892 is linked up to our newer buildings and is still very much a part of our day-to-day operations. This is even more true of our branch office housed in the listed building Bronnbach Abbey, where the former administrative building from the 16th/17th century is used as a research facility. We have also been using a coach house dating from the 19th century as additional workspace since March 2011.

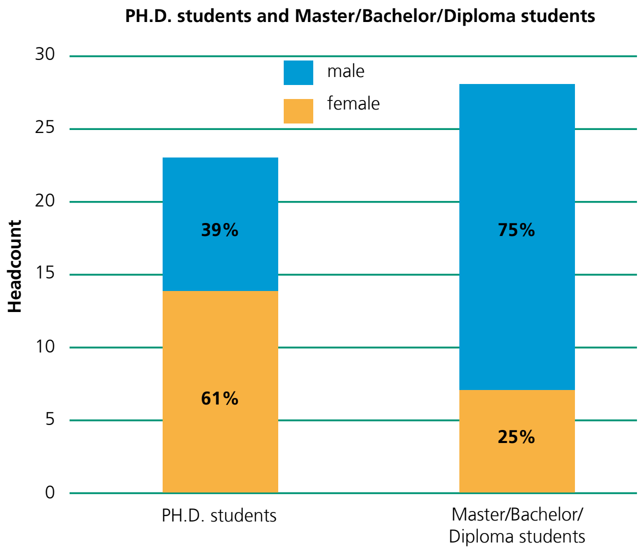
This project will enable us to identify and tackle any weak points or gaps in our procedures and activities. We are convinced that our intensive commitment to the issue of sustainability will not only lead to new perspectives on the challenges we face but also provide us with a whole new toolbox of solutions.

Although the Fraunhofer-Gesellschaft has not yet completed the process of embedding sustainability as a core component of its strategy, Fraunhofer ISC is already running a number of projects that fit within this remit. Our work on fostering resource and energy efficiency in manufacturing processes and substituting dangerous substances under REACH is carried out in both a research and advisory capacity with plenty of support provided throughout the process. We consider this work to be just as important for our own projects as for our customers' and partners' products. Research conservation and product durability are already implicit components of our research work. In the future, we will be placing a particular focus on the availability and substitution of raw materials and on product recyclability and repairability.

The Sustainability Network emerged from an initiative which has been a major focus of the work of Fraunhofer ISC staff member Dr. Johanna Leissner since 2007.

The network was officially established in December 2009, when Prof. Thomas Hirth from Fraunhofer IGB in Stuttgart was unanimously chosen to head up its operations.





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New Technikum III pilot-plant building sets out to attain the seal of approval from the German Sustainable Building Council (DGNB)

Thanks to continuous growth at Fraunhofer ISC in recent years, the Institute is running out of space. Based on the number of people it employs, the Institute is already short of 300 m² of office space alone – and the situation is even more desperate when it comes to laboratories and pilot-plant facilities. The 19th-century building which has been used as a research institute for more than 50 years and parts of which enjoy the protection of listed status, had not seen a complete renovation since the 1950s. This led the Institute to begin drawing up plans for a new laboratory building in 2006, and the foundations were laid in the summer of 2010. Once finished at the end of 2012, it will provide around 2,500 m² of laboratory and pilot-plant space for the various divisions of the Institute to establish and expand new and existing areas of work.

Fraunhofer ISC's research activities are focused on the areas of energy, environment and health, so it also has a particular responsibility to protect the environment and conserve resources. In an effort to ensure that the Institute fulfills its responsibility to society and lives up to the example set by the Fraunhofer-Gesellschaft in the area of sustainability, during the planning phase the decision was made to ensure the new building was given the German Sustainable Building Council's seal of approval. That means the Fraunhofer ISC Technikum III could be one of the first laboratory and pilot-plant buildings to be certified by the German Sustainable Building Council – known by its German abbreviation of DGNB.

The DGNB was founded in 2007 on the initiative of the construction and real estate industry. Its aim was to create a uniform development system for sustainable structures. It awards its seal to buildings which are environmentally friendly and which use resources efficiently. Rather than looking just at the construction phase, it takes into account the entire life cycle of a building – from the planning stage to use of the building and beyond, right through to demolition. The focus is on minimizing the consumption of energy and resources and the building's impact on its local environment.

Sustainability is assessed on the basis of a large number of »fact files« in the six topics of ecological, economical, socio-cultural and technical quality and the quality of the process and site. The total number of points obtained in all areas decides whether the building is given a bronze, silver or gold award by the DGNB. Fraunhofer appointed the Nuremberg-based engineering consultancy firm Sorge to oversee the project.

The DGNB fact files

For the first topic, an ecological assessment is produced in line with the German Institute for Standardization and the total primary energy requirement (renewable/non-renewable) is assessed in accordance with German Energy Conservation Regulations (EnEV). Other factors which are then evaluated include the global warming and the ozone destruction potential. The potential for the formation of ground-level (tropospheric) ozone (POCP) is also calculated and included in the evaluation. Further aspects include the requirement to use only certified European timber from sustainable forests. When it comes to insulation, coatings, adhesives, waterproofing agents and the like, care is taken to ensure that no halogenated materials are used and that only substances are used which are not sensitizing and which do not pose any health risks. All substances used must be accompanied by documentation in the form of product data sheets.

Another topic concerns the sociocultural and functional quality of the building. The focus here is on the effect of the building both on those who use it and on the surrounding community. Consideration of the building's impact on its users takes into account health and wellbeing, as well as the level of comfort in the building. In order to check the indoor air quality, one of the new laboratories will be selected at random upon completion of the building and tested for its air quality. This will include measuring both the temperature and humidity and also tests for possible pollutants. The criteria for the thermal, visual and acoustic comfort of the building will also be assessed at this time. The external effect of the building considers its relationship with the local community. Because public buildings are often built in exposed locations, they attract a great deal of attention among the general public. And since architecture is an important component in a society's identity, buildings serve as examples and so they have a particular responsibility to express and maintain lasting values.

Public acceptance of the new Technikum III building is particularly important to Fraunhofer ISC, and this acceptance was evident even before construction began through the widespread approval of the plans when presented by the Institute, and also later during construction of the shell. The Institute's local ties were also demonstrated through schemes such as having the hoarding decorated by school children from the area and locally known graffiti artists.

Right up until the Technikum III is opened in early 2013, staff at the Institute will be working closely with construction department C3 at Fraunhofer headquarters, with the project planners and with the DGNB-certified auditor to achieve the best possible result in terms of sustainability for people and for the environment.

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HEALTH

TO MARK GERMANY'S YEAR OF SCIENCE 2011 – RESEARCH FOR OUR HEALTH, THE FOLLOWING SECTION OF OUR ANNUAL REPORT FOCUSES ON OUR RESEARCH ACTIVITIES IN HEALTHCARE AND RELATED TOPICS OF CURRENT INTEREST.

FOCUS ON HEALTH

New materials and the technologies to characterize and process them take a major part in today's research for tomorrow's healthcare which should be more effective and of utmost quality. This is not feasible without affordable new or improved methods of diagnosis and therapy or without innovative concepts and approaches in preventive medicine which should be open to all. To support its long-term strategy, the German government has set aside no less than 5.5 billion euros, spread over a period of four years from 2011 to 2014, to fund research into the most common diseases such as cancer, rheumatism, diabetes, osteoporosis, caries, or cardiovascular and neurodegenerative diseases. At a time of growing pressure to reduce costs in national health schemes, this amount reflects the serious concern posed by a life-expectancy which is still on the rise in industrialized countries and which inevitably entails an increase in the diseases typically associated with old age.

In a society where people are increasingly aware of the issues affecting their health, there is a need for a more interdisciplinary approach. Concepts such as wellness, the healthy home, or ambient assisted living – which regard technologies in a social context – or the drive to minimize the presence of toxic substances in the environment and in the food chain, are just some of the many examples of interdisciplinary research topics that have a direct or indirect bearing on personal well-being and health.

Fraunhofer ISC contributes to progress in these areas by developing application-specific solutions based on nonmetallic materials, hybrid polymers, ceramics, and glass. In this context, scientists' growing understanding of the mechanisms that govern interactions between biological systems on the nanoscale provides us with the starting point for the development of materials with entirely novel functions, or sometimes even multiple functions. One area of particular promise is that of biohybrid materials with integrated diagnostic and therapeutic functions.

A major focus of current research and development work concerns materials for use in regenerative medicine, dentistry, and diagnostics. Two typical applications in regenerative medicine are three-dimensional cell scaffold materials made of resorbable fibers for use as wound dressings and freely structurable, triggerable hybrid polymers for use as implant materials. Another related area is that of silicon-based, controllable active materials for use in tissue engineering.

The new materials being developed for applications in dentistry include monomer-free, highly cross-linked hybrid polymers, glass ceramics, and infiltratable hybrid materials. The main focus lies on products for chair-side procedures and dental restoration of changes due to ageing. One group of products that has already met with considerable success on the market is dental fillings based on a particularly hard-wearing ORMOCER® hybrid polymer matrix. These products are constantly being improved in terms of their properties and ease of use through our ongoing collaboration with industrial partners.

A novel bioresorbable wound dressing made of silica gel fibers was approved by the European drug authorities at the end of October 2010 for the treatment of diabetic ulcers and second-degree burns, among other applications. Further significant areas of research involve the use of multifunctional nanoparticles for diagnostic imaging in analysis devices and biological assays or in living organisms, and for drug encapsulation. One of our current projects is devoted to biocompatible particles for in-vivo applications (ORMOBEAD® vivo), which can be detected by many different methods (photoluminescence, CT, NMR) and enable the non-destructive imaging of biological processes.

Fraunhofer ISC's new laboratory building, currently under construction, will provide the business unit Health with 300 m² of laboratory space for the development of new materials, equipped to clean-room and near-GMP standards. These facilities will enable Fraunhofer ISC to conduct research in an industry-compatible environment that permits newly developed products to be scaled up to commercial production levels more rapidly.

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Microcapsules containing an oily liquid

A NOVEL, NON-DESTRUCTIVE ENCAPSULATION TECHNIQUE

Encapsulation techniques are used to enclose solid particles, liquids or gases in a coating that enables liquids to be converted into powder form, volatile substances to be stabilized, reactive components of a compound material to be kept apart, sensitive materials to be protected against environmental factors, and drug ingredients to be released in a controlled manner. The encapsulation of active substances is a topic of growing interest in many industrial sectors, including pharmaceuticals, medicine, cosmetics, food processing, textiles, chemical engineering, agriculture, and environmental protection.

The encapsulation techniques available today are often difficult to implement, only suitable for a limited range of substances, and frequently require major modifications to existing production processes, especially in the case of liquid or semiliquid substances. They also present a high risk of contamination or denaturation of the original substance as the result of prolonged contact with the unreacted coating material, exposure to solvents, or the input of process heat. The thickness of the capsule walls can also be a problem in certain cases. None of the presently available techniques is capable of providing an efficient alternative, for instance through the use of ultrathin, mechanically stable, glass-type coating materials.

The new technique developed by Fraunhofer ISC

Fraunhofer ISC is working on a new technique that involves providing an adaptive development environment capable of meeting customers' requirements for the rapid implementation of encapsulation processes for a wide variety of materials that takes account of their specific properties. The new solution makes use of light-curable encapsulation materials based on inorganic-organic hybrid polymers. The materials in question are pre-crosslinked polymers that can be hardened rapidly within a very short exposure time.

This solution promises a particularly non-destructive and clean method of encapsulation that minimizes temperature gradients, works without the use of solvents, and prevents all contamination or damage by foreign substances, such as the unwanted infiltration of monomers. Hybrid polymers can be both hydrophilic and hydrophobic, and are thus interfacially active. This makes them suitable for use as both polarized and unpolarized components, enabling the process to be utilized in many applications and in connection with a wide range of different substances. For instance, one and the same coating material can be used to encapsulate aqueous suspensions and oily contents, or even sensitive biological components.

Process description

The new encapsulation process is based on the technique of co-extrusion. A concentric nozzle arrangement, consisting of a central nozzle surrounded by an outer ring-shaped nozzle, is used to inject the liquid or paste-form active ingredient directly into the drops of encapsulation material. The drops pass through the rays emitted by a UV light source in free fall and harden in a fraction of a second. The entire encapsulation process, from the time the separate materials enter the nozzle assembly to the time the finished microcapsules are deposited in the collection tray, takes no more than two-tenths of a second.

This simple drip-casting process, in which microcapsules are formed and released from the nozzle one by one under the effect of gravity, was subsequently enhanced by applying the principle of vibration-induced laminar flow breakup, also


Volume of microcapsules produced in 1 minute

known as the Brace process. This involves superimposing a vibration on the flow of core and shell material emerging from the nozzle, which causes the formation of equidistant pinch zones which then break to form microcapsules. The result of increasing the throughput by several orders of magnitude, comparable to the difference between a dripping faucet and a continuous laminar flow, is an efficient, cost-effective process. The enhanced process has a flow rate of approximately three liters of material through each nozzle per hour, transforming it into symmetrical microcapsules with a diameter of 1.8 mm. The size of the microcapsules and the thickness of their shell can be precisely set, independently of one another, by selecting the appropriate nozzle geometry and material flow rates. This process is capable of producing microcapsules with a diameter ranging from approximately 0.2 to 5 mm, and a shell wall thickness of between approximately 0.05 and 1 mm.

Current status

Most of the work done so far relates to process design. The different stages of the process – microcapsule formation, laminar flow breakup, and UV hardening – were studied on the basis of a model hybrid polymer formulation of a multi-acrylate-silane compound. These reference data were used to design and build a plant capable of producing test samples on a liter scale.

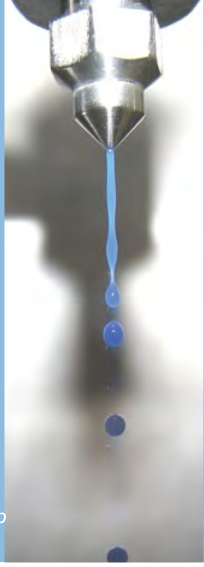
It was proven in demonstrations that the plant is able to correctly form microcapsules with diameters ranging from 0.6 to 5 mm. As expected, both aqueous and oily compounds can be encapsulated using the same hybrid-polymer system. Examples of substances that have been successfully processed include aqueous dye solutions, salt-hydrate phase change materials (PCMs), particle suspensions, essential oils, and a sunscreen product of a paste-like consistency.

The encapsulation process is currently being tested on reactive monomers for two-component adhesives. This work is being conducted in collaboration with the chemicals and consulting firm ratiochem GmbH as part of a research project funded by the German Federal Ministry of Economics and Technology (BMWi).

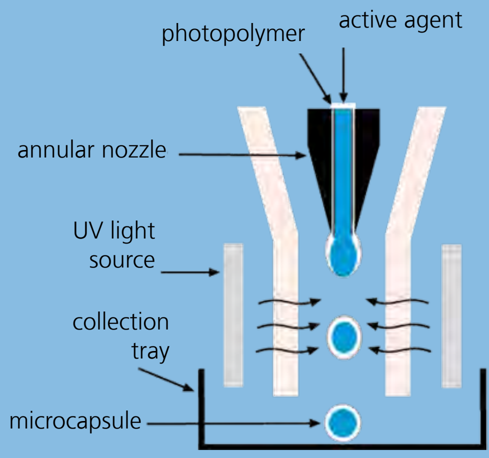
A broad portfolio of different shell materials

Now that the fundamental features of the process have been defined, attention is turned to property modulation of the shell material, to meet the diverse requirements of different applications. The first of these concerns microcapsules in which the shell provides a barrier function, e. g. impermeability to water vapor, oxygen, or aromatic compounds: a function commonly associated with hybrid polymers. A second application concerns semipermeable membranes for the encapsulation of absorber materials or biologically active substances. The third area is controlled-release microcapsules, an application of special interest to manufacturers of pharmaceuticals, medical devices, and cosmetics. Other applications include the encapsulation of reactive agents such as those used to initiate regenerative processes or balance the pressure in micro-reactors. Screening studies for specific applications are in preparation.

Through this experimental work, a broad portfolio of shell materials will be built up to provide a wide variety of encapsulation solutions that can be rapidly adapted to individual user’s requirements.



Laminar flow breakup



Schematic of the production process

Process characteristics

Microcapsule geometry

Diameter:	0.2 – 5 mm
Shell thickness:	0.05 – 1 mm

Materials

Shell material:	Hybrid polymers, photopolymers (acrylate, methacrylate)
Core material:	liquid, paste aqueous, oily

Capsule output rate per nozzle (laboratory plant)

Diameter 2 mm:	approx. 60 ml/min or 15,000 capsules/min
Diameter 1 mm:	approx. 15 ml/min or 30,000 capsules/min

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Milling a fully anatomical crown

DEVELOPING MATERIALS TO PROMOTE AFFORDABLE DENTISTRY

Requirements in the field of dental care

Back in 2006, the WHO Global Oral Health Programme already underlined the importance of oral and dental health to an individual's overall health and quality of life, stressing the need to raise public awareness of this issue. However, tighter budgets on the part of health insurance funds and the soaring cost of dental treatment have fed through into enormous cost pressure. In the tooth replacement segment alone, spending by insurers rose from 5.7 billion euros in 2007 to over 6.2 billion euros in 2009, as noted in the government's healthcare statistics.

The key trends at the leading dental trade fair IDS in Cologne reflect this need:

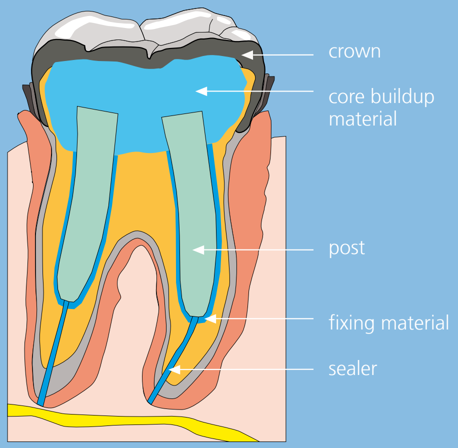
- Natural teeth are retained as long as possible using early, extensive diagnostics and minimally invasive treatment methods.
- Whenever a tooth replacement is necessary, it should look as natural as possible and offer optimum esthetics and functionality.
- Digitization and networking of dentist's office and laboratory increase efficiency in a bid to reduce the cost of producing replacement teeth.

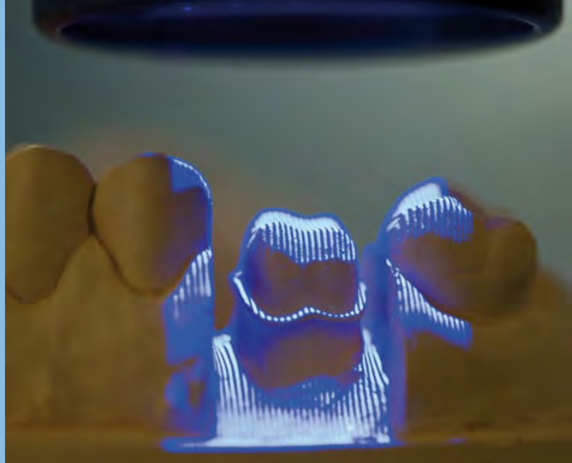
This development gives rise to major demand for inexpensive, easy-to-apply yet nonetheless high-quality solutions for both tooth-conserving and prosthetic treatment. In this context, esthetic factors also need to be taken into account along with functionality, durability and physiological compatibility in order to meet the requirements of dentists, dental technicians and, most importantly, patients.

With development focused on various forms of dental treatment and methods of application, Fraunhofer ISC has extensive experience in this sector. In particular, the dental filling materials based on hybrid-polymer composites (ORMOCER®s) have been on the market for many years and have been constantly improved. One such ORMOCER®-based product range is Admira®, which was developed in collaboration with VOCO GmbH, Cuxhaven. It includes a filling composite together with a tailored bonding agent, a flowable restorative for minimally invasive dental work and for filling cavities with undercuts (e. g. for core buildup), a desensitizer for exposed cervical areas and – as a preventive treatment – a fissure sealant. The Ceram•x™ filling composite marketed by Dentsply has also been very successful for many years. Such research has enabled Fraunhofer ISC to build up an impressive store of expertise in dental issues and generate appropriate solutions based on its knowledge of materials science.

Material base ORMOCER®s – Diversity thanks to multifunctional precursors

In tune with market needs, research and development work at Fraunhofer ISC focuses on the field of (bio-/active) functionalized materials for tooth conservation – including restoration, prophylaxis/prevention and regeneration – as well as for tooth replacement. Core competences include the synthesis/development of multifunctional precursors through to materials tailored to specific applications, such as resin systems without the use of dental monomers, (nanohybrid) composites and glass-ionomer cements. Such solutions form an excellent basis for direct and indirect restoration using fillings, core buildup and sealants or crowns, inlays, onlays and prosthetics. Tailor-made self- or total-etch adhesives provide a force-fit joint between tooth tissue and restoration material. These developments are accompanied by comprehensive and specialized application-specific (bio-)chemical/physical characterization.





Scan process for a plaster casting (inset: prepared tooth core)

The techniques are being continually modified to take account of new insights and customer specifications. The following are just some of the techniques used:

- Chemical analysis ↔ (Solid) multicore NMR, IR, (micro-) Raman, XRD, ICP, GC, etc.
- Rheology/flow behavior ↔ Rheometer
- Hardening/polymerization development/conversion ↔ (Micro-) Raman, (photo)DSC, IR, in-situ temperature measurement
- (In-situ) shrinkage ↔ Laser/ buoyancy method
- Coefficient of thermal expansion ↔ Dilatometer
- Mechanical materials testing ↔ (Fracture/compressive/ tensile strength, elasticity modulus, fracture toughness, elongation) ↔ DMA, universal testing machine
- Surface analysis and mechanics ↔ ACTA abrasion, Vickers hardness, SEM, TEM, AFM, roughness measurement
- Interfacial analysis and mechanics re. tooth tissue and model systems (sheer strength) ↔ (Micro-) tensile test, sheer test
- Etching and wetting behavior ↔ Micro-Raman
- Water absorption/solubility ↔ Gravimetry
- Esthetics ↔ Color/scattered light measurement
- Filler/particle characterization ↔ DLS, Fraunhofer diffraction, SEM, TEM.

Materials for restoring endodontically treated teeth

Root canal treatment, also known as endodontic therapy, can preserve teeth long term whose pulp is diseased or even already dead. Badly damaged teeth with major substance loss occasionally have to be completely rebuilt. Conventional treatment concepts for restoration use a host of different materials, which are not always compatible with one another or with tooth dentin. Inappropriate degrees of hardness and elasticity are cited as the cause of root fractures, post fractures and the premature reduced retention of posts and cores – the failure rate is accordingly high. That failure rate could be reduced dramatically by utilizing materials whose properties can be precisely matched to one another. Together with industry partner VOCO GmbH, based in Cuxhaven, Fraunhofer ISC has developed an innovative, purpose-designed materials concept based on a chemically homogenous material class. By developing and utilizing differently functionalized precursor silanes and modified condensation parameters, monomer-free resin systems with high levels of biocompatibility were created, which cover a large viscosity range (1.4 to 39 Pa·s at 25 °C) and a wide elasticity modulus range (0.05 to 2.35 GPa). Compared with conventional monomer-based matrix systems, very low hardening shrinkage of just 4.0 to 5.8 % by volume was achieved. In combination with agglomerate-free, functionalized nanoparticles, restoration materials with extremely low hardening shrinkage of just 1.3 % by volume and a very high flexural strength of up to 155 MPa can be produced. Adhesion, elasticity characteristics and the thermal expansion coefficient of the hybrid endodontic materials can be adjusted in such a way that reliable bonding is achieved in the different dentin areas of the tooth.

All-in-one adhesive: Easy-to-apply material solution for dentistry with long-term stability

In conjunction with composite technology, adhesive technology constitutes another research focus. Polymerizable organic compounds containing acid groups are important components for medical products, enabling the required materials properties to be achieved such as wetting, etching effect, complexation and thus the adhesive effect on biological interfacial surfaces, such as bonding to the tooth dentin. Today, self-etch dental adhesives are made out of conventional monomer compounds, which, however, often still present significant shortcomings. One notable problem tends to be the reduced storage stability due to susceptibility to hydrolysis. By the time these materials are applied, the expected life of the composite may therefore already be shortened. Furthermore, released breakdown products and non-crosslinked monomers can impair compatibility. The innovative ORMOCER®-based adhesive systems, which are still in the development/testing phase, should help eliminate the

Scanning a plaster casting for virtual modeling of a tooth crown

	MATRIX SYSTEMS	COMPOSITES / GLASS-IONOMER CEMENTS
Viscosity (at 25 °C)	2.0 – 250 Pa·s	adjustable
Shrinkage	2 – 8 % by volume	adjustable
Bending elasticity modulus	1 – 4000 MPa	up to 17 GPa
Flexural strength	up to 130 MPa	up to 180 MPa
Compressive strength	up to 300 MPa	up to 500 MPa
Coefficient of thermal expansion	≈ 50 – 250·$10^{-6}K^{-1}$	≥ 20·$10^{-6}K^{-1}$

	ELASTIC SYSTEMS
Tensile elasticity modulus	1 – 550 MPa
Bending elasticity modulus	5 – 2,100 MPa
Elastic elongation	8 – 130 %

use of conventional monomers. In addition, the incorporation of acid groups promises to increase the etching effect (and thus adhesion) while making the product easier to apply. As a result, the dreaded margin gap formation between the dental work and the dentin along with the associated secondary caries can be substantially reduced.

Material base ORMOCER®s – property profiles adapted to the indicated treatment

The material properties of inorganic-organic hybrid polymers from the materials class of ORMOCER®s can be controlled very precisely, due to the many opportunities for functionalization present at different stages of the synthesis route, from precursor through to the final material. Consequently they offer an excellent basis for developing property profiles adapted to the indicated treatment – they can be hydrophilic or hydrophobic, can be of thin consistency or structurally viscous so they can simply be applied in various applications, they can be hard or flexible after slow or rapid hardening. The integration of functionally structured hybrid or classic particle systems further enhances the properties, giving rise to high-quality, biocompatible (nano-)hybrid composites. The teams working on these development projects are equipped with a wide variety of manufacturing and processing techniques:

- Silane/resin/matrix synthesis incl. scale-up ↔ Reactors with capacities of up to 60 l
- Particle synthesis and functionalization ↔ Spray drying, precipitation and emulsion techniques
- Filler incorporation/composite manufacturing ↔ SpeedMixer, three roll mill, planetary mixer
- Application-adapted hardening techniques ↔ Photo-, thermal-, redox-induced polymerization/polyaddition
- Processing technology ↔ Dental CAD/CAM-based milling unit

Inexpensive, high-quality tooth replacement

Another major application relates to the use of materials for indirect restoration. These include prosthetic solutions such as full and partial prostheses with fully anatomical artificial teeth as well as the area of crown technology. The ORMOCER®-based composite technology offers an outstanding material base for crowns, inlays, onlays, and veneers, etc. To further develop innovative composites, the aforementioned tooth replacement material requires a high level of strength, good biocompatibilty and must be adapted to the natural tooth esthetics.

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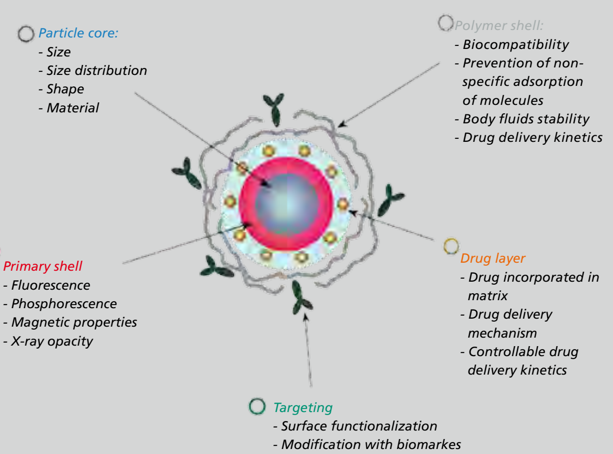
ORMOBEAD® – A NEW GENERATION OF PARTICLE SYSTEMS

Given the rising cost of providing healthcare services coupled with the increasing average age of the population, modern medical practice needs to focus its attention on preventive diagnostics, reliable techniques for the monitoring of disease progression and responses to treatment, and efficient therapies. In order to develop solutions to these requirements, there is an imperative need for intelligent low-cost material alternatives. For high-sensitivity in-vivo and in-vitro diagnostic and therapeutic applications, the business unit Health of Fraunhofer ISC has come up with a novel concept for the design of customized particle systems, which bears the name ORMOBEAD®[1].

ORMOBEAD® stands for a new generation of multifunctional particle systems and for an all-round concept that is based on variable structural units and therefore able to provide solutions for even the most complex requirements profiles. The modular structure of the core/shell-type ORMOBEAD® particle systems offers a maximum of flexibility with regard to size, materials, effective targeting, and the type of medical imaging technique. The resulting ORMOBEAD®s can bind to biomarkers or deliver drugs and they are visible to different types of imaging systems. They can be used in vivo and in vitro.

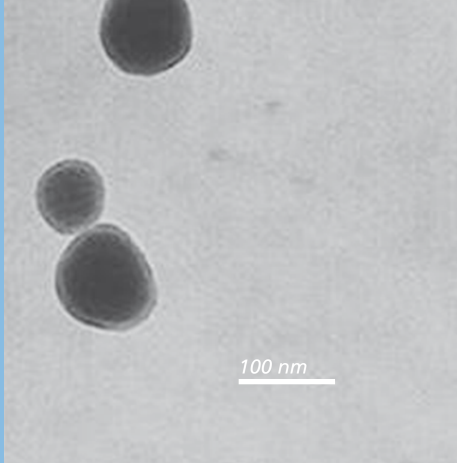
The core and shell materials can be designed separately to meet the requirements of specific applications and then later be combined in particles with a multilayered »onion-skin« structure. The particle core, in the center, defines the shape of the particle and can be used to control its ultimate size and the particle size distribution. Other properties of relevance to the application, such as density or magnetic properties, can also be controlled through the choice of a suitable core material. The next layer is the primary shell, which surrounds the core and defines further characteristics such as fluorescence, phosphorescence or X-ray opacity. Depending on the requirements profile, either an inorganic material with an amorphous or crystalline structure or a hybrid material is generally utilized to form this shell. Another layer can be added on the outside of the primary shell, incorporating drugs or serving as a drug delivery mechanism. Finally, the entire structure is enveloped in an outer polymer shell that serves to control the drug delivery kinetics and the stability of the active drug ingredients in various environments. To enable the ORMOBEAD® to bind to or detect the presence of specific pathogenic biomarkers, the surface of the particle is additionally functionalized with reactive agents and modified with biomolecular targets such as antibodies. In each case, the particle's structure is designed on the basis of the characteristics required for a specific application.

ORMOBEAD® concept for the fabrication of customized multifunctional nanoparticles.

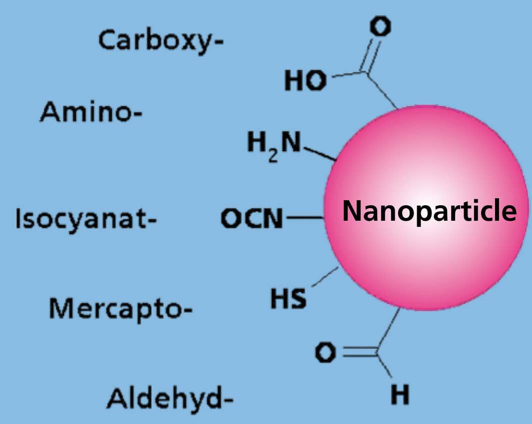


1 *ORMOBEAD® : Registered trademark of the Fraunhofer-Gesellschaft für Angewandte Forschung e. V.*

Luminescent SiO_2/calcium-phosphate: Eu^{3+}-doped core/shell particles seen under UV light



SEM image of nanoparticle with SiO_2 core and calcium-phosphate shell doped with Eu^{3+}



Schematic drawing of surface functionalities for the binding of biomolecules to the particle surface

The ORMOBEAD® vivo nanoparticle development project has revealed the huge potential of multifunctional nanoparticles as a diagnostic tool.

ORMOBEAD® vivo

These luminescent nanoparticles have considerably evolved since they were first created as a biocompatible alternative to semiconductor nanoparticles containing cadmium or mercury, commonly known as quantum dots or Q-dots. ORMOBEAD® vivo nanoparticles consist of an amorphous SiO_2 core and a crystalline, luminescent calcium-phosphate shell.

The core is formed by spherical SiO_2 particles manufactured using a variant of the Stöber process. Their diameter ranges from 20 nm to 800 nm and they exhibit a very narrow size distribution, creating an almost monodispersed system. These core particles then undergo a sol-gel process in which they are coated with precursor compounds which, after subsequent heat treatment, lead to the formation of a crystalline calcium-phosphate shell. The size of the particles is determined by the size of the core and the thickness of the outer shell. The desired crystallinity and phase composition of the inorganic calcium-phosphate shell is obtained by regulating the parameters of the synthesis process, such as pH value, educt ratio, and temperature.

Calcium phosphate offers many advantages as a shell material for multifunctional nanoparticle systems destined for use in medical diagnostics and therapy. It exhibits a high degree of biocompatibility, is relatively cheap to produce, and lends itself to doping with different types of ions. Its luminescent properties can be fine-tuned through targeted selection of the implanted ions.

In the first generation of ORMOBEAD® vivo products, lanthanoid ions (Eu^{3+}, Tb^{3+}, Sm^{3+} and Dy^{3+}) provide the required luminescent properties of the calcium-phosphate shell. The desired emission wavelength is obtained as a function of the position of the ions in the calcium-phosphate matrix and the intensity of the luminescence can be varied as a function of the doping level.

Tests to determine the non-specific toxic action of particles with a SiO_2 core and a calcium-phosphate shell doped with Eu^{3+} ions have been conducted by Fraunhofer IME in connection with a number of different cell lines. Initial toxicity tests on calcium-phosphate-coated nanoparticles have shown that their biocompatibility is 100 – 200 times greater than that of commercially available luminescent semiconductor particles (Q-dots). No degradation of cell viability was observed in viability tests at different concentrations, except at levels far in excess of the concentrations typically employed in in-vitro studies involving marker experiments, and hence of negligible interest to practical applications (see Fig. 4).

Extensive experimental studies on the primary functionalization of the particle surface were conducted with a view to the use of ORMOBEAD® vivo nanoparticles as biomarkers. The particle surface was modified with different reactive agents, including carboxyl and amino groups, to test the nanoparticle's ability to bind with specific regions of the biomolecule. The surface functionality can be set as a function of the desired application and the structure of the biomolecule, making use of established methods such as silanization or particle functionalization that take advantage of the high affinity of Ca^{2+} ions to phosphates and carboxylates. A variety of different characterization methods are used to control the surface configuration, including zeta-potential analysis, infrared spectroscopy, and titration. The diagram above shows the principal range of possible surface functionalities available for the binding of antibodies and other biomolecules.

Dispersion of luminescent particles with SiO_2 core and calcium-phosphate shell doped with Eu^{3+}, seen under UV light

Luminescent, inorganic core-shell nanoparticles in powder form, seen under UV light

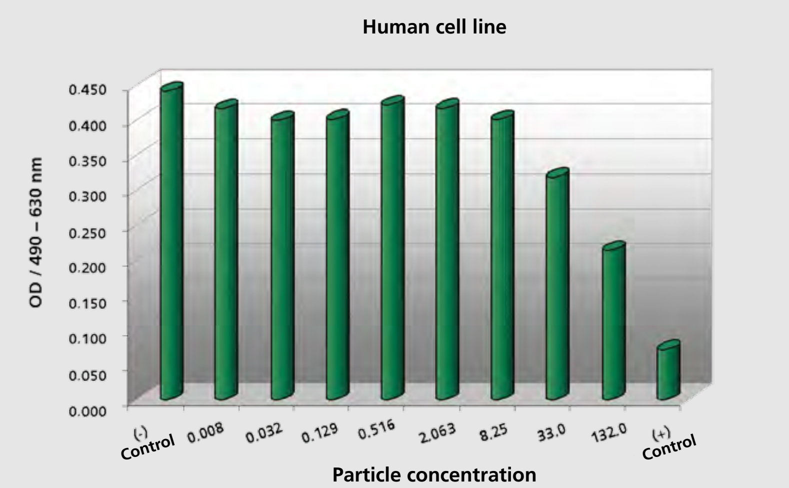
The next stage

The research projects of the past few years have established the groundwork for the future synthesis of multifunctional, biocompatible nanoparticles. The initial idea of developing a novel platform technology for the design of customized, particle-based materials was successfully implemented.
This fundamental experimental work will now enable to transfer real-life, intelligent nanoparticle systems for biomedical applications in the fields of in-vivo and in-vitro diagnostics and therapy applications, and in personalized medicine.

The next focus of the research work will now concern multimodal particle systems and their use in connection with different, multiple diagnostic methods.

Summary of particle properties

- Particle diameter ranging from 20 to 800 nm
- Narrow particle size distribution
- High intensity of luminescence
- High photostability of luminescent particle systems
- Ability to select and combine suitable particle components
- Application-specific surface functionalization
- Biomodification
- Redispersible particle powders



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True size replica of ossicles

THREE-DIMENSIONAL SCAFFOLD MATERIALS

The term »regenerative medicine« is used to describe an emerging field of medicine that opens up considerable scope for new therapeutic options by harnessing the human body's natural ability to heal itself. One of the subdisciplines in this field is tissue engineering, which is based on the judicious combination of high-tech materials and biological cell culture.

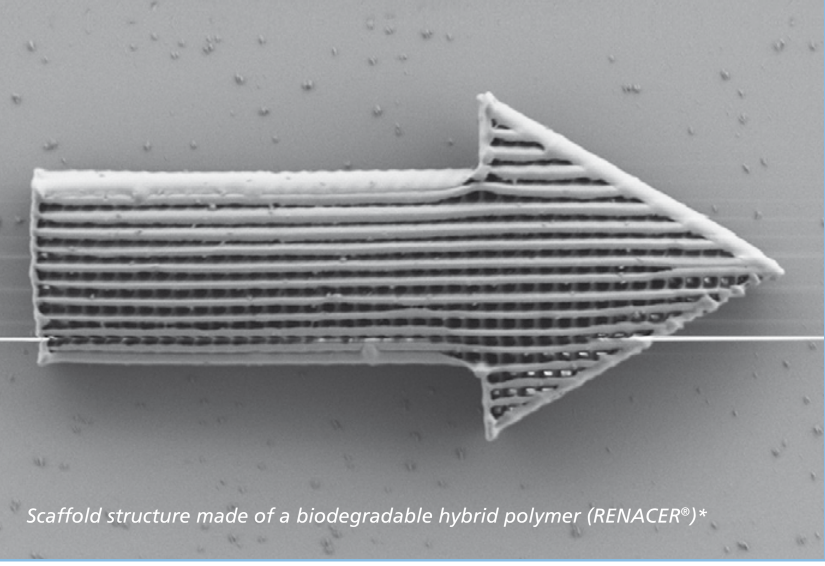
All degradable, synthetic implant materials available up to now have proven to have serious disadvantages in clinical use. Their degradation products lead to a significant local reduction in pH, thereby provoking an inflammatory response. Moreover, it is technically very difficult, and sometimes impossible, to form these materials into the desired reproducible shape, and achieve the necessary shape stability. In order to overcome these drawbacks, an intensive research effort is underway to seek out alternative materials and suitable manufacturing processes that will have the added benefit of improving the compatibility of implants with the patient's own body tissues. The greatest challenge is to design a product that is 100% biocompatible, allows the rate of biodegradation to be controlled to suit the circumstances, and offers the maximum of three-dimensional formability.

Three-dimensional scaffolds are used by cells in in-vitro cultures as a supporting framework for the construction of new tissue. Factors that favor cell population include a customizable three-dimensional structure with interconnecting pores that will assure the even distribution of nutrients and enable the cells to grow into a stable configuration that mimics the structure of natural tissue. Targeted surface functionalization of the scaffold material will enable the cells to adhere more efficiently. The replacement tissue grown in the laboratory is then reimplanted in the patient's body. The availability of modifiable scaffolds for tissue engineering thus plays a major role in the regeneration of tissue and organs and the restoration of their functions in the body.

Pushing material properties beyond the limit

The further development of existing materials science techniques will contribute to the design of new (hybrid) materials with properties that go beyond the limits of present-day materials. The next challenge is to develop materials that not only meet the requirements for biocompatibility and programmed degradability, in other words materials that break down at a rate adapted to their physiological environment, but can also be structured in three dimensions. The answer lies in a technique based on two-photon absorption (TPA), which involves the use of ultra-short-pulse lasers. The interesting aspect of laser-induced two-photon absorption is that it is a scalable technology. Whereas it has been used up to now on a laboratory scale to produce 3-D structural elements with a diameter in the order of a few 100 µm and feature dimensions of around 100 nm, researchers at Fraunhofer ISC have succeeded in developing the technique to the point where it is capable of producing 3-D structures as large as one centimeter.

But before TPA technology can be used to fabricate larger 3-D structures for applications in tissue engineering, certain challenges still remain to be resolved, to which nobody in the world has yet found an answer. Firstly, a suitable exposure strategy needs to be developed that will enable structures of the desired size to be produced. Secondly, the time it takes to fabricate such structures must be significantly reduced – a complicated task given that the chemical, process-engineering and mathematical aspects are interrelated and mutually dependent. In an initial step, therefore, materials commonly employed in microsystems engineering were used to investigate the suitability of TPA technology and to adapt the processes by varying the exposure parameters (including writing speed, average laser output). Scaffolds with a wide range of different initiator combinations were produced and a comparative evaluation of the resulting structures was carried out.



*Scaffold structure made of a biodegradable hybrid polymer (RENACER®)**

True size ossicles made of ORMOCER®

The data arising from this experimental work were furthermore entered in a database of structural parameters that serves as a reference source for the manufacture of new biodegradable materials developed at Fraunhofer ISC. The scaffolds were used to test the reaction of different materials to the selected level of input energy and to determine suitable process windows. These vary because each material requires a different dose of photons – calculated as the product of the exposure time t and the square of the laser output P – to initiate the polymerization process. The chemical reaction volume, which varies as a function of material-specific parameters such as density and viscosity, also affects the quality of the structure. To facilitate cell colonization and enhance cell polymerization, highly porous scaffolds with variable pore structures were fabricated with reproducible results.

To obtain scaffold materials that can be structured using TPA technology, biocompatible and potentially biodegradable molecules with photochemically active functional groups were synthesized. The selection criteria for the functional groups were that they should exhibit high reaction kinetics during organic polymerization and that no toxic substances should be used during synthesis. A number of potential candidate materials were developed for the application at hand and then tested to determine their actual photochemical reaction kinetics, degradability in a physiological environment, and suitability for TPA processing.

With a defined quantity of added photoinitiators, these materials exhibit a short polymerization reaction time after exposure to light, and a high throughput is obtained. Structures were generated according to the TPA process using the materials both in their pure form and in compound formulations containing a defined proportion of selected inorganic-organic hybrid polymers (ORMOCER®s)*, whose material profiles can be precisely defined. Tests performed using different material formulations revealed that both components of these compounds take part in the reaction. However, the available measuring equipment does not allow any information to be obtained on the homogeneity of the composition of the resulting (hybrid) polymer. Initial degradation tests were conducted on rod-shaped samples of different material compositions, which were stored in 1.5-ml containers filled with a phosphate-buffered saline (PBS) solution at a temperature of 37 °C and weighed at predefined intervals to determine the rate of loss. Initial cell colonization tests were conducted on pellets of the (hybrid) material prepared to formulations containing various photoinitiators and colonized with L929 mouse fibroblast cells. These revealed that while none of the photoinitiators has a negative impact on cell colonization, they do affect the rate of colonization.

A material of the future

The adopted technological approach offers significant advantages compared with other methods applied in tissue engineering, including the fabrication of porous structures from a mixture of polymer solutions by means of spray techniques, the fabrication of woven scaffolds made of biodegradable polymer fibers, and 3-D inkjet printing. These advantages result from the unique combination of materials tailored to the specific application and the corresponding process in a single, integrated technology. It permits the manufacture of any type of three-dimensional, shape-stable scaffold with a controllable pore structure composed of interconnecting pores in a biodegradable material. The wide choice of materials and process parameters provides greater control over the pore structure (geometry, size, porosity) and degradation rate than that offered by other approaches based on specific combinations of materials and processes.

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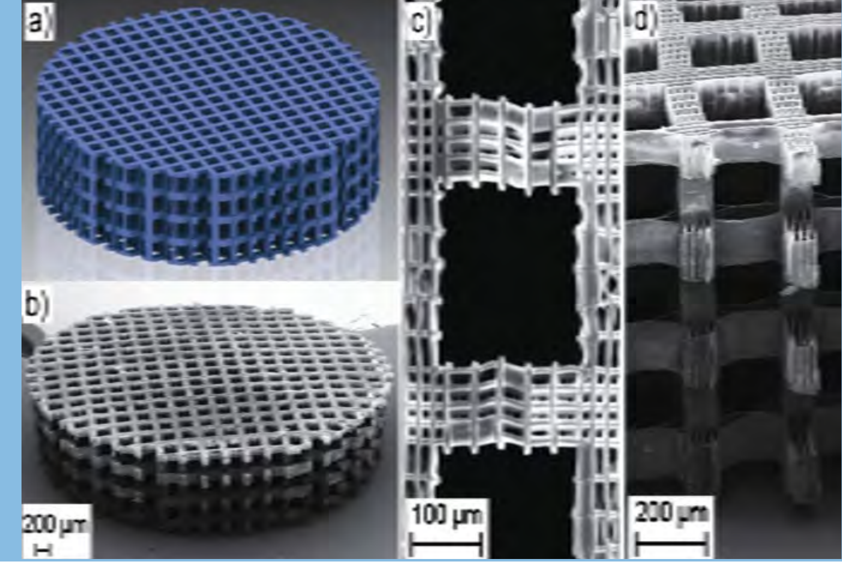
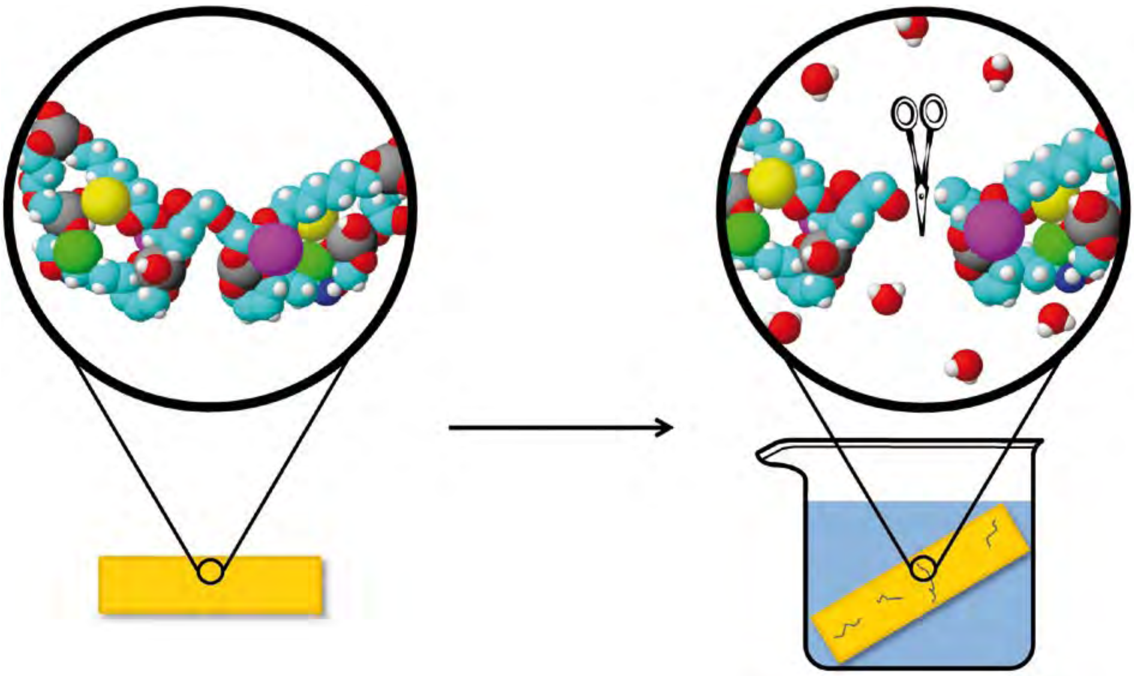


(a) Scaffold design;
(b-d) SEM images of a scaffold made of ORMOCER®



The majority of plants and systems developed up to now were designed to generate microstructures with a very high degree of resolution. They employ write speeds that limit the rapidity at which the structures are laid down to a rate in the order of 10^{-4} to 10^{-3} mm^3/h. Already in the early stages of this project, it was possible to achieve a build-up rate of approximately 10 mm^3/h merely by optimizing the process parameters. In the next stage the focus will be on the specific requirements of scaffolds for tissue engineering applications and the optimization of the technology as a whole. The solution offers an unprecedented opportunity to adapt the chemistry of biodegradable materials to a clearly defined profile of requirements and to combine these two aspects in a single process capable of generating structures of any shape. The ultimate aim is to provide a basic technology for the industrial-scale manufacturing of customized implants.

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MATERIALS FOR THE HEALTHY HOME

People today place great value on a healthy indoor environment. The choice of materials used in home construction and furnishing can significantly influence well-being. One of the most important criteria is that such materials should not be in any way harmful to the occupants. Going beyond this passive approach to health protection, various research projects are also under way to actively improve comfort and well-being through the use of special materials. Fraunhofer ISC is developing new materials to provide solutions of both types: active and passive.

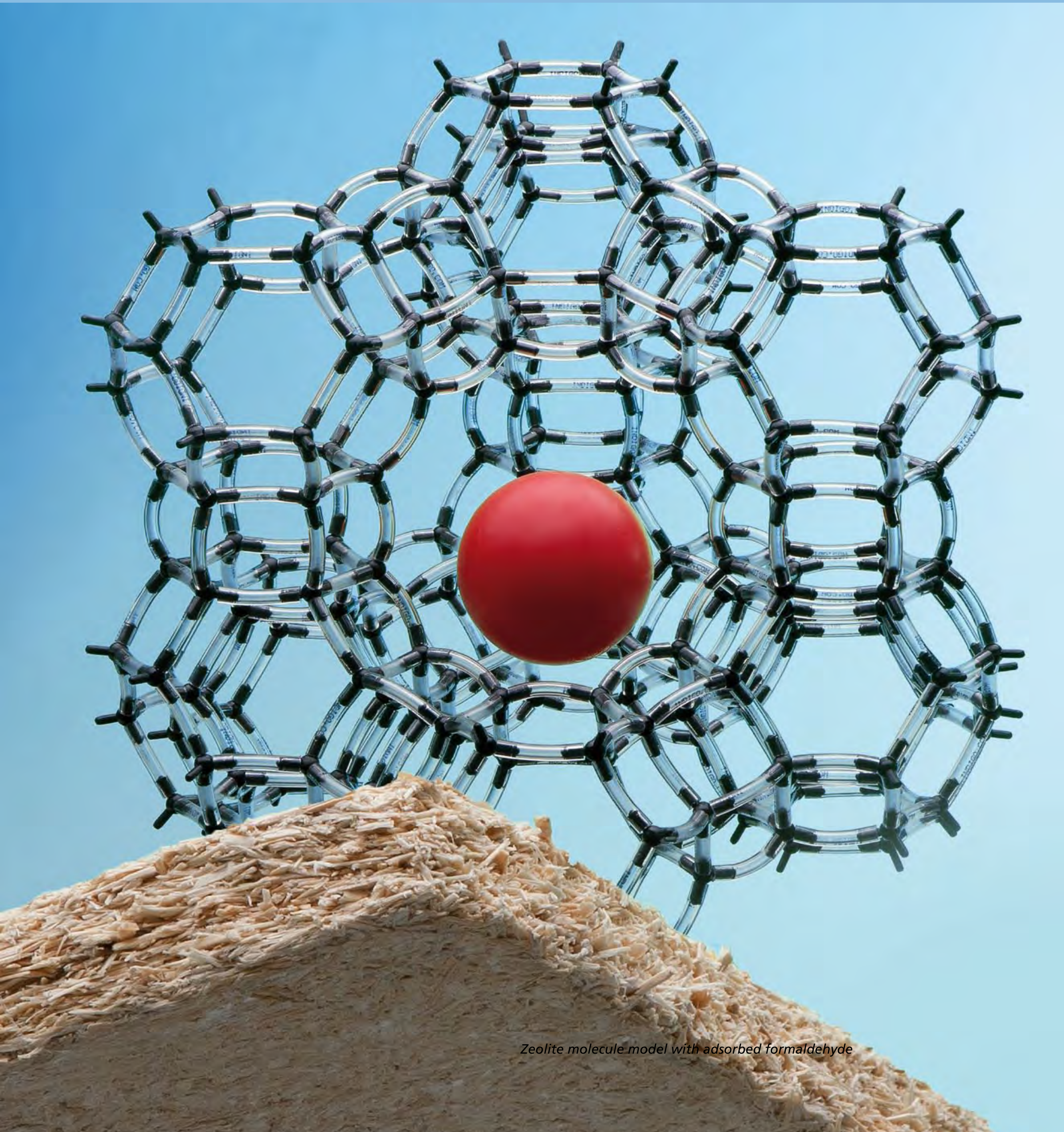
For example, one way of reducing indoor pollution involves incorporating photocatalytic agents in interior surfaces, or using nanoporous adsorbers capable of capturing or even breaking down volatile toxic substances emitted by furnishings. Indoor humidity levels can be automatically regulated by nanoporous additives that enable walls to adsorb water vapor during the day and release it when the temperature drops at night. Fraunhofer ISC is investigating the use of nanoporous glass flakes as a filler material for paints and plaster as part of a publicly funded research project. Systems to regulate the indoor environment require monitoring devices capable of measuring not only temperature but also CO_2 levels and humidity. Such sensors must be capable of operating without any external source of energy. Fraunhofer ISC is collaborating with industrial partners and the Munich-based Fraunhofer IZM in an EU-funded project to develop a high-scale-integrated, energy-autonomous sensor solution based on thin-film technology. Fraunhofer ISC is tasked with designing the CO_2-detector films.

Building materials are just one aspect of health-oriented home design. It is a recognized fact that natural and artificial lighting conditions have a major impact on people's alertness and performance levels. Through the use of special glazing products designed to filter light at defined wavelengths, it is possible to increase melatonin production, which has the known effect of increasing attention span and alleviating the symptoms of seasonal affective disorder (SAD). Researchers at Fraunhofer ISC have developed window glazing that exhibit a transmittivity which replicates the spectral curve of natural light controlling the human sleep-wake-cycle. This »feel-good« glass exhibits a particularly high transmissivity at wavelengths around 460 nm, which boosts melatonin synthesis and so contributes to a feeling of well-being.

Window glass that promotes well-being

It used to be thought that the human eye was a purely visual organ. This long-held belief was overthrown thirty-five years ago when researchers first discovered the existence of the retinohypothalamic tract (RHT), a direct neural pathway linking the retina and the hypothalamus. In the retina, this pathway terminates in the non-image-forming (NIF) receptors which have a spectral sensitivity in the range between 380 and 580 nm. These receptors forward light/dark signals over the RHT to the suprachiasmatic nuclei (SCNs) situated directly above the optic chiasm. The SCNs are the anatomical seat of the body's biological clock or circadian rhythms. The signals they receive control numerous vegetative and hormonal functions in the human body, including those responsible for regulating melatonin levels, which in turn control the sleep-wake cycle.

If the intensity of the light falling on the NIF receptors in the corresponding wavelength range is too low, melatonin secretion can be inhibited, which in turn may have a negative effect on mental and emotional well-being. Possible consequences of a lack of melatonin include insomnia, depression and other mental health disorders.



Zeolite molecule model with adsorbed formaldehyde

The formaldehyde adsorption is measured at the Fraunhofer WKI (© Fraunhofer WKI)

This correlation is particularly noticeable in studies investigating the phenomenon of seasonal affective disorder (SAD), which occurs during the winter months when natural lighting levels are low. According to statistics published by the North Rhine-Westphalian Ministry of Labour, Health and Social Affairs, 27% of all notified cases of incapacity to work are due to mental health disorders, many of which can be attributed to disturbance of the mechanism that regulates melatonin production.

Development of special glass with optimized transmission properties

Up to now, the design of anti-reflective structural glasses has focused exclusively on optimizing performance in the area of the spectrum that matches the maximum sensitivity of the human retina (approx. 555 nm in natural lighting conditions). This is almost identical to the peak emission wavelength of sunlight. The main applications for this type of glass are shop windows, glazed façades, lobbies and entrance halls, panoramic viewing platforms, and solar panel glass. Examples of products for this market include AMIRAN® anti-reflective glass from Schott and CENTROSOL microstructured solar glasses from Centrosolar.

But none of these products takes into account the effects of exposure to optical radiation on the human organism, and more particularly light-induced melatonin suppression, a process that entrains (synchronizes) the human body's circadian rhythm (from Latin circa dies, meaning approximately one day) to a 24-hour cycle and sets the inner biological clock. Anything that disrupts this cycle can have an adverse effect on many different physiological functions. Studies by Brainard and Thapan reveal that the action spectrum for melatonin suppression is shifted more toward the short-wavelength region of the visible spectrum compared with the spectral intensity curve for day vision. This indicates that the blue light region has a greater effect on melatonin suppression, reaching maximum effectiveness at a wavelength of around 460 nm.

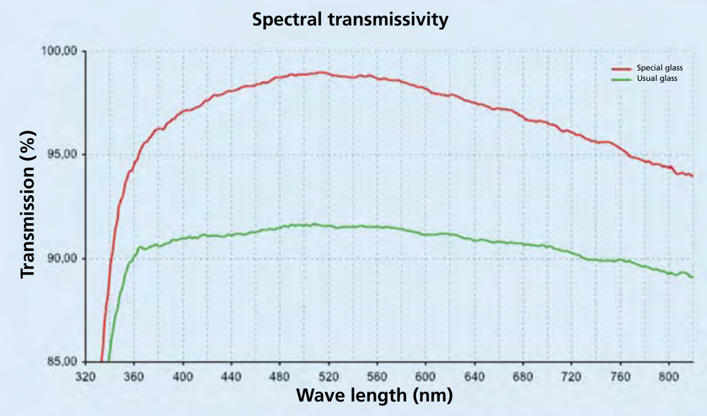
The ideal solution for window glazing would therefore be to coat the glass with materials that provide peak transmissivity in the 450 nm – 550 nm region. In this way, a glass is obtained that combines two objectives simultaneously: an almost invisible anti-reflective glass that also allows the maximum of light to pass at the wavelengths in the action spectrum responsible for circadian regulation.

The researchers at Fraunhofer ISC have developed glasses with precisely these properties. Their transparency is adapted to the spectral curve of natural light and especially to the blue wavelengths that constitute the action spectrum for non-visual photoreception in the human eye and regulate the body's circadian rhythm. At these wavelengths, the loss of light intensity due to internal reflection in the glass is close to zero, allowing the full natural spectrum of sunlight to enter the room and act positively on the melatonin levels of the occupants. The glass performs its usual function as a wind- and waterproof barrier, but in terms of the admittance of light the effect is the same as if the window were wide open. Potential applications include window glazing for homes, offices and leisure centers, and specialty glasses for radiation shielding, light therapy, and mood-enhancing dynamic lighting.

Better indoor air quality by adding formaldehyde adsorbers to chipboard

Formaldehyde is a harmful, volatile gas that is irritating to the mucous membranes and can cause cancer if inhaled, as confirmed by recent studies conducted by the German Federal Institute for Risk Assessment (BfR). For this reason, it is classified as carcinogenic to humans by the International Agency for Research on Cancer (IARC). Nevertheless, it continues to be used in low-cost binding agents employed in the manufacture of pressed wood products, albeit in much lower concentrations than in the past.

The outgassing of formaldehyde from furniture and other sources pollutes the air in homes and offices, at levels that normally lie below current safety limits. But the trend toward more highly



Spectral transmissivity of the glass developed by Fraunhofer ISC with its peak at 510 nm (red curve). Green curve shows transmissivity of usual glass.

insulated buildings with airtight windows has increased the risk of pollution by lessening or even eliminating natural ventilation of indoor spaces. Consequently, it is likely that emission standards for pressed wood products will have to be brought down to the same level as those for natural wood in the not-too-distant future. The need for non-polluting building materials is thus becoming increasingly urgent.

To meet this need, Fraunhofer ISC is collaborating with Fraunhofer WKI on the development of a new solution in which specially modified zeolites, which are capable of adsorbing a large proportion of the outgassed formaldehyde, are incorporated in chipboard during its manufacture. Because there is a limit to the zeolites' capacity to adsorb formaldehyde, the researchers plan to take their idea further by developing a system in which the zeolites integrated in the wood product not only adsorb formaldehyde but also assist in its catalytic breakdown. In this way, only a small residual amount of formaldehyde gas is emitted into the surrounding air, at a level well below the currently authorized concentration of 0.1 ppm dictated by the European E1 emissions standard.

The zeolite in question is a fine silicate powder that is mixed with the wood chips that are subsequently pressed into boards, resulting in an even distribution of the zeolite throughout the finished product. The advantage of this method is that the formaldehyde gas is adsorbed in situ, as soon as it is released, thus preventing outgassing. Tests on a model chipboard specimen incorporating the specially modified zeolite demonstrated that formaldehyde emissions could be reduced by 40 % in this way. The use of the additive had no negative effect on the properties of the chipboard.

Scope for even better effectiveness

In the further course of the project, the researchers will be focusing their attention on testing suitably modified zeolites for their ability to catalyze the formaldehyde breakdown process. The best candidates will be selected for further development. The aim is to reduce formaldehyde emissions from pressed wood products by a further significant degree and ensure that the zeolites remain effective for a long period of time. The team is also investigating the ability of modified zeolites to adsorb other volatile organic compounds (VOCs), such as those released by products made of plastic, which similarly contribute to indoor air pollution. The long-term objective is to incorporate suitable zeolites in other building materials, giving them the capacity to improve indoor air quality by adsorbing and catalytically removing a wide range of pollutants.

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HAZARDOUS MATERIALS ANALYSIS IN THE LIGHT OF CURRENT EU-REQUIREMENTS

REACH, WEEE and RoHS*

With the entry into force of the European Waste Framework Directive 2008/98/EC on December 12, 2008, a revised legislative framework for waste recovery and disposal was established. Among other things, this has implications arising from the ban on incandescent light bulbs. One of the side-effects of phasing out traditional light bulbs and replacing them with low-energy alternatives is an increase in the quantities of hazardous substances entering the waste cycle: lead and mercury from fluorescent and gas-discharge lamps, cadmium from electrical contacts, and hexavalent chromium used as a corrosion inhibitor. The proposed criteria for determining the end-of-waste status of glass cullet presents new challenges with respect to the analysis of waste glass and the definition of limits on the level of contamination.

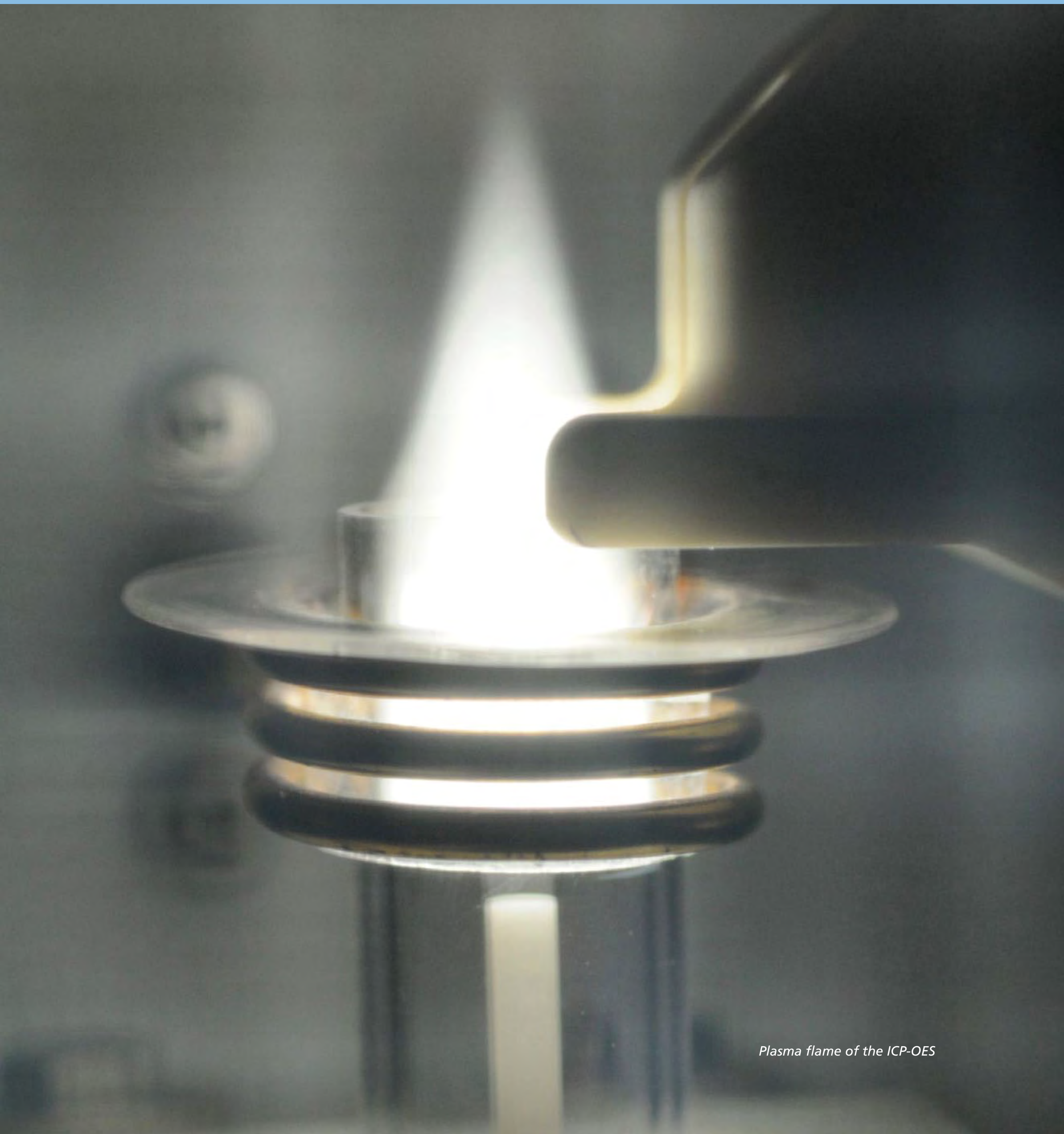
The Framework Directive complements related European Union (EU) regulations and directives, such as the REACH Regulation on the safe use of chemicals, the WEEE Directive on waste electrical and electronic equipment, and the RoHS Directive on the use of certain hazardous substances in electrical and electronic equipment. The purpose of this legislation is to regulate the recovery and disposal of end-of-life electrical and electronic equipment and protect human health by restricting or banning the use of certain dangerous substances. Modern electronic devices contain substances that present a high risk to the environment, either due to their toxicity or because they are not or not completely biodegradable. The RoHS directive aims to ultimately ban the use of certain substances of very high concern. The current list of restricted substances comprises lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs). The maximum concentration values tolerated by weight in homogenous products are 0.01 percent for cadmium and 0.1 percent for lead, mercury, hexavalent chromium, PBBs and PBDEs. Applications exempted from the restriction (Annexes to RoHS Directive 2002/95/EC resp. 2011/65/EC) will be reviewed by the Commission at least every four years to decide whether they are still justified in the light of recent scientific and technical progress. The Directive makes provision for the use of other substances to be restricted if new scientific studies provide evidence that they present a substantial risk to human health or to the environment. The European Commission intends to review the scope of the RoHS Directive over the next three years and issue an amended version at the latest within 10 years. To date, no further chemicals have been added to the candidate list of substances of very high concern.

The EU's REACH Regulation that came into force on June 1, 2007 imposes an even wider range of restrictions on manufacturers and importers, requiring them to assess the human health hazards and environmental fate properties of all substances (synthetic or natural) that they use or sell that have been identified as being toxic or carcinogenic, or which persist in the environment. As well as requiring the transmission of data on substances incorporated in products, authorization is required for the use of substances of high concern (list of substances subject to authorization published in Annex XIV of the REACH Regulation).

**REACH: Registration, Evaluation, Authorisation and Restriction of Chemical substances, Regulation No.1907/2006 EC*

WEEE: Waste Electrical and Electronic Equipment Directive, 2002/96/EC.

RoHS: Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, 2002/95/EC resp. 2011/65/EU



Plasma flame of the ICP-OES

ICP-OES spectrometer

The REACH Regulation has been transformed into national law in all EU member states. The main exemptions from the obligation to register, apart from substances with an annual production volume of less than 1 metric ton and substances used in process and product R&D, are listed in Annex IV (substances considered to cause minimum risk, as sufficient information is known about their intrinsic properties, e. g. water, CO_2) and Annex V (where registration is deemed inappropriate or unnecessary, and where exemption does not prejudice the objectives of the Regulation, e. g. natural products, glass). For the purposes of Fraunhofer ISC's materials research, the REACH Regulation has little or no relevance. But its provisions may need to be observed in the context of future upscaling projects and by the industrial customers and users we work for. It could also affect our procurement of specialty chemicals which in certain cases might not be registered in the EU by the manufacturer or importer due to their low production volume.

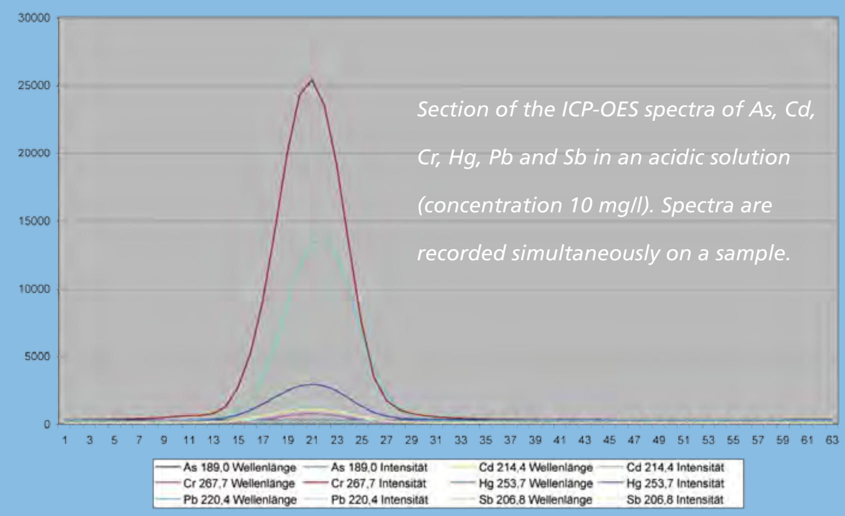
Glass as a special case – avoidance of dangerous components

Glass is exempted from the obligation to register under the terms of Annex V, paragraph 11 of Commission Regulation No. 987/2008 amending the REACH Regulation, with the exception of mineral insulation fibers, to which the registration obligation still applies. The conditions according to Council Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances, which concerns approximately 5,000 dangerous substances, are that the glass itself is not dangerous, does not contain any dangerous components, and does not give rise to dangerous components at any point in its life cycle. Nonetheless, glass manufacturers are downstream users of certain substances requiring registration, e. g. soda and borate. The European Chemicals Agency (ECHA) has recommended a further eleven substances for inclusion in the list of substances subject to authorization (Annex XIV to the REACH Regulation) and entered them in its candidate list of substances of very high concern (SVHCs). To date, a total of 38 SVHCs have been identified that meet the criteria for classification as CMR (carcinogenic, mutagenic or toxic for reproduction) or as PBT (persistent, bioaccumulative and toxic) or as vPvB (very persistent and very bioaccumulative) or that have been identified as having similarly harmful effects, such as endocrine disrupting properties, i. e. serious unwanted effects on human health and the environment. In total, the ECHA plans to recommend 136 substances for inclusion in the candidate list by 2012. Of these substances, those of relevance to the glass industry are the feedstocks anhydrous disodium tetraborate, boric acid, diarsenic trioxide, and cobalt(II) sulfate, as well as refractory ceramic fibers used in insulation materials. Suppliers of articles containing listed substances are legally obliged to communicate information as prescribed in REACH, Article 33, and if necessary comply with registration requirements and restrictions. Given that borate compounds are a major component of borosilicate glasses and mineral fibers, these substances will be registered and technical dossiers and safety data sheets will be compiled for the REACH authorization procedure, proving that all necessary safety measures concerning the use of borates have been complied with. Compliance with European legislation, equivalent initiatives in Japan and the United States of America, and UNO's Globally Harmonized System of Classification and Labelling of Chemicals (GHS), is not the only reason for developing more environmentally compatible materials and products. Such efforts are also in the interests of public health and environmental protection and widely supported by consumers in general. The consequences include a growing need for professional analysis and consulting services, especially on the part of SMEs, a more limited choice of raw materials, and the need to reformulate products using suitable alternative components or entirely new materials.

Hazardous materials analysis of glass – methods for detecting specific components

Glass has long been appreciated for its neutral properties that make it the material of choice for food and drug packaging. In rare cases, it can contain traces of inorganic elements such as As, Cd, Cr(VI), Hg, Pb and Sb, which may be harmful if

Glass batch ingredients



Section of the ICP-OES spectra of As, Cd, Cr, Hg, Pb and Sb in an acidic solution (concentration 10 mg/l). Spectra are recorded simultaneously on a sample.

present in high concentrations. Surface attrition tests have proved that the oxidation products of these components are unable to accumulate in sufficient quantities to represent a health risk to the human organism, because they are efficiently trapped in the structure of the glass. The limits defined in the REACH Regulation, by contrast, relate to the total content of toxic components in the material, including the concentration of unleachable substances. Methods to detect the presence of these substances call for highly sophisticated instruments, because they are stably bonded in the glass. Fraunhofer ISC has established a number of accredited test methods that meet the specific needs of quantitative element analysis, including inductively coupled plasma optical emission spectroscopy (ICP-OES). This method involves the use of special procedures to dissolve the glass or ceramic in an acid aqueous solution. The solution is sprayed into a plasma flame (6000 to 8000 K) and analyzed according to DIN 51086-2. Under these conditions, excited ions reveal the presence of the hazardous substance by emitting light at specific wavelengths (flame color). The spectrometer simultaneously records the levels of intensity for Li to U down to the ppm range (mg/kg), and in some cases even the ppb range (µg/kg). The oxidation level of an element can be decisive in evaluating its toxicity – an important example is chromium. Whereas trivalent chromium or Cr(III) present in concentrations of several 1000 ppm in green glass is harmless, even traces of hexavalent chromium or Cr(VI) of a few ppm result in a classification of the glass as carcinogenic. This very sensitive distinction and quantitative analysis is achieved using a spectrophotometric technique on the solution (DIN 51086-3).

Among the materials tested for the presence of hazardous substances at the Fraunhofer ISC are chemical feedstock and waste. A particularly challenging area is the treatment of waste electrical and electronic equipment in accordance with the RoHS and WEEE Directives. The diversity of materials involved, their inhomogeneity, and the often very low concentrations of certain elements are all factors that render quantitative and qualitative analysis difficult. But it has already been demonstrated that it is possible to prepare representative test samples for the identification of toxic components by means of appropriate processes for pre-sorting, milling preparation, fine grinding, and sample separation.

DIN 51086-2 (issue 2004-07): Testing of oxidic raw materials and materials for ceramics, glass and glazes – Part 2: Determination of Ag, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Er, Eu, Fe, La, Mg, Mn, Mo, Nd, Ni, P, Pb, Pr, S, Sb, Se, Sn, Sr, Ti, V, W, Y, Yb, Zn, Zr by inductively coupled plasma optical emission spectroscopy (ICP-OES)

DIN 51086-3 (issue 2007-04)
Testing of oxidic raw and basic materials for ceramics, glass and glazes – Part 3: Spectrophotometric determination of chrome(VI) with diphenyl carbazide in the presence of chrome(III)

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SUBSTITUTION OF SUBSTANCES OF VERY HIGH CONCERN IN GLASS MANUFACTURING

The glass industry has traditionally made extensive use of dangerous substances such as lead (in optical lead glass and low-melting-point glass solder), or of arsenic and antimony as refining agents. Toxic substances such as cadmium and hexavalent chromium are also occasionally used as pigments (to give a red-orange or green-yellow color). Attempts to replace them with alternative substances can give rise to numerous problems in the glass-melting process. In addition to its expertise in the control and monitoring of glass manufacturing processes, Fraunhofer ISC also offers support by developing new specialty glasses for the substitution of toxicologically harmful or expensive components.

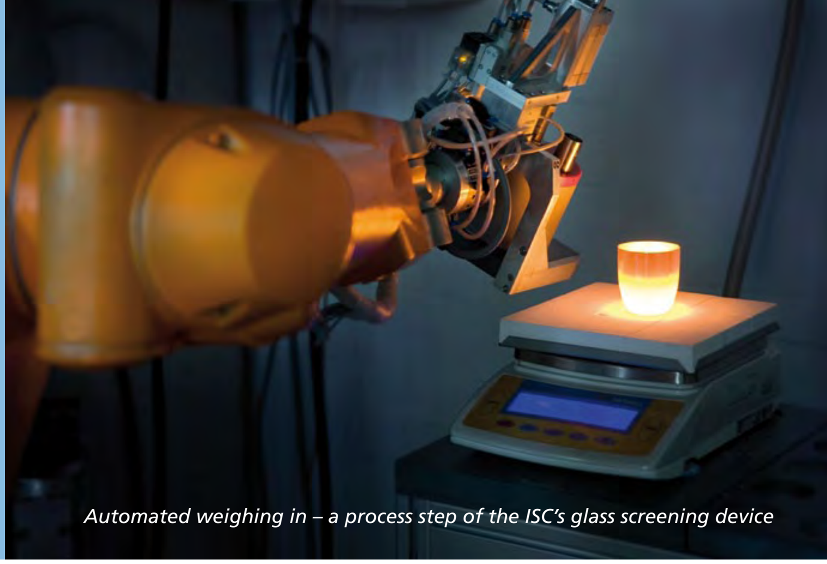
Substitution of lead

The lead used in optical glasses – usually incorporated in the glass melt in the form of Pb_3O_4 – principally serves to improve their diffraction properties. The lead content of these glasses can be very high. Lead crystal glass, for example, contains more than 50 percent of lead by weight, and is still manufactured in huge quantities today: the annual output in Germany is approximately 100,000 metric tons. There are a number of possible substitutes for lead in glass, including Ti, Bi, Ta, and the lanthanide series of elements, but alternative optical glasses that meet the same requirements as traditional lead glasses are often more complex in their chemical composition and some have a marked tendency to crystallization. And in almost every case, the viscosity of lead-free optical glasses is more temperature-dependent than that of traditional lead glass. As a result, the melt flow during glass processing has to be controlled much more precisely and the process window in terms of temperature is narrower than that for lead glass. Fraunhofer ISC has developed various special measurement techniques to monitor temperatures during the glassmaking process at high spatial, thermal and temporal resolution. Lead-free alternatives to traditional low-melting-point glass solders also require new solutions, because the chemical interaction between the glass and the joining material is more difficult to control than in the case of lead glass, owing to the greater number of components in these glasses.

Substitution of arsenic and antimony

Arsenic and antimony are excellent refining agents, capable of removing even the smallest gas bubbles from the glass melt thanks to their ability to modify their oxidation level at typical glass-melt temperatures. This property enables them to adsorb and release dissolved oxygen and aggregate small bubbles in the melt into larger bubbles that can be removed during processing. The arsenic or antimony content of conventional glasses rarely exceeds one percent by weight. To eliminate arsenic and antimony – both equally toxic – from the glass melt, alternative refining methods need to be found. One meanwhile established method goes by the name of gas bubbling. This involves injecting a gas such as helium into the glass melt, which has the effect of »capturing« gas inclusions and drawing them off. The drawbacks of this method are the high cost of helium and the reduction of oxygen partial pressure in the melt by the bubbling process. This can lead to the reduction of the reduction-sensitive components of the glass. If bubbling is not a viable option for this reason, it is nevertheless possible to significantly reduce the arsenic and antimony content by modifying the melting process in other ways.

Pb_3O_4-mixture component for high-diffractive glass



Automated weighing in – a process step of the ISC's glass screening device

These include careful selection, preparation and feeding of the raw materials. Moreover, by increasing the temperature and duration of the refining stage, it is possible to reduce the volume of gas inclusions by a factor of 5-10 to a level significantly below 0.1%.

Substitution of cadmium and hexavalent chromium

The manufacture of transparent red, orange or yellow-green glass is a complex undertaking. Whereas there is a wide choice of elements capable of imparting a blue, green or yellow color to glass, there are very few ionic salts that can be incorporated into glass to provide a red coloration. Apart from the addition of ionic salts to change the intrinsic color of the glass, other coloring methods are also available. One involves incorporating microscopically small colloidal particles in the glass. The best-known example is cranberry or gold ruby glass. However, whereas ionic glasses can be mixed in any proportion to produce a homogenous new color, this is not the case with colloidal glasses. Each color variant requires a corresponding adjustment of the tempering process. Cranberry glass is also very expensive to produce because it contains particles of noble metals such as gold and also platinum. But with the use of adapted process-control systems and a carefully chosen combination of noble metals, it is possible to reduce the consumption of these very costly raw materials.

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PROJECT

GROUP

PROJECT GROUP CERAMIC COMPOSITES

THE FRAUNHOFER PROJECT GROUP CERAMIC COMPOSITES HAS BROUGHT ITS 5-YEAR FOUNDING PHASE TO A SUCCESSFUL CONCLUSION, ESTABLISHING THE EQUIPMENT AND TECHNOLOGY REQUIRED FOR THE MANUFACTURE OF CERAMIC MATRIX COMPOSITES AND FOR THE 3D CHARACTERIZATION OF COMPONENTS.

THIS IS A SHORT REVIEW OF THEIR ACTIVITIES:

PROJECT GROUP

Wound tubes made of oxide CMC

PROJECT GROUP COMPLETES ITS FIFTH YEAR

The Fraunhofer Project Group Ceramic Composites was founded in June 2006 with funding from the German federal state of Bavaria. Its assignment was to conduct further research into the frontline theme of high-temperature (HT) lightweight construction to better cater to market requirement. Its ongoing goal is the formation of an independent Fraunhofer Institute for High-Temperature Lightweight Construction in Bayreuth. In early 2007, Prof. Dr.-Ing. Walter Krenkel, the Head of the Project Group, and the four members of his initial core team moved into a 350 m^2 pilot plant facility in the NMB GmbH building in Bayreuth-Wolfsbach where they began work on the development of lightweight structural materials made from fiber-reinforced ceramic matrix composites.

Today, the Project Group employs eight full-time staff, five part-time research scientists, three doctoral students and numerous graduate students as it continues to pursue a path of steady growth. The space available for technology development has been expanded to 700 m^2, enabling the team to offer a self-contained process chain designed for the manufacture of parts from fiber-reinforced ceramics on a semi-industrial scale. The key focus defined for the first five years of project funding was the ongoing development of ceramic matrix composites (CMCs), with basic research conducted at the Chair of Ceramic Materials Engineering at the University of Bayreuth and pilot scaling to full component size taking place at the Project Group's facilities. This close collaboration between the research and teaching communities has produced a number of successful joint and bilateral industrial projects in the field of oxide and non-oxide ceramic matrix composites.

Against the backdrop of worldwide increases in raw material costs and ever scarcer resources, lightweight construction is steadily gaining ground and has long since extended its reach beyond the aerospace industry. The continuous demand for individual mobility in society has created a need for new lightweight and ultra-lightweight design concepts for future transportation systems, while the energy and propulsion systems envisaged for tomorrow's world typically require the materials used to function at higher operating temperatures. Improvements in temperature resistance thresholds directly affect the efficiency of energy conversion by reducing the need for cooling air in power generating and propulsion machinery. The market potential for a new generation of matrix composites is therefore considered to be tremendously high. Some of the most interesting and promising applications for ceramic matrix composites outside the aerospace industry include gas turbine engineering (stationary and mobile), drive and combustion technology, and tribological applications such as friction and bearing materials.

HT lightweight construction is a distinctly interdisciplinary field of science and engineering that covers a broad array of materials. It ranges from the synthesis of new HT materials and their design, modeling, fabrication and system integration right through to fatigue analysis of structural components, including in-process quality assurance. Their high potential to enable more efficient use of energy and resources make fiber-reinforced matrix composites with a ceramic, metallic or even polymer matrix the perfect choice for HT lightweight structural materials.

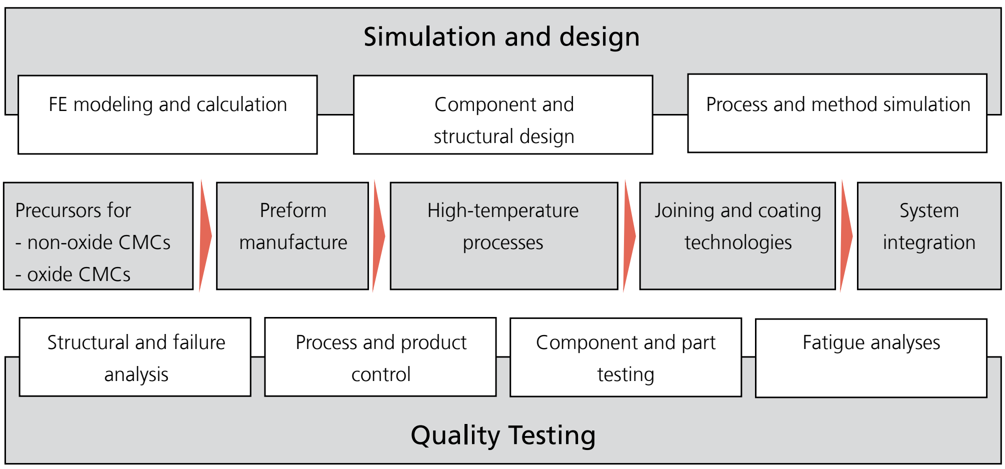
Yet before they can be used on an industrial scale researchers are faced with the task of developing the design tools, joining technologies and cost-effective manufacturing technologies that are suitable for each specific material. CMC brake disks and friction linings are a good example of just how successfully this research-intensive technology can be scaled up to high-volume industrial production.

The first major milestone on the path towards an independent center for HT lightweight construction in Bayreuth has already been reached: The team has completed all the technical systems in the two leased facilities that are required to establish a self-contained process chain for developing and manufacturing CMC structural parts on a semi-industrial scale. Various methods are available for green body production including hot press technology, an ultramodern filament winding machine and RTM (Resin Transfer Molding) technology. The pilot plant equipment was rounded off with the high-temperature furnaces for pyrolysis and silicon melt infiltration which came into operation at the end of 2009.

Another of the Project Group's key areas of expertise involves using analytical methods for process and quality control: A computed tomography system designed to scan large components with diameters up to 700 millimeters enables the non-destructive testing and depiction of components as 3D models at a high resolution of just a few millimeters. The Project Group's next goal is to establish simulation and calculation tools for component design together with special component test benches.

Alongside its R&D activities, the Project Group also fosters the exchange of scientific knowledge and expertise in the field of ceramic matrix composites. A number of advanced training courses and two materials science conferences have been held in Bayreuth to further this goal: The 17th symposium on matrix composites and compound materials took place at the University of Bayreuth in April 2009 with the participation of some 200 scientists and researchers from Germany and other German-speaking countries, while Bayreuth attracted international interest in September 2010 as the setting for

Self-closed process chain for developing and manufacturing CMC structural parts



The goal of the Fraunhofer Project Group Ceramic Composites is to develop a self-closed process chain for the manufacture of components made of fiber composite materials on an industrial scale.

the 7th International Conference on High Temperature Ceramic Matrix Composites (HT-CMC 7), which was attended by 350 participants. There was great enthusiasm among the conference participants – especially those from other countries – to learn more about the Bayreuth Project Group's research topics by taking guided tours of the Institute while attending the symposium.

One of the key milestones in the formation of professional networks in this field was the founding of Ceramic Composites in Bayreuth, a department of the Carbon Composites association in Augsburg. The former Director of the Fraunhofer ISC, Prof. Dr. Gerd Müller, agreed to head up this department, and just two years after it was founded it had already acquired 34 members, including 22 from industry. Working on a project-oriented basis within a total of nine workgroups, these members pool their skills to tackle key issues of CMC production, testing and processing.

The start-up funding assigned to the Fraunhofer Project Group Ceramic Composites runs until the end of 2011 and an evaluation of the Project Group's work is scheduled for the summer of 2011. If successful, this will see the CMC workgroup form the centerpiece of an expanded institute of HT lightweight construction which will also incorporate further high-temperature materials. »Ceramic coatings« is the first topic the team is planning to integrate in its research activities, once again in close collaboration with the Chair of Ceramic Materials Engineering. Other topics which are due to be newly implemented and built upon include »High-Temperature Polymer Matrix Composites (HT-PMC)« and »High-Temperature Metal Matrix Composites (HT-MMC)«. However, this planned growth will only be possible if a long-term solution can be found to alleviate the current space problems.

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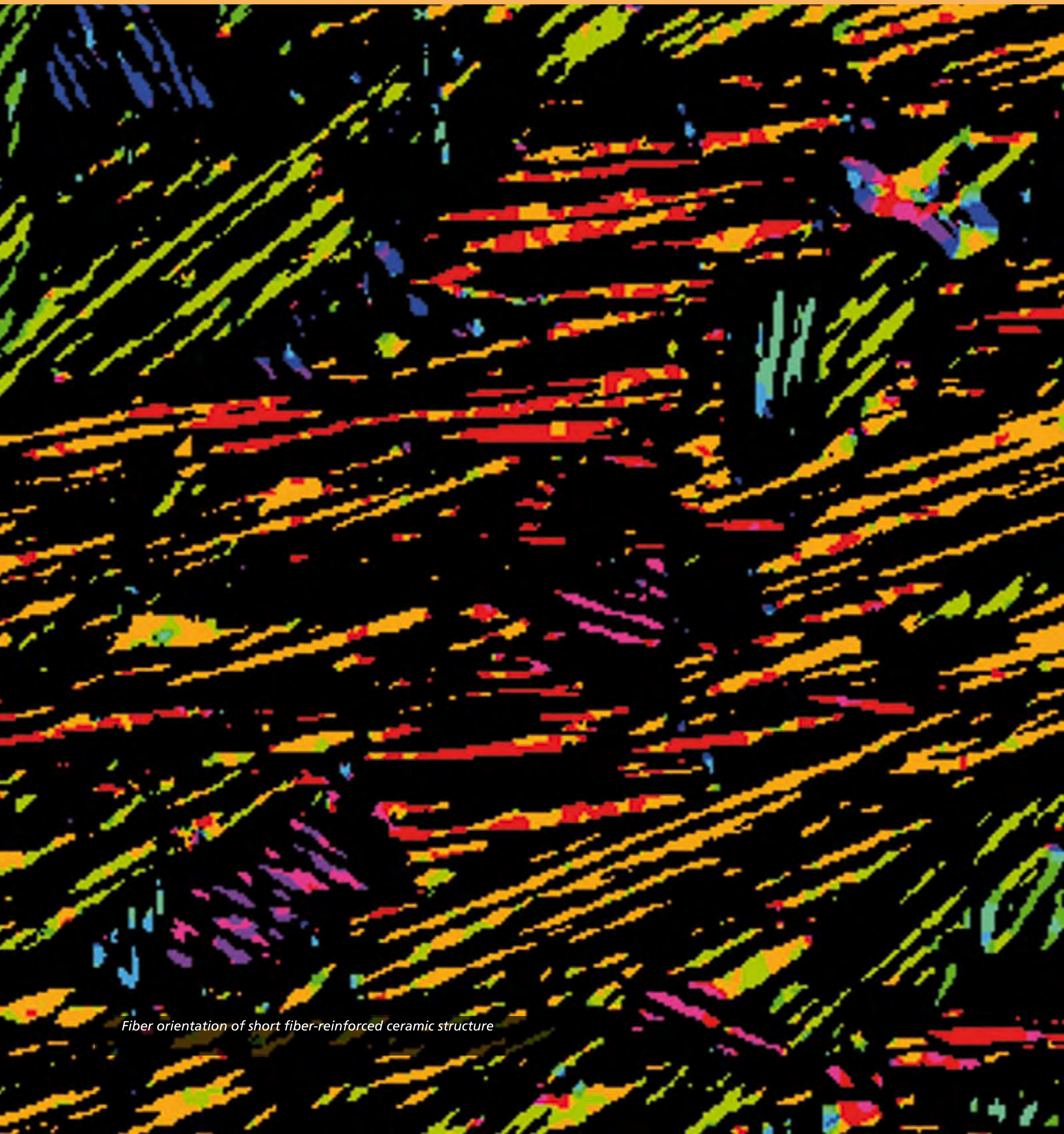
PROJECT GROUP



Fiber orientation of short fiber-reinforced ceramic structure

A new method of quantitatively determining the fiber orientation in fiber-reinforced materials for FE modeling

When developing fiber-reinforced materials – especially with short-fiber reinforcement – it is essential to precisely know the orientation of the fibers in order to design components that are able to withstand specified loads. This is because the orientation of the fibers significantly influences the properties of the resulting material, in particular its strength and stiffness. The fiber orientation in a component is generally heavily dependent on the selected manufacturing technique – for example, injection molding techniques produce different preferential orientations than compression molding techniques.

Previous methods of analysis have only permitted scientists to determine the fiber orientation in indirect ways. For example, the production of short fiber-reinforced plastics by injection molding uses flow analysis to estimate fiber orientations, a method in which the orientations are calculated dependent on the flow properties (flow mold technique). A destructive test method is to metallographically examine individual layers and then to extrapolate the results to the entire part. So far, however, none of the methods has ever been able to provide a reliable quantitative determination of the fiber orientation in actual industrial parts.

A new method of quantitative, non-destructive testing of fiber orientation is now being developed by the Fraunhofer Project Group Ceramic Composites in collaboration with the Chair of Ceramic Materials Engineering at the University of Bayreuth.

This new approach is based on the analytic evaluation of three-dimensional volume images of composite parts, generated using computed tomograph (CT) scans, a process in which the first step is to use segmenting of the data to separate the fibers from the surrounding matrix.

The local spatial orientation of the fibers in the part is then determined and evaluated. The result either shows the exact fiber distribution in any required planes as a combination of the azimuthal angle (angle in the xy plane) and polar angle (angle with the xy plane measured from the z-axis) or the overall distribution represented spherically. The method enables users to determine the fiber orientation in any fiber/matrix combination (e. g. polymer or ceramic matrix, glass or carbon fibers) provided that there is enough contrast between the fibers and the matrix.

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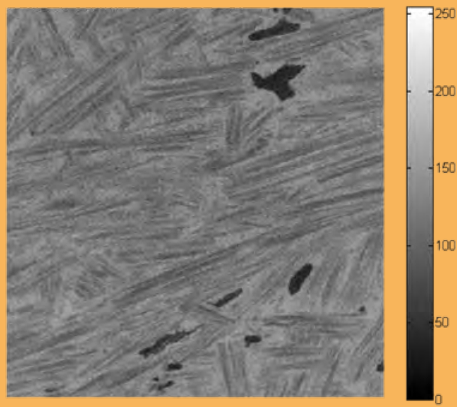

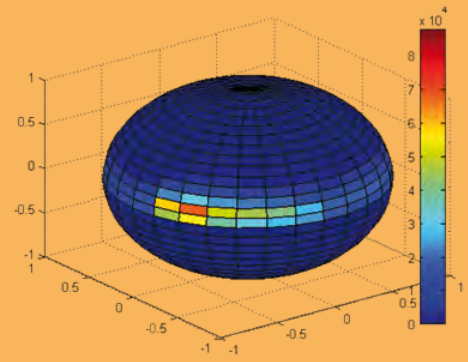

1 *Fiber orientation in short fiber-reinforced C/SiC with approx. 50 percent fiber volume fraction (a-d)*

(a) A selected plane from the CT volume image

(b) Spatial orientation distribution: Orientation of the fibers in the respective spatial directions

Figure 1 shows a sectional plane through a carbon fiber-reinforced silicon carbide ceramic (C/SiC) with a fiber volume fraction of approximately 50 percent. The image shows a sectional plane from the CT (Figure 1a) plus the corresponding overall distribution as a spherical representation (Figure 1b) and the angular distribution of the fibers in the plane (Figures 1c, d). The fibers reveal a preferential orientation in the xy plane, i. e. perpendicular to the direction of pressing, as can be seen from both the spherical representation (Fig. 1b) and the plane representation. The orientation in the xy direction (azimuthal angle) in Fig. 1c reveals a preferential distribution of approximately 20 degrees within the plane, while the orientation in the z direction (polar angle) is virtually constant at 0 degrees. This corresponds to the summation of all the fibers in the spherical representation (Fig. 1b).

In a publication entitled »Correlation Between Fiber Orientation and Mechanical Properties of Short-Fiber C/C Composites«, the algorithm was employed to determine the fiber orientation in various C/C bending test specimens with oriented short fibers. The correlation between the global fiber orientations determined using this algorithm and the bending strength revealed the expected increase in bending strength due to the increased concentration of fibers.

Knowledge of the local fiber orientation can also be used to generate finite element (FE) models which take into account local changes in strength/stiffness due to known fiber orientations. This involves determining the geometry of the part using the volume data and depicting it by means of individual finite elements (FEs). The prevailing direction of orientation in each element is then determined, thereby allowing the individual material properties to be assigned.

The result is an FE model which takes into account both the geometry and the corresponding morphological characteristics of a structure. As an example, Figure 2 shows the FE model of a three point bending test specimen taking into account local fiber orientation.

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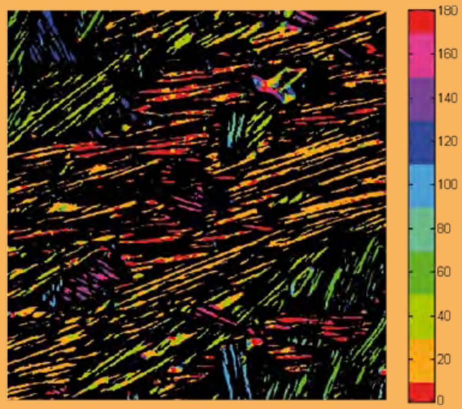
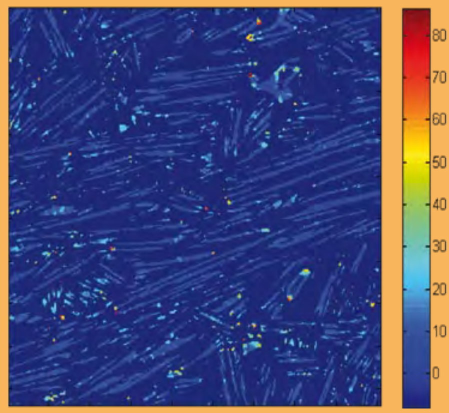
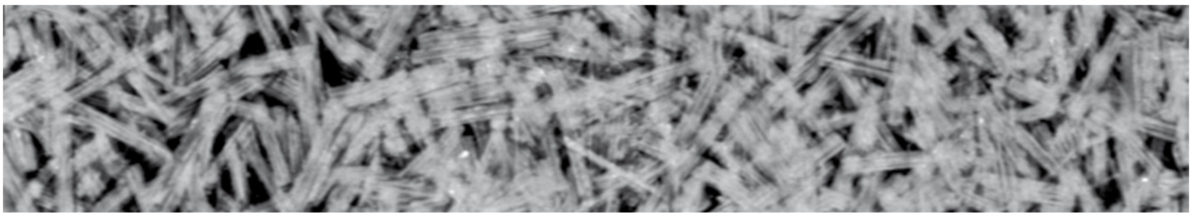


(c) Fiber orientation in the xy plane (azimuthal angle)



(d) Fiber orientation perpendicular to the xy plane (polar angle)

2A)



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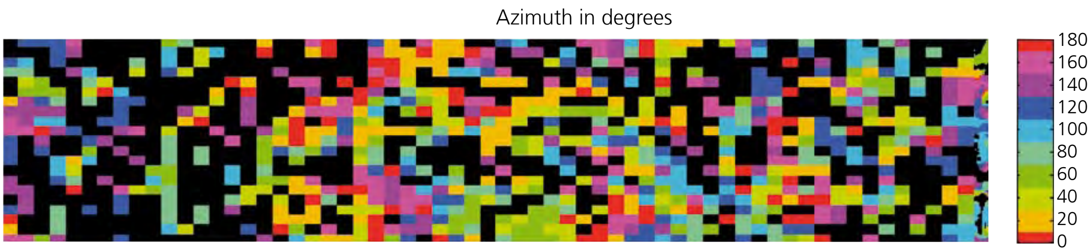
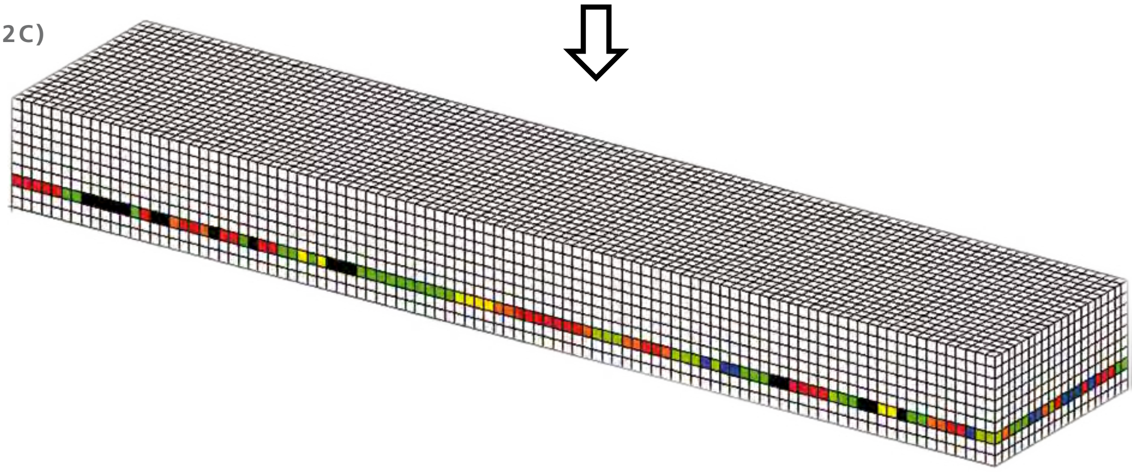


2C)



2 *Generation of an FE model from CT volume data. The local fiber orientation is determined from the volume data (A), refined down to square elements (B) and converted into an FE model (C).*

PROJECT GROUP

A380 with four GP7000 engines, source: MTU Aero Engines

DEVELOPMENT OF FIBER-REINFORCED CERAMIC MATRIX COMPOSITES AND COMPONENTS FOR A NEW GENERATION OF ENGINES

Aiming to raise the efficiency of gas turbines, the Fraunhofer Project Group Ceramic Composites at the ISC is developing lightweight materials and components with high damage tolerance for engine applications. Researchers are investigating ceramics with fiber reinforcement and high thermal and mechanical performance – ceramic matrix composites (CMCs) – for use in combustion chambers and low-pressure turbines. As well as pursuing the original goals of achieving higher operating temperatures through the use of ceramics, modern research into engine manufacturing also places a key emphasis on the weight-saving benefits offered by lightweight structural materials.

The motivation for this development work is twofold: Commercial air traffic is increasing at a rate of approximately 4.9 percent a year (Airbus 2007) – climbing almost 30 percent since the year 2000 alone – and emissions are also on the rise. These increases have prompted the need for greater investment in new lightweight construction materials and structures. Engine manufacturers are aiming for an 80 percent reduction in NO_x emissions and a 50 percent reduction in CO_2 emissions by 2020 based on a voluntary commitment by the European aviation industry formulated by the Advisory Council for Aeronautics Research in Europe (ACARE).

A range of optimization strategies are being developed to improve the efficiency of aircraft design and operation. These include further reducing the specific kerosene consumption of jet engines in order to cut emissions by improving their overall efficiency. Current thermal efficiency figures of 50 percent could be raised by increasing component efficiency, which is technically feasible with high-strength ceramic materials.

However, hot engine components are currently produced exclusively from nickel and cobalt based alloys. These materials cannot be used at temperatures higher than approximately 1,000 °C and their wall temperature cannot be raised beyond 1,200 °C even with intensive cooling and thermal barrier coatings.

In a bilateral project with project partner MTU Aero Engines Munich, researchers are working to determine test conditions and test standards that closely reflect the real-life application of newly developed CMCs; they are investigating corrosion, creep resistance and fatigue behavior under realistic test conditions. The team has already developed a first batch of specimen materials using commercially available, oxide ceramic fibers made of mullite and aluminum with zirconium oxide and aluminum oxide as matrix components. However, the processing of SiC fibers with Si polymers to make SiC/SiC ceramics is still at a comparatively early stage of development.

Various methods are used to produce test specimens. Oxide ceramic matrix composites are manufactured using wet filament winding techniques and sintering processes, while the fabrication of SiC/SiC utilizes infiltration methods such as polymer infiltration, pyrolysis and liquid silicon infiltration.

The goal is to produce high-strength, highly damage-tolerant ceramic materials. The key to achieving high damage tolerance is to tailor a suitable fiber/matrix interface layer using vapor deposition or sol-gel processes.

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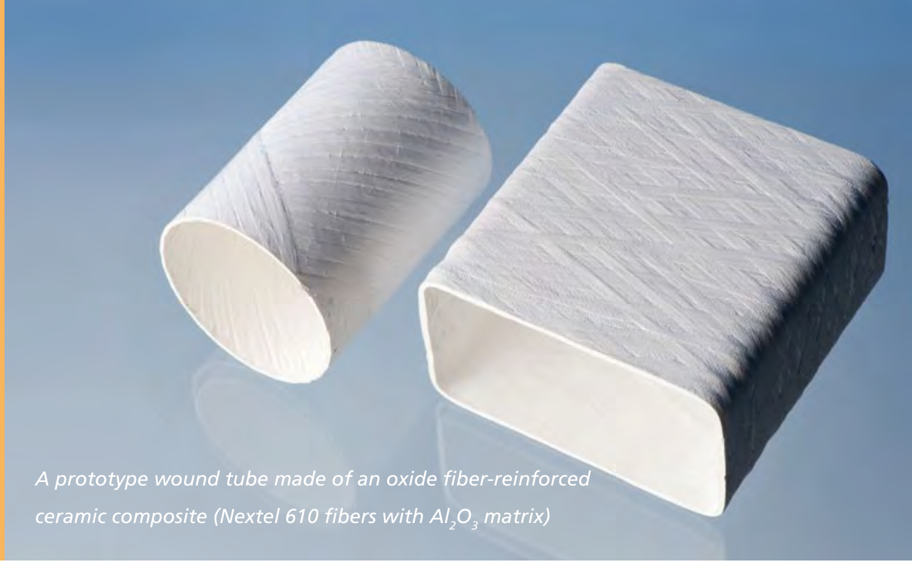
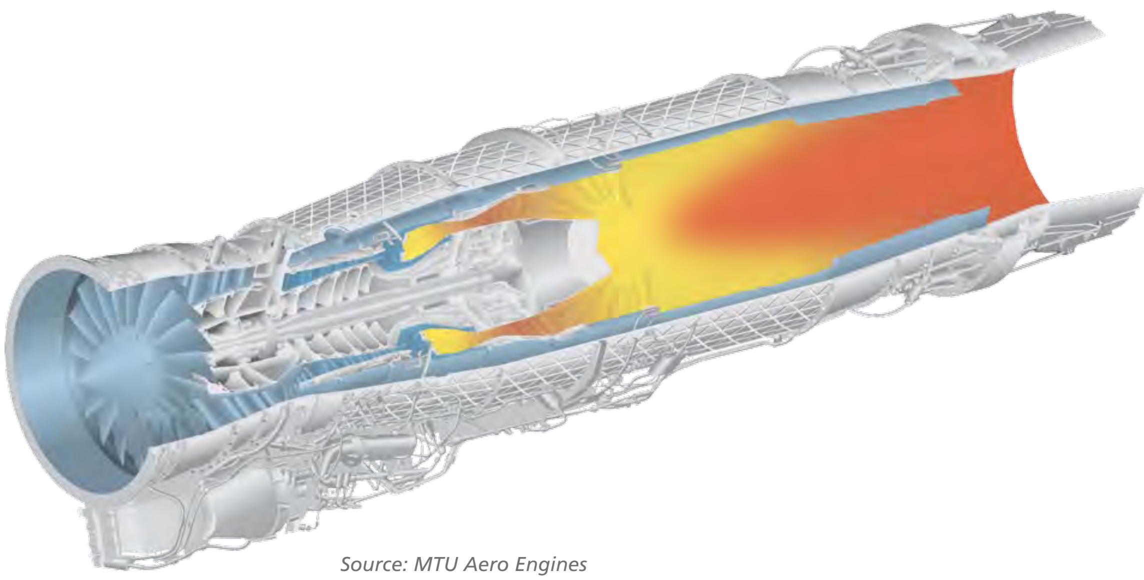


A prototype wound tube made of an oxide fiber-reinforced ceramic composite (Nextel 610 fibers with Al_2O_3 matrix)

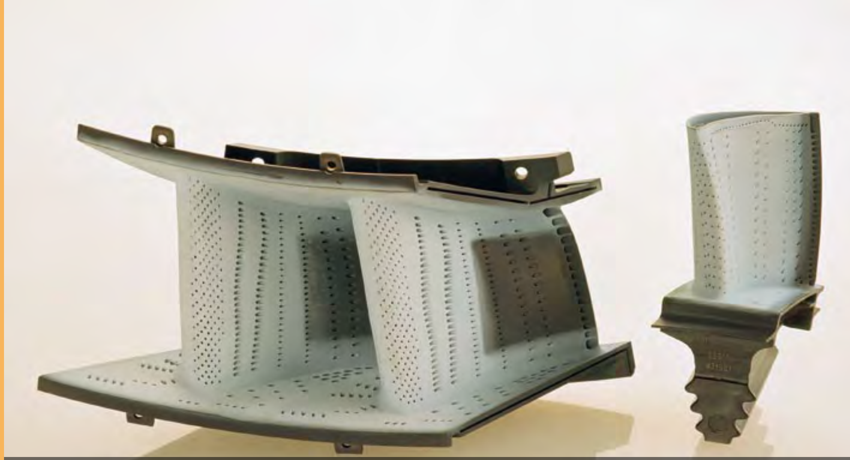
In early 2011, the researchers plan to start testing the long-term durability of these CMCs on the hot gas test rig at high temperatures (> 1,000 °C), high gas velocities and high pressure with corrosive media such as water vapor. However, previous experiments have shown that material degradation in a gas turbine atmosphere as a result of the formation and removal of volatile compounds such as oxides and hydroxides is also a problem that affects ceramics. Hence it is also necessary to focus on the medium-term development of ceramic coatings designed to protect against corrosion (environmental barrier coatings, or EBCs) which scientists hope will significantly increase the materials' long-term durability to several 10,000 hours.

Fabrication of the fiber-reinforced ceramic composites for engine components is currently still at an early stage of development. Until the next milestone is reached, researchers will be working on the mechanical and thermo-physical characterization of both oxide and non-oxide ceramic matrix composites

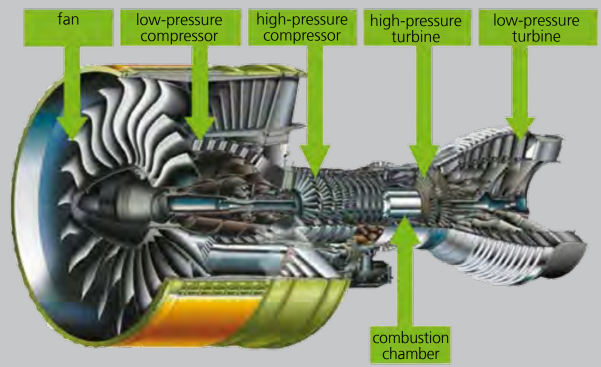
Once results have been obtained from the hot gas tests, the researchers will carry out a preselection of the most suitable material systems. The next task as part of a follow-up project is to design and develop a selected turbine component using a damage-tolerant ceramic matrix composite, employing techniques that make the best use of the ceramic material's properties. The Bayreuth-based Project Group has access to a range of different forming methods which provide the manufacturing technologies required to fabricate these ceramic lightweight structures.



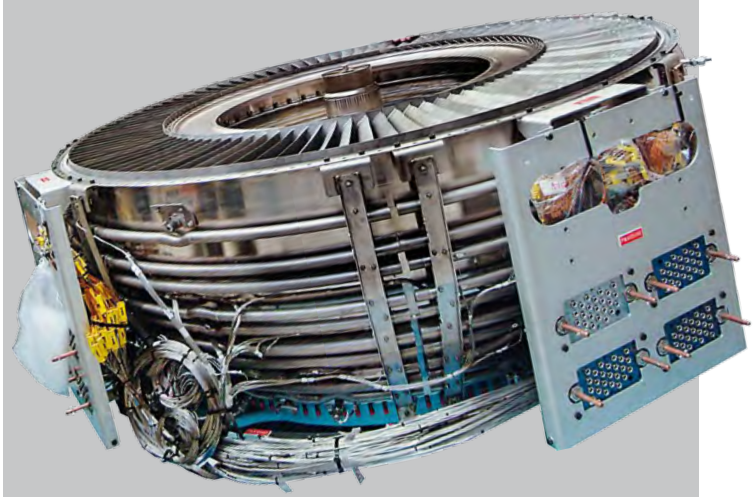
Source: MTU Aero Engines



Stator and rotor blades made of metal alloys and equipped with thermal barrier coatings from the GP7000 high-pressure turbine, source: MTU Aero Engines



Sectional drawing of a commercial two-spool GP7000 turbofan engine. Potential areas of application for ceramics include the combustion chamber, turbine and low-pressure turbine. Source: MTU Aero Engines



First GP7000 low-pressure turbine to be assembled at MTU Aero Engines shortly before its delivery to Pratt&Whittney. Source: MTU Aero Engines

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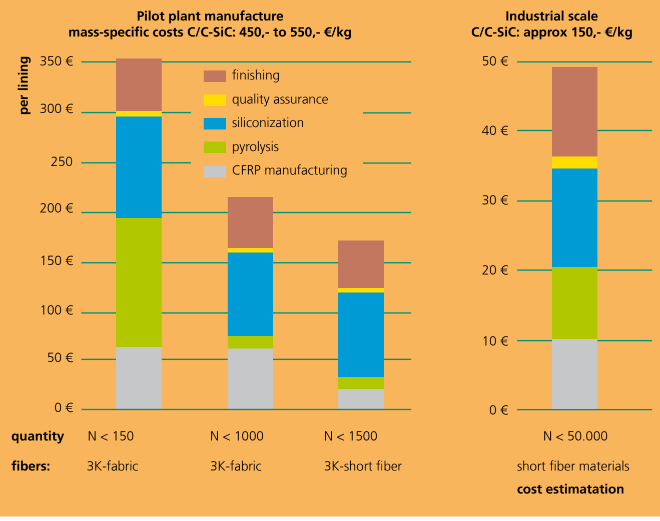
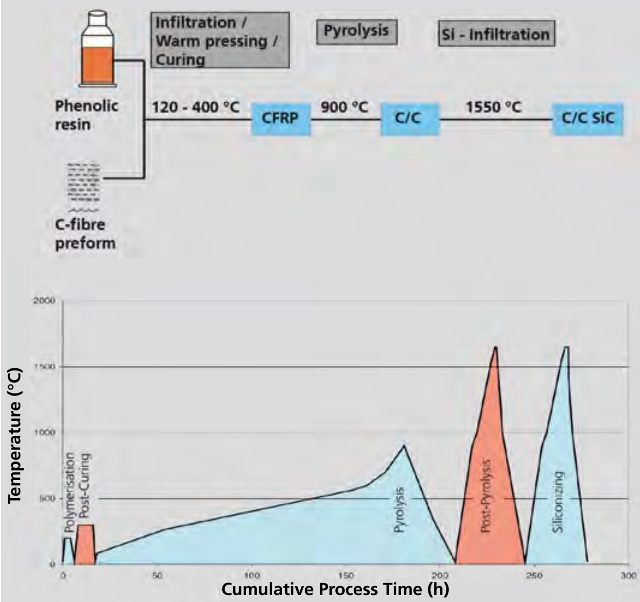


1 *Cost analysis based on the example of a C/SiC friction pad showing the ratio of individual steps in the LSI process, preforms and volumes*

COST-EFFICIENT MANUFACTURING OF CARBON FIBER-REINFORCED SiC CERAMICS

In addition to their original fields of use in the aerospace industry, carbon fiber-reinforced SiC ceramics (C/SiC) have also been used in friction applications in mechanical engineering and the automotive industry for a number of years. Currently, the manufacturing costs of C/SiC parts are very high, due to expensive raw materials and preforms (phenolic resins and carbon fiber fabrics with aviation approval) as well as costly manufacturing processes (Fig. 1). This has hampered broader market penetration, with the result that these kinds of parts currently remain limited to premium-segment niche applications.

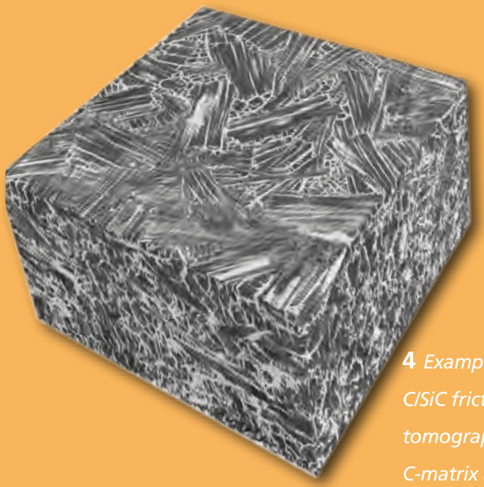
The goal is therefore to significantly reduce manufacturing costs for C/SiC parts without making concessions in terms of material properties (strength, failure behavior, temperature resistance, tribology). Researchers are trying to achieve this by finding and implementing alternative raw materials and semi-finished components and by reducing process costs. The latter involves finding ways to significantly shorten individual process steps or to combine established manufacturing methods into more cost-efficient hybrid processes.



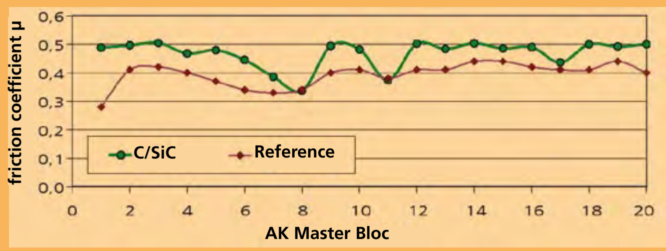
2 *LSI-Process (Liquid Silicon Infiltration)*

As part of a project funded by the Bavarian Research Foundation, a team of scientists has succeeded in identifying potential savings in C/SiC manufacturing and significantly saving costs by combining cost-efficient preform manufacturing with new pyrolysis and siliconization techniques. One of the key goals was to reduce the process time of more than 200 hours which is required for the production of C/SiC parts while paying close attention to the proportion that each individual process represents of the overall cost (Fig. 2).

The researchers applied the short-fiber technology, which enables the near-net-shape production of C/SiC parts (e. g. friction pads). This eliminates the considerable amounts of cut-off material that are typically scrapped during the manufacture of fabric-reinforced parts. By using 3D preforms that retain their shape, such as felts and non-woven fabrics, the team also succeeded in constructing matrices which do not require the extremely time-consuming and cost-intensive process step of pyrolysis (Fig. 3).



4 *Examplary illustration of a part of a ceramic C/SiC friction pad, 20x20x10 mm (computed tomography image), dark areas: amorphous C-matrix and C-fiber bundles; light areas: SiC and residual silicon*

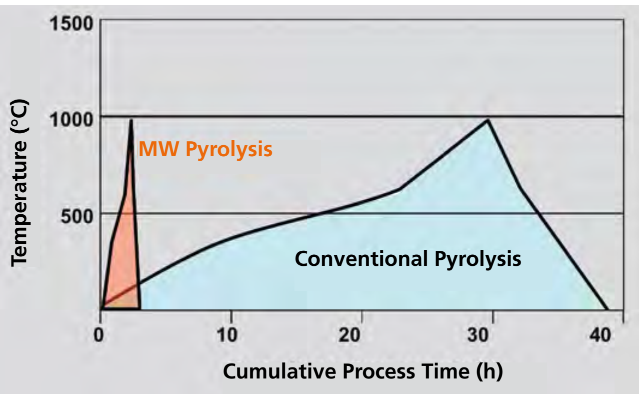


5 *Comparison of friction values between a modified C/SiC pad and an organically bonded friction pad (reference benchmark).*

The team also developed a hybrid heating technique which substantially reduces the time required for pyrolysis and post-pyrolysis, enabling a cost reduction per part of at least 50 percent. This technique involves a combination of conventional resistance heating and microwave heating. High heating rates up to 50 K/min make it possible to reduce the time required for pyrolysis and post-pyrolysis by up to a factor of 10. The C/SiC parts manufactured in this way are equivalent to conventionally manufactured C/SiC parts in terms of their microstructure and their thermal and mechanical properties.

Ways have also been found of reducing processing times and saving costs within the siliconization. By directly heating C/C preforms with a pulsed direct current using FAST (Field Assisted Sintering Technology) methods, researchers have significantly reduced the time required for siliconization. By using heating rates of up to 300 K/min, they succeeded in reducing the processing time to around one tenth of the conventional liquid silicon infiltration.

In addition to developing more economical manufacturing processes for C/SiC materials, the team had also set itself the goal of replacing conventional organically bonded friction pads with lighter, fiber-reinforced ceramic C/SiC brake pads. Their aim was to maintain or improve the tribological properties of conventional C/SiC friction materials. In comparison to the organic phenolic resin used in conventional pads, the ceramic matrix possesses far greater temperature stability. Over the course of the project, the scientists developed C/SiC brake pads modified with additives for passenger vehicles (Fig. 4), which, in the first tests conducted on real components, exhibited wear comparable to that of the organically bonded friction pads that are currently used, though at friction values that were, on average, higher (Fig. 5). The team applied the AK-Master standard, an inertia simulation test procedure for measuring the performance of friction pads under realistic test conditions.



3 *Comparison of process time between pyrolysis–microwave (MW) vs. conventional*

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PROJECT GROUP

HT-CMC 7 attracts record number of participants to Bayreuth

The 7th International Conference on High Temperature Ceramic Matrix Composites (HT-CMC 7) was held at the University of Bayreuth from 20–22 September 2010. Organized as a Franco-German cooperative venture and run by Prof. Dr.-Ing. Walter Krenkel and Dr. Jacques Lamon (CNRS, Lyon), the conference was a tremendous success, attracting some 350 participants, two-thirds of whom had travelled from a total of 21 different countries. Several institutes worked together to set up the conference, including the Fraunhofer Project Group Ceramic Composites, the Chair of Ceramic Materials Engineering at the University of Bayreuth, the New Materials cluster in Nuremberg, the Lyon-based Institut National des Sciences Appliquées (INSA) and the Laboratoire des Composites Thermostructuraux in Bordeaux.

Originally developed for applications in the aerospace industry, ceramic matrix composites (CMCs) are lightweight, wear-resistant materials with excellent temperature stability that have already entered mass production as a useful alternative to metallic materials. They are increasingly being used to manufacture linings for high-performance elevators and lifetime brakes for premium-segment motor vehicles. Industry efforts are now focused on finding cost-effective manufacturing techniques to open up broader access for CMC materials and their extraordinary properties (e. g. high damage tolerance, high mass-specific properties).

The conference in Bayreuth broke all records: This seventh version of the event attracted more than 350 experts – almost twice as many as the average of 200 participants seen at previous conferences. This jump in the participation rate and the high quality of the presentations demonstrate the progress that has been made since the last HT-CMC conference, which was held in New Delhi in 2007. Together with presentations on new, cost-effective fiber developments and new fields of application, there was also a tangible spirit of optimism at the conference which suggests that this class of materials may be close to achieving a major breakthrough in the near future.

The accompanying trade exhibition gave a total of 16 exhibitors from industry and the research community the opportunity to show off Germany's impressive technological capabilities in this area. This was the first time the exhibition had been held in tandem with the conference, and it certainly helped attract a far higher proportion of industry representatives than you would normally expect at a scientific congress, amounting to more than 20 percent of the participants.

A total of 260 contributions showcased the latest developments in the field of ceramic matrix composites. The high number of presentations made it necessary to run four parallel programs simultaneously on all three conference days. These were divided into the subject areas of Ceramic Matrix Composites, Carbon/Carbon Composites, Polymer Derived Ceramics, Thermal and Environmental Barrier Coatings, MAX Phases and Ultra High Temperature Ceramics. The selection of topics covered all aspects of the manufacture, processing and testing of these high-performance ceramics, highlighting how the different groups of materials are currently at different stages of technical development and industrial application. Compared to previous conferences, there was a clear shift towards simulation, modeling and fatigue analysis in the topics covered, suggesting that this class of materials is increasingly ready for real-life application.

Prof. Krenkel, who heads up the Fraunhofer Project Group Ceramic Composites and holds the Chair of Ceramic Materials Engineering at the University of Bayreuth, invested a lot of time and efforts over the past two years to get Bayreuth chosen as the setting for this renowned conference which is held once every three years in Europe, Asia or North America. This certainly paid off: The event fully accomplished his goal of positioning Bayreuth as the center of a steadily developing CMC network and showcasing the current status of CMC research in Germany. The attendees expressed great interest in the topics presented and in the outlines of current activities in Bayreuth and Würzburg. Guided tours of the institute, which were offered at the end of the conference, also proved popular, providing international participants with information on the current status of research in Bayreuth. At its joint exhibition booth, the Bayreuth-based Department of Ceramic Composites of the Carbon Composites e. V. association displayed an impressive series of exhibits designed to present the full spectrum of its members' work. It gave visitors an insight into the many potential applications of ceramic matrix composites.

Bayreuth has quickly built up a superb reputation as a focal point of ceramics technology in this highly advanced and promising field of materials research. The broad materials science background of the Faculty of Engineering Science at the University of Bayreuth combined with the focus on applied science and engineering at the Fraunhofer Project Group Ceramic Composites form an excellent basis for meeting the stated goal of establishing a center of high-temperature lightweight construction in the capital city of the Upper Franconia region of Germany. The success of this year's HT-CMC 7 marks yet another key milestone on the path towards that goal.

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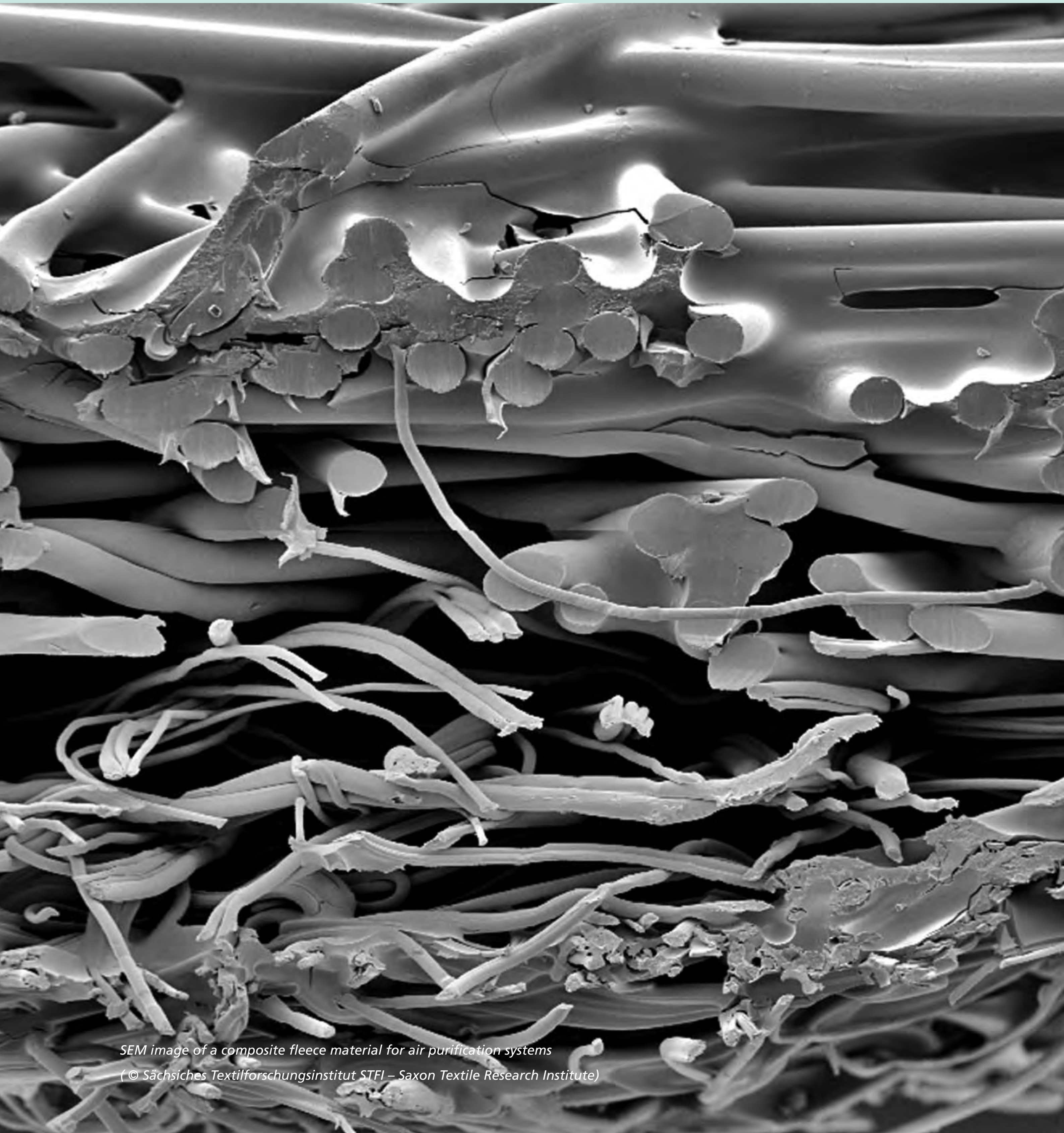
SURFACES AND COATINGS



SEM image of a composite fleece material for air purification systems
(© Sächsiches Textilforschungsinstitut STFI – Saxon Textile Research Institute)

A key area of the business unit's activities is the development and characterization of innovative nanocomposites with multi-functional property profiles using chemical nanotechnology techniques, along with adaptation of corresponding production processes.

The services offered by the Surfaces and Coatings business unit include the development of materials and technologies for wet-chemical coating processes, with a view to enhancing the value of and conserving numerous polymeric, vitreous, ceramic and metallic materials. For this, the Institute can draw on a wealth of materials science expertise and a wide range of coating application technologies. Functional or active coatings change the surface properties of components and products and thereby increase their value or change the scope of their applications and functions.

The sol-gel process serves as a chemical synthesis method for producing inorganic and hybrid materials – from molecular dispersion precursors through nanoscale clusters and particles to thin films with a thickness of up to a few micrometers. Using commercially available silanes and metal alkoxides, this method opens up numerous possibilities for functionalizing materials and customizing the properties of surfaces and coatings.

Color, susceptibility to wear and corrosion, optically functional and electrical properties can be influenced just as well as can biocompatibility, the adhesion of dirt particles or the wettability by oil, solvents and water. The permeability of coating systems can be selectively induced in such a way that they attain barrier properties against certain materials but are permeable to others. In the sol-gel process, the starting materials can be varied to combine an extremely wide range of coating properties to meet any customer requirement.

From passive protective functions to active coatings

Current development work in coating technology is moving on from passive protective functions, such as scratch-resistant coatings for transparent plastics and corrosion protection applications, and is increasingly advancing in the direction of active coatings, e. g. photochromic and electrochromic coating systems which respond to external influences and self-adapt their optical properties. A second major goal of current research into thin film coatings is to endow surfaces with easy-to-clean or even largely self-cleaning properties. The aim is to realize several functions at the same time with a single or just a few thin films. An important example is provided by the already commercially available antireflective coatings made of porous SiO_2 on glass covers for solar panels, which significantly increase the energy input into the solar collector and provide a dirt-repellent surface which is cleaned by the rain. This is made possible by coating systems with suitable pore radius distribution and roughness. Such porous sol-gel coatings have enabled the following application in the protection of cultural heritage.

Antireflective coatings for external protective glazing on Cologne Cathedral

The use of external glazing to protect ancient glass windows from the effects of the weather and pollution is the internationally recognized standard in the preservation of historic monuments: Protective panes of glass are placed at a certain distance in front of the historic originals. With a proper supporting structure and appropriate air circulation in the gap, a good protective effect is achieved. The disadvantage is, however, that the appearance of the surrounding architecture is negatively affected by the reflection from the protective glass.

Window North VI, circa 1300, (© Dombauhütte Köln - Cologne Cathedral Works Department) Partners: Cologne Cathedral Works Department, Centrosolar Glas GmbH

In a project conducted with Dombauhütte Köln (Cologne Cathedral works department) in 2003, protective glazing with an antireflective coating based on porous SiO films was fitted on one of the 17-meter-high four-panel Royal Windows in the choir of the cathedral. Regardless of the viewing distance, this antireflective glazing disturbs the aesthetic appearance of the architecture much less than conventional protective glass and does not spoil the look of the historic originals. Last year, a further Royal Window (South VIII) was fitted with the same type of protective glazing. The antireflective coating has proved highly successful since 2003 – also because of its low susceptibility to soiling. In the coming years it is planned to install protective glazing with the new antireflective coating on the other 13 Royal Windows in the cathedral choir. The 19th-century stained-glass windows in the cathedral transept will also be gradually provided with protective glazing. The antireflectively coated glass is produced by CENTROSOLAR GLAS GmbH & Co. KG Fürth.

New mold release agents

In the production of plastic products by injection molding, powder-slush or foam molding, mold release agents are needed to ensure clean demolding. They also determine the look and feel of the products. Their performance has a direct impact on process cost and reliability, as well as on product quality.

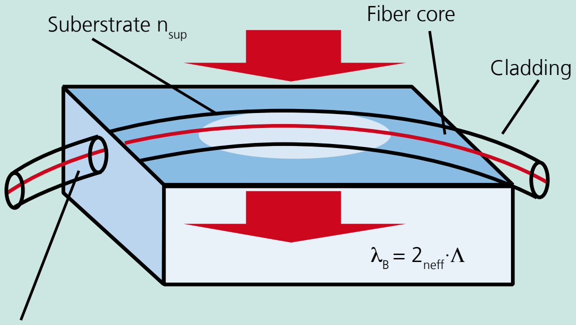
The method most commonly used to demold polyurethane (PUR) and PVC products involves applying mold release agents to the inside of the mold (external release agents). The disadvantage of this method is that the mold has to be re-coated before each molding operation. An alternative approach is to add substances to the plastic that enhance the release behavior, but they modify the properties of the finished product and they are expensive. Semi-permanent mold release agents permit multiple demolding. Permanent mold release agents, however, are more cost-efficient and reduce downtime.

Usually, polytetrafluoroethylene materials are used as permanent mold release agents, but they do not keep for very long, are difficult to renew and tend to be quite sensitive.

In the »Permanent mold release agent coating based on hybrid nanocomposites (Perma Trenn)« project funded by the German Federal Ministry of Education and Research (BMBF), Fraunhofer ISC has, in cooperation with industrial partners, advanced the development of an innovative permanent mold release agent coating for plastic-processing operations in the automotive supply industry. For the first time ever, heteropolysiloxane-based nanocomposites (H-POS) were evaluated for this purpose and compared with various release agent systems used by other partners in the project. The findings from the successful clarification of damage mechanisms in current semi-permanent demolding agent coatings were channeled directly into the development. Project partner Intier Automotive has tested the manufacture of molded skins for automobile cockpit modules using the (in-mold coating) powder-slush process, and the manufacture of acoustically effective automobile interior paneling backfilled with flexible PUR foam, in its production facilities.

To provide the permanent coating for metallic mold surfaces, thin films exhibiting good adhesion are required which also display high hardness and resistance to abrasion, good frictional properties and excellent non-stick behavior. To optimize the release effect, Fraunhofer ISC has further reduced the already low surface tension of inorganic-organic H-POS and induced specific mechanical properties. No environmentally harmful fluoro-organic components were used. In the industrial PVC slush molding process, the coating exhibited an excellent, scarcely diminished release effect even after 200 cycles. What's more, the new coating enhanced the level of productivity vis-à-vis currently used semi-permanent systems with no deterioration in the appearance of the demolded parts. This high-performance, environmentally friendly mold

Opto-chemical sensor basing on side-polished optical fiber bragg grating FBG sensitive to superstrate



Embedded and side-polished optical single-mode fiber (Source: IPHT)

coating minimizes the use of release agents and in some cases renders them completely unnecessary – which all adds up to a noteworthy success, both economically and ecologically.

Innovative coatings for special optical fibers

Thermal and mechanical sensors and high-power lasers with outputs up to several kilowatts require special optical fibers exhibiting excellent surface properties. In industrial application such high outputs are transmitted by optical waveguides made of highly pure synthetic quartz glass fibers with coatings able to withstand the high loading involved. For loss-free transmission, high thermal loadability and a low refractive index are required. By contrast, excellent adhesion of the coating on the glass fiber and good mechanical stability at a high refractive index are essential on glass fibers for fiber Bragg grating elongation sensors. Also, the respective coatings must be UV-curable so that they can be directly, i. e. cost-effectively, integrated in the fiber drawing process.

Conventional fiber coatings either exhibit inadequate adhesion on glass or are not UV-curable. In the »Innovative coating systems for special optical fibers based on nanoscale hybrid-polymer layer systems (BEOS)« project funded by the German Federal Ministry of Education and Research (BMBF), Fraunhofer ISC has developed UV-curable and stable sol-gel coating materials with an individually adapted refractive index and high thermal stability for both applications.

The coatings developed for high-temperature fiber Bragg grating sensors have a refractive index of over 1.46 and exhibit thermal stability at temperatures in excess of 300 °C. For fiber lasers and power transmission the coatings can be adjusted by variably deployable fluorine components to various low refractive indices down to 1.38 and exhibit a thermal stability of over 200 °C.

Multifunctional fleece materials for depth filtration

In many public buildings, office complexes and production halls, air purification systems filter dust, moisture particles and pollen from the incoming air. In Germany alone, around 400,000 of these systems are in operation. Increasingly efficient filter media are required to deal with the air pollution caused by industry and traffic and also to make life more comfortable for the increasing number of people suffering from allergies. The filter media must ensure that the finest dust and moisture particles are trapped and also that the microbial loading is reduced.

Particle binding by the deep filters used in air purification systems takes place inside the filter medium. The filters are made up of multi-layer fleece composites of synthetic fiber materials which create a complex labyrinth of fibers and pores. The aim of the »Functionalization of fleece materials for deep filtration with water-based inorganic-organic coating sols« -project funded by the German Federation of Industrial Research Associations (AIF) was to develop high-performance deep filter media for air purification for use in air conditioning systems in public buildings and vehicle interiors.

The multifunctional coatings developed for this application at Fraunhofer ISC combine a range of different properties such as rigidity, hydrophobicity, and antistatic and antimicrobial effects. The production of water-based inorganic-organic hybrid polymers with these characteristics opened the door to practical use in the textile industry.


Combined unit for anodic, cathodic, and electrochemical dip painting

The coatings applied served the purpose of producing an electret effect, i. e. a permanent charge on the fiber surfaces to improve the deposition of particles with a diameter from 0.05 to 0.5 µm inside the fleece material. To produce the necessary electrically insulating coatings, fluorosilanes were integrated and fluoropolymers such as PTFE dispersions were added to the aqueous sols. Another aim was to render the fleece materials water-repellent in order to create a barrier against absorption of moisture.

Anti-microbial agents were also added to the coating material to prevent bacteria from colonizing the filter surfaces. Selected antimicrobial coating sols unleashed their effect at solids contents of just 5 percent.

The project team succeeded in raising the performance of the filters and efficiently reducing their microbial loading. Apart from air purification installations and filters for vehicle interiors, potential applications of these new deep filter media include industrial cleanrooms and emission control plants.

Combined pretreatment and dip painting device

Electro-assisted techniques are used in industry for coating large volumes of complex structural components with organic paints. A distinction is made between anodic and cathodic dip painting, depending on whether the workpiece is connected to the positive (anode) or negative (cathode) pole. The paint particles are oppositely charged and deposited. Coatings can also be applied electrolytically using a potentiostat.

In order to coat workpieces with hybrid polymers and inorganic sol-gel layers using the established anodic and cathodic dip painting methods and new electrolytic deposition techniques, Fraunhofer ISC commissioned a combined electrophoretic (anodic, cathodic) and electrochemical dip painting unit including pretreatment.

In the development of innovative corrosion protection coatings, it is important to be able to pretreat and coat metals under the same conditions as encountered in industrial painting and electroplating operations. Fluctuations in coating adhesion can be avoided by means of defined pretreatment methods. Automated painting processes minimize variations in the quality of the coated surface.


Metal substrates in detail


Hydrophobic surface © STFI


SEM image of the composite fleece material, © STFI

The two projects »Multimetal-capable environmentally compatible corrosion protection« (German Federation of Industrial Research Associations / German Federal Ministry of Education and Research) and »INGRAD - Innovative gradient coatings with nanoscale hybrid polymers« (German Federal Ministry of Education and Research) benefit from being conducted in realistic industrial conditions. The objective of INGRAD is to distinctly raise the overall performance of a coating by producing gradients in density, hardness and flexibility. For example, scratch protection of various substrates can be improved by increasing the density of inorganic components toward the surface of the coating, while a high degree of flexibility can be retained by increasing the proportion of organic or hybrid components in the deeper-lying regions of the coating. Stresses introduced in the surface of the coating can be absorbed by the gradient layers throughout its volume and not just at the interface with the substrate. This also has the effect of improving the composite coating's resistance to fluctuations in temperature. The use of pretreatment and coating methods analogous to those employed in industry is helping to accelerate the development of customized chromium (VI)-free systems for production applications as a substitute for chromating and primer systems used in corrosion protection.

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ENERGY TECHNOLOGY

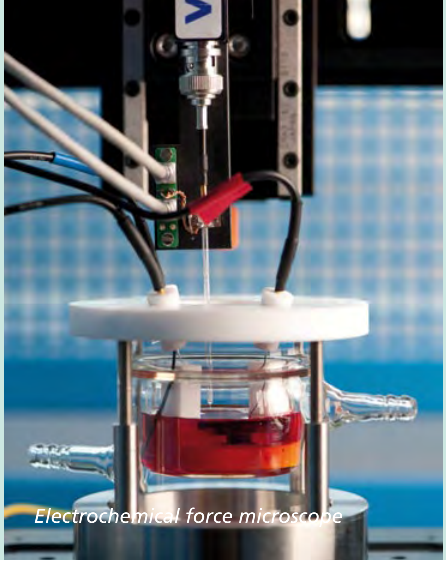
Measurement of battery-cell charging cycles

The current work of the Energy Technology business unit focuses on issues of applied electrochemistry in the field of electrochemical energy storage devices. In addition to the development of materials for lithium-ion batteries, this includes the development of nanostructured electrodes for electrochemical double-layer capacitors and their combination with battery electrode materials.

Electrochemical storage devices play an essential role in day-to-day life. In every car and portable electronic device such as laptops or cell phones, rechargeable batteries, also referred to as accumulators, are used in their millions every day. While the good old lead-acid battery still does a great job in automobiles, the market for portable electronic devices requires ultra-modern battery systems. The lithium-ion battery, introduced to the market by SONY in 1991, has become the standard and is replacing the nickel-metal hybrid battery previously used. The success of the lithium-ion battery is attributable to the high energy densities of over 200 Wh/kg it achieves, which are at least three times better than for any other rechargeable electrochemical energy storage device and which have boosted laptop battery time and made the many functionalities of today's multimedia cell phones possible at all. In other areas, however, things are more difficult for the lithium-ion battery. More than 99 % of all hybrid vehicles, for instance, run on nickel-metal hybrid batteries – the lithium-ion battery is something of an exotic choice and only to be found in a few luxury-class models. As we advance from plug-in hybrid vehicles to the all-electric car, however, the lithium-ion battery has a key role to play, because no other battery system achieves a range of 200 km and beyond without considerably restricting the space available for passengers and luggage.

The German government aims to have about a million electric vehicles on the road by 2020 and to make Germany the leading market for electromobility. If this aim is to be fulfilled, battery research will have to make a lot of progress, not only to increase the driving range of electric vehicles by raising the energy density of the storage devices but also to take their power density, service life and, in particular, intrinsic safety to the levels needed for these applications.

Lithium-polymer batteries are particularly promising for improving safety. Here the Energy Technology business unit draws on the many years of experience gained by Fraunhofer ISC in the field of inorganic-organic hybrid polymers (ORMOCER®s) which it deploys as a lithium-ion-conducting separator layer to replace the inflammable organic liquid electrolyte used up to now. Electrolyte separators have to fulfill two fundamental criteria. Firstly they have to function as an electrical insulator to prevent a sudden discharge between the electrodes and thus minimize the risk of explosion and fire, and secondly they must exhibit adequate ion-conductivity to facilitate a fast but controlled transfer of charge between anode and cathode. Solid electrolytes with a high degree of cross-linking exhibit distinctly lower ion conductivity than liquid electrolytes. Gels whose conductivity at room temperature is located between solid and liquid electrolyte are therefore preferred. The inorganic polysiloxane structure of the hybrid polymers makes for high thermal, mechanical and electrochemical stability – and thus for particularly high safety – and can also be functionalized without difficulty. The electrolyte properties can be adapted to the specific requirements by way of molecule design, chain length and degree of cross-linking. To optimize conductivity, a further, extremely promising approach is being pursued: nanobuilding blocks based on siloxanes are embedded in the ORMOCER® matrix and functionalized and cross-linked by organic groups. The conductivities of close on 1 mS/cm achieved so far prove the performance capability of this concept.



Electrochemical force microscope

In addition to the innovative polymer electrolyte systems, new electrode materials are being developed for lithium-ion batteries and electrochemical double-layer capacitors on the basis of Fraunhofer ISC's expertise in solid-state synthesis by sinter processes and solvothermal synthesis. The aim here is to synthesize materials with high specific capacitance which permit high voltages and therefore high energy densities in operation, but which also, thanks to their nanostructuring, facilitate rapid charging and discharging and ensure the high power density of the energy storage devices.

After considerable investment in materials development and sample preparation, as well as in electrochemical measurement techniques, the materials can now be processed to make electrodes and be characterized. The samples are prepared in a planetary ball mill or three-roll mill and the electrodes are prepared using lab coaters and screen printers. The electrochemical measuring cells are assembled in a series of glove boxes from which air and moisture are excluded. For electrochemical characterization of the developed materials, the measuring cells are tested on a multi-channel measuring device under controlled temperature conditions. More than 200 measuring channels are available for various mutually independent measurements. Long time cycles with a reference electrode provide detailed information about the behavior of various anode and cathode materials in conjunction with the electrolytes. Special methods such as scanning electrochemical microscopy (SECM) and impedance spectroscopy widen the portfolio of electrochemical characterization methods.

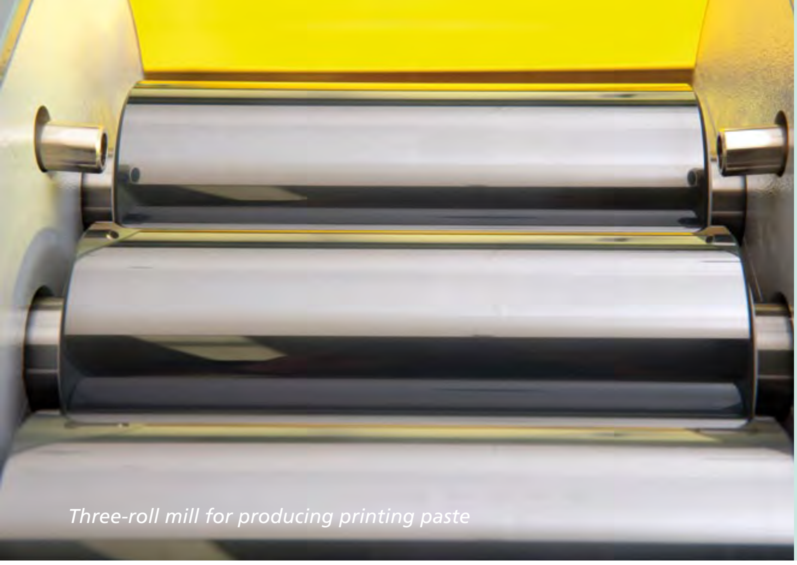
Electromobility system research

By engaging in electromobility system research, Fraunhofer seeks to support the transition to a sustainable »all-electric economy«. The special feature of the Fraunhofer approach is to study all the value-adding stages of electromobility and to conduct harmonized research into them – from energy generation, through transmission and distribution of the energy by the electricity networks as interfaces between the power grid and the vehicle, to energy storage and new vehicle, use and billing concepts. In the materials development subproject coordinated by Dr. Kai-Christian Möller, Fraunhofer ISC is collaborating with eleven other Fraunhofer Institutes to raise the energy density and safety of lithium-ion batteries. In addition, new types of battery are being investigated which could provide the basis for future energy storage systems. Fraunhofer ISC is contributing its expertise in the production of anode and cathode materials as well as in polymer electrolyte synthesis. Here the focus is on the synthesis of inherently safe anode and cathode materials and non-inflammable electrolytes for lithium-ion batteries. For the »Batteries of the next generation« work package, electrode supports with a high surface area are coated with materials capable of intercalation in order to develop hybrid concepts between batteries and double-layer capacitors.

High-performance storage devices for renewable energy applications

In the EnergyCap project, a consortium of research institutes, material manufacturers and users aims to raise the efficiency of electrochemical double-layer capacitors and improve their production quality and reliability, while at the same time reducing manufacturing costs. Although very similar in structure, double-layer capacitors are, compared with batteries, very fast electrochemical energy storage devices because no solid-state reactions occur but only rapid charge transfers in the electrochemical double layer on the electrodes. The stored energy can be released within seconds, which means that very high power densities can be achieved. Compared with lithium-ion batteries, however, the energy density is at least a factor of 20 lower.

Fraunhofer ISC is involved in a subproject for the development of desired properties of lithium-ion batteries and double-layer capacitors in hybrid capacitors. Like a battery, hybrid capacitors use a redox mechanism additionally for storing charges on a double layer and are thus able to improve the low energy


Three-roll mill for producing printing paste


Screen printer

densities of double-layer capacitors. For this purpose, highly porous materials are used and coated with various battery materials, so that porosity is largely retained and a harmonized pair of electrodes, consisting of anode and cathode, is produced. In addition to the development of hybrid electrodes, suitable electrolyte components which facilitate both the double layer and the battery storage mechanism need to be evaluated.

Lithium-ion battery innovation alliance

In the Lithium-Ion Battery LIB 2015 innovation alliance, eight partner institutes within the KoLiWIn collaborative research project, which has a research budget of four million euros, are jointly developing new materials concepts for electrochemical energy storage devices under the direction of Dr. Kai-Christian Möller. These will not only speed up charging and provide a greater quantity of energy than conventional battery types but will also be considerably safer. Alongside two further Fraunhofer Institutes, the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden, specialist units at the universities of Münster, Marburg, Ulm and Cologne and the Karlsruher Institute of Technology are involved in the development. A prominent battery manufacturer is in the advisory board of the research project. The object of KoLiWIn is to match together the individual battery components – nanostructured cathodes, anodes and polymer electrolytes – in such a way that they can be used to make fast, powerful and safe battery cells. During the three-year term of the project, findings will be collected from solid-state chemistry and electrochemistry as well as from materials research, supported by extensive characterization methods at Fraunhofer ISC and new simulation techniques at Fraunhofer IWM, which will assess the new materials across all scales from the interaction of the atoms in the material to the behavior of the materials in the product. In the end the aim is to produce an industrially implementable, effective and safe battery concept which is also suitable for use in vehicles.

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GLASS AND CERAMICS

Section through a kiln for sintering silicon carbide slide rings

This business unit pools the expertise of Fraunhofer ISC in technical speciality glasses, glass ceramics, high-performance ceramics and ceramic high-temperature reinforcing fibers.

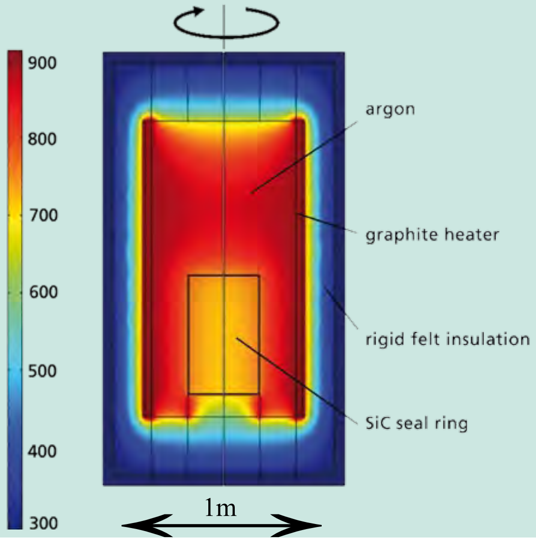
A key area of activity is process and parameter optimization for the inherently safe and cost-efficient manufacture of high-performance ceramics at low energy consumption. Within the process chain, the central process steps of shaping, debinding and sintering stand in the forefront. The combination of modeling and in-situ measurement permits the targeted optimization of materials and the determination of adapted process parameters. The work performed by the business unit also includes the development and construction of measuring instruments, such as thermo-optical in-situ measuring systems for process monitoring, which are in demand worldwide by customers from the glass and ceramics industry.

Other key areas of work in the field of technical ceramics include the development and synthesis of starting materials as well as the development and adaptation of manufacturing techniques for temperature-stable ceramic reinforcing fibers through to fiber production at pilot-plant scale. Highly stress-resistant materials with low susceptibility to wear can make an important contribution to improving the efficiency of combustion processes. For example, ceramic composites that can withstand the high temperatures at which conventional metallic materials fail make it possible to achieve higher process temperatures in power plants and thus help to raise efficiency.

The development of customized speciality glasses, as used e. g. in the optical industry, the construction sector and in electronics, is another main subject area addressed by the business unit. The entire development and manufacturing process is covered, from simulation techniques to identify suitable glass compositions for a specific requirements profile over actual glass development and glass characterization through to process development. The automated glass screening system at Fraunhofer ISC considerably shortens development times. On special demand, the glass is optimized for specific applications and can be supplied in small quantities of up to a few kilograms.

A deeper knowledge of the material and the analysis of structural property relationships form the basis for the targeted improvement of products and processes. The Center for Applied Analytics (ZAA) has a wide range of methods and processes at its disposal for chemical analysis, surface analysis and microstructure analysis. The combination of artifact-free preparation methods such as cross-section polishing and focused ion beam (FIB) techniques with ultra-high-resolution electron microscope analysis provides the basis for the rapid analysis of possible causes of damage as well as for making improvements. The Center for Applied Analytics is thus a central point of contact for analytical issues in industrial product development and optimization.

The following project examples provide information on the development status of high-temperature-resistant oxide-ceramic reinforcing fibers for insulation applications and on energy minimization in ceramics manufacture, the development of new thermo-optical testing facilities and the development of an opalescent glass exhibiting high resistance to changes in temperature.



Simulation of the temperature distribution in the kiln

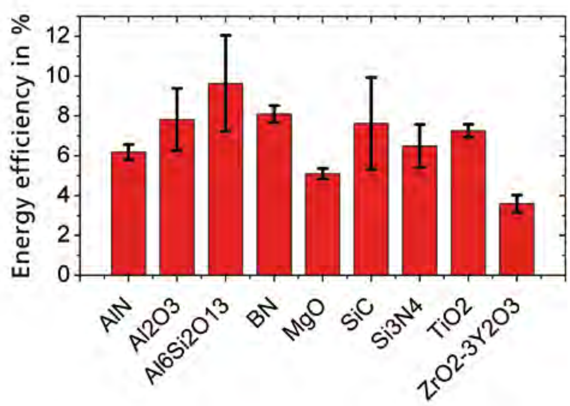
Energy and cost reduction in the heat treatment of ceramics

Design engineers select materials primarily according to aspects of function and cost. Increasingly, however, the carbon footprint is being taken into account in the manufacture of materials and is expected to become an important competitive criterion in the near future. The theoretically necessary energy requirement in ceramic firing is calculated from the change in the internal energy of the material being fired. The energy efficiency of the firing process is derived from the quotient of theoretical energy requirement and actual energy consumption. At present this is about 3 to 10 % and thus holds great potential for improvement.

In the ENITEC collaborative research project, methods are being developed for minimizing the energy required in ceramics manufacture. Three ceramics manufacturers: CeramTec AG, Lapp Insulators GmbH & Ko. KG and BCE Special Ceramics; two kiln equipment producers: Eisenmann Maschinenbau KG and FCT Systeme GmbH; as well as Fraunhofer ISC and Fraunhofer IWM in Freiburg are cooperating in this project. The heat treatment process is being studied on continuous kilns as well as in batch operation. Oxide and non-oxide ceramics in component sizes from the millimeter to the meter range are being studied. The aim is to reduce the energy requirement by at least 40 %.

In the attempt to minimize the energy consumed in heat treatment, a conflict of objectives arises for many process parameters. If the heating and cooling rates are increased, the energy requirement decreases – owing to the shorter cycle time – but the scrap rate can rise. Furthermore, because of the temperature gradients, excessive heating rates can cause warping of the component or uneven sintering results in the fired stack. As a result, an increased amount of energy is required for rework.

Computer simulation is essential in the design and development of new kiln facilities and processes in order to precisely determine the optimal course to pursue in the conflict of objectives deriving from energy minimization, higher throughput, low scrap rate and near-net-shape sintered parts. The temperature distribution and energy efficiency of the kiln must be coupled to the component and – in the case of large parts – also to smaller areas within the component. The relevant size scales therefore range across three orders of magnitude: from a few meters in the kiln to a few millimeters in the component. FE models which are connected by way of submodels are used for the simulation. The stack of slide rings for firing was homogenized in several steps. The model kiln was equipped with a virtual temperature controller, enabling any temperature cycles to be calculated. The computer time on a standard PC only amounts to about 20 minutes for the simplified model, and the simulated energy consumption matches the measured energy consumption to within 10 %.



Energy efficiency of the firing process

TOM-AC device for measuring sintering properties in controlled atmospheres

Using the FE simulation both the energy required as well as the temperature-time curve for the stack to be fired can be predicted. Applying thermo-optical measuring techniques, the firing result can be precisely calculated from the temperature-time cycle. Simulation therefore enables the firing conditions to be specifically optimized.

Thermo-optical testing units for the refractory industry

Refractory materials are mainly used for cladding industrial furnaces, e. g. in the production of steel or glass. The operating costs and energy consumption of such furnaces depend considerably on the thermal insulation capacity and service life of the refractory materials. These must have good mechanical and thermal high-temperature properties – high creep strength, damage tolerance and thermal shock resistance, as well as low thermal conductivity.

Testing the high-temperature properties of refractory materials is important for comparing the performance of products from different manufacturers, for targeted further development of materials and for precise configuration of the furnace equipment in FE models. Around the world, therefore, the search is on for suitable testing methods. Owing to the conditions in which they are used, the testing of refractory materials imposes exacting demands on the measuring technology. Temperatures frequently exceed 1700 °C and the atmosphere can be oxidic, inert or reducing. What's more, the heterogeneous structure of refractory materials means that large sample volumes comprising several cubic centimeters have to be measured, which goes beyond the scope of conventional thermo-analytical testing techniques. In a project for the European Centre for Refractories (ECREF), Fraunhofer ISC's special thermo-optical measuring methods (TOM) are currently being developed further for the high-temperature testing of refractory materials. Two new units are being built for the purpose: TWIN-TOM-AC and TOM-IR.

TWIN-TOM-AC consists of two different measuring furnaces. One of them is intended for measuring mechanical high-temperature properties, the other for determining thermal properties. Viscose moduli are measured using the refractoriness under load and hot bending method, fracture toughness is measured using the wedge splitting method, the modulus of elasticity by means of reversible pressure deformation and the coefficient of thermal expansion using dilatometry. In all cases, inductive travel sensors are combined with optical measuring methods to obtain as complete a description as possible of the material behavior. While the travel sensors can only be deployed in the direction of force, they offer a very high accuracy, the optical methods provide a two-dimensional image of the samples. In order to rule out temperature measurement errors caused by temperature gradients in the furnace, the temperature is monitored by thermocouples inserted in holes drilled in the refractory material samples. On the second TWIN-TOM-AC measuring furnace, the laser flash method is used to measure temperature conductivity. One face of the sample is heated by a laser pulse while the rise in temperature on the opposite face is recorded by a sensitive pyrometer. The temperature conductivity is determined by inverse simulation from the temperature increase behavior on the rear face. The thermal conductivity can be calculated from the temperature conductivity.

The second facility, TOM-IR, is intended for automated measurement of the thermal shock resistance. In a controlled atmosphere, samples of refractory material are quickly heated to temperatures of up to 1200 °C by infrared heating and then very quickly cooled in a cold environment. Resulting cracks are measured by sensitive acoustic sensors. In addition, the shadow image of the sample is recorded and analyzed for crack formation. Temperatures and temperature gradients in the samples are determined by two pyrometers. The facility permits automatic testing of many temperature cycles on one sample as well as automatic sample changing. The new measurement method reflects the real stress profile of refractory materials more closely than conventional thermal shock tests, which use cooling in liquid media. The aim of this work is to develop new standard tests on the basis of the new high-temperature methods.

Polycrystalline long fibers for high-temperature applications

Fiber mats of aluminum oxide and silicon oxide are used as thermal insulation material in the high-temperature range e. g. for industrial furnaces. Particular attention is paid to their technical material properties. The aim of a project being conducted with a prominent manufacturer of such fiber mats, the company Rath GmbH, is therefore to develop and establish a production process for oxide fibers which will permit precise control of mat manufacture in production.

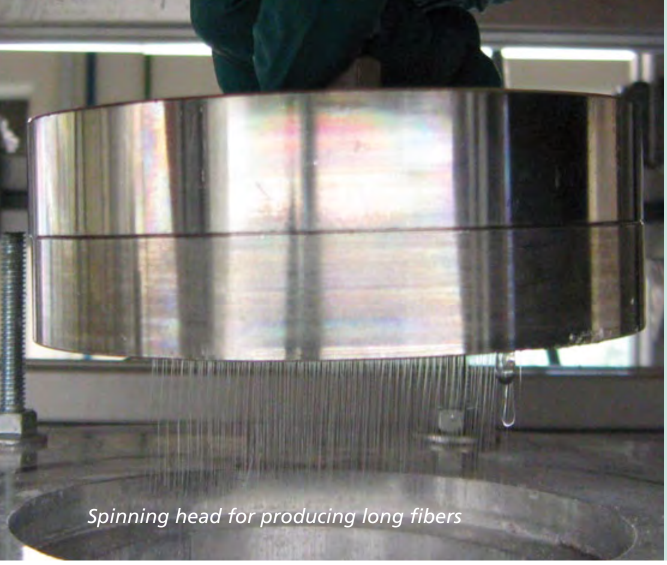
In today's mat manufacturing, the staple fibers in the Al_2O_3-SiO_2 material system are produced using the centrifugal spinning method. As a result of this production method, they exhibit a widely fluctuating range of properties. Rath GmbH and Fraunhofer ISC have already shown in an earlier joint project that if the centrifugal spinning process is optimized the fiber properties fluctuate much less. A small proportion of the fibers were still in the critical diameter range, however, and so a carcinogenic risk could not be completely ruled out.

In the current »Polycrystalline long-fibers for high-temperature applications« project funded through the ZIM innovation program, the aim is to develop a ceramic long fiber in the Al_2O_3-SiO_2 material system and to replace the manufacturer's existing centrifugal spinning process with a long-fiber spinning process. The long fiber spinning process enables the fiber properties to be more precisely induced than in the centrifugal spinning process, while also distinctly reducing the scope for fluctuation. The aim is to achieve a mean fiber diameter of µ10 with a diameter fluctuation of ±10 %. This will render the fibers non-respirable, so that according to present knowledge a carcinogenic effect of the fibers can be ruled out.
These long fibers can be used to produce homogeneous fiber mats if the fiber baling process upstream of the ceramization kiln can be successfully rendered continuous.

In the period under review a laboratory-scale unit at Fraunhofer ISC for spinning long fibers was modified to meet the requirements of the funded project. The spinning sols were produced and adapted by Rath. A stable long-fiber spinning process with 300 filaments and less than 3 % filament tear was realized at laboratory scale. The first tests on thermal refinement of the spun green fibers showed that the desired phase composition can be induced after ceramization of the fibers. In addition, a concept was drawn up at Fraunhofer ISC for construction of a pilot plant facility to produce fiber mats using the long-fiber spinning process. Work is now commencing at Rath, the fiber mat manufacturer, to build the pilot plant in order to develop the process under production-like conditions.

Development of a glass composition with increased resistance to changes in temperature

The special glass development work conducted at Fraunhofer ISC often involves the adaptation of certain physical glass properties to special requirements for use of the glass products. Last year, for instance, a new batch formulation was developed for a white opal glass, which is used as container glass in dental surgeries. This development was commissioned by the company Alfred Becht GmbH in order to ensure the customary quality in the face of higher product requirements.
As the new generation of autoclaves used in dental surgeries to sterilize glass containers permits a faster change in temperature, the glass containers must be able to withstand wide fluctuations in temperature. The aim was to modify the formulation used by Becht to this end. As an additional challenge, the look and feel of the white opalescent glass had to remain unchanged.



Spinning head for producing long fibers

White opal glass with increased temperature change resistance

The temperature shock behavior of glass depends to a large extent on the coefficient of temperature expansion, which is influenced by the batch composition. The basic formulation was changed specifically in several steps and as a result the coefficient of temperature expansion was reduced by 25%. The look and the feel of the glass produced were not affected. As the batch composition also determines the processing properties such as melting temperature and viscosity, adept selection of the constituents achieved a balance between desired and undesired effects on the physical properties of the glass melt and the glasses. The processing temperatures of the glass in the glass foundry only had to be increased moderately in the end for the new batch composition. The new formulation has been handed over to the customer and the glass foundry. Further temperature change tests in accordance with DIN ISO 7459 will be conducted on the glass containers made using the new formulation.

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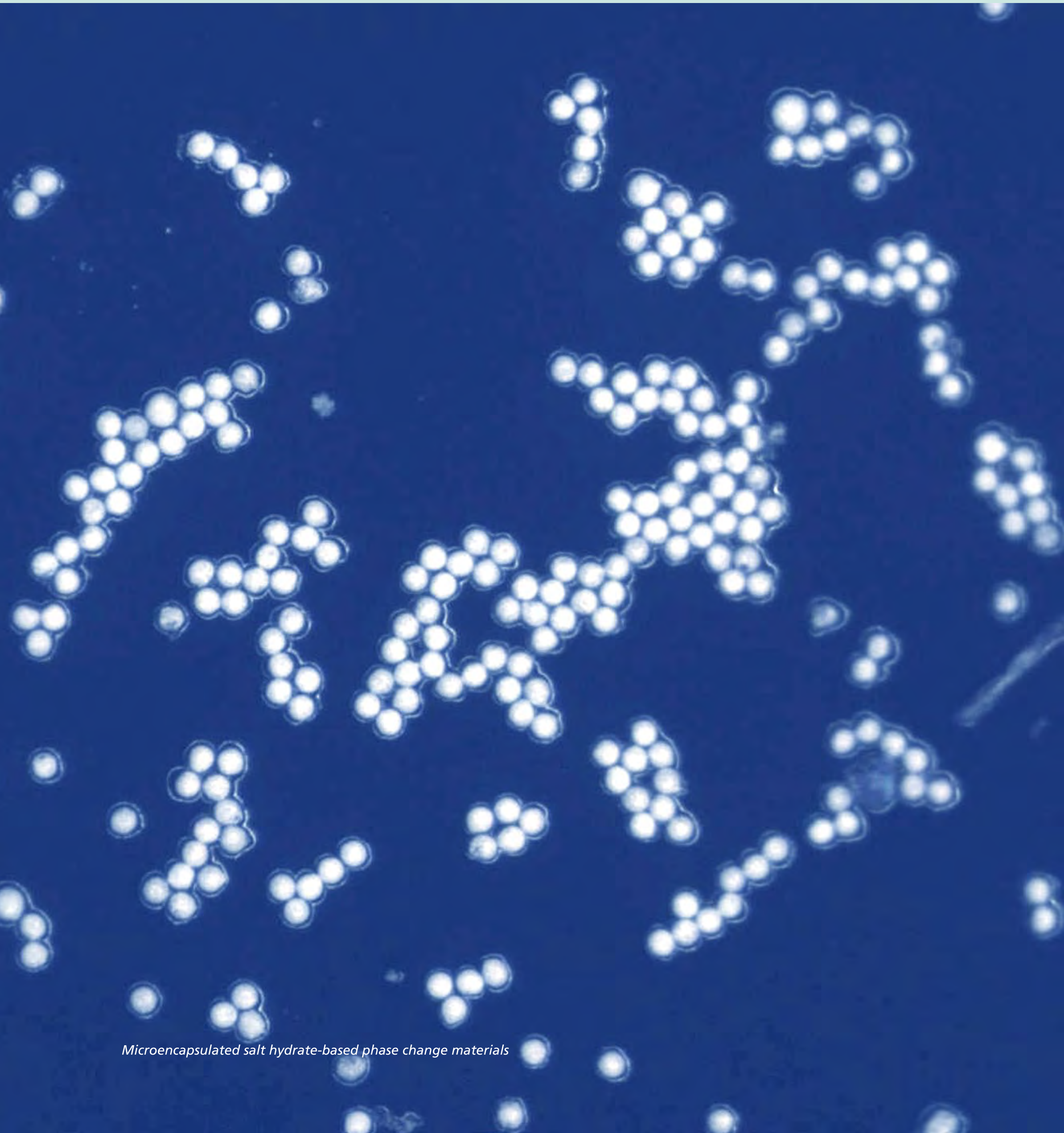
CONSTRUCTION AND ENVIRONMENT



Microencapsulated salt hydrate-based phase change materials

In addition to conventional building materials such as concrete, the Construction and Environment business unit primarily conducts work on inorganic and hybrid functional materials in order to render the many different possibilities of chemical nanotechnology usable for the building materials industry and for the sustained protection of the environment.

This work includes multifunctional, nanotechnologically optimized coatings which are easy to clean, have an antimicrobial effect or can remove pollutants such as NO_x and formaldehyde from the air by means of photocatalytic processes. Examples of applications for the healthy home can be found in the special section on health research.

The main aim of the business unit is to improve the resource efficiency of energy and materials, also in existing applications. One example is the use of secondary raw materials through the partial replacement of cement by fly ash and granulated blast-furnace slag. A major contribution to research into the still relatively unknown reaction mechanisms in the use of secondary raw materials can be made by Fraunhofer ISC's Center for Applied Analytics (ZAA), which has high-resolution analysis equipment at its disposal. Processes can only be controlled if they are precisely understood.

Resource efficiency is also the aim of current projects such as the development of a new type of latent heat storage material based on salt hydrate or the search for ways to increase the chemical and mechanical resistance of concrete by using micro- and nanosilica.

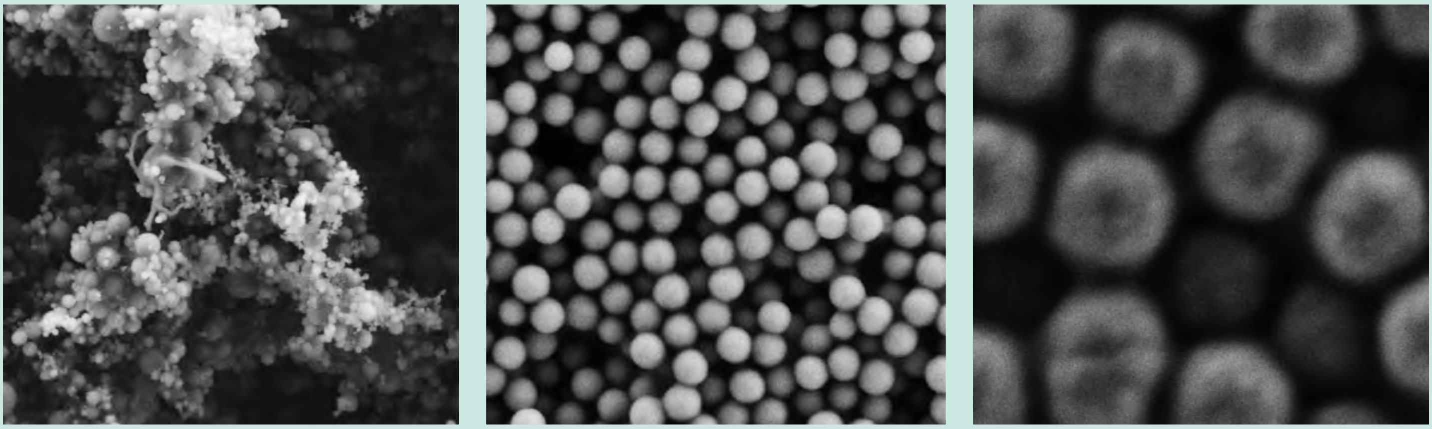
Cold-hardening ceramics through nanotechnological microstructure optimization

Usually, ceramics (at least partially crystalline, inorganic, nonmetallic materials) are produced by ceramic firing at very high temperatures of up to well in excess of 1000 °C. During firing, the individual grains (particles) of the starting materials are sintered with each other and thus form a compact material. These processes are energy-intensive and may be difficult to control, e. g. with regard to shape retention despite considerable shrinkage. Ceramic firing can be replaced by chemical reactions at moderate temperatures < 100 °C to produce what are referred to as »cold-hardening ceramics«. Many well-known binder systems are among these – cement, for instance, sets in a chemical reaction with water. Instead of forming sinter necks, which bind the individual grains firmly together, the calcium silicate hydrates (CSH phases) produced by the reaction of the calcium silicate particles (CS phases) with water form a felted aggregate. Cement is therefore a hydraulic binder and is used to make concrete.

Particularly high strengths are obtained in ceramics if a very dense microstructure is successfully produced, which contains few cavities (pores) and is therefore more resistant to external corrosive attack. To achieve as high a packing density of the individual components as possible, their grain sizes and grain size distributions must be matched to each other and smaller particles must fit exactly into the gaps which are not filled by the larger particles. In concretes this matching relates to the grain sizes of the aggregates (gravel and sand with grain sizes of several centimeters to tenths of a millimeter) and of the cement (0.1 to 100 µm).

The packing density can, however, be increased into the nanometer range (10 to 1 000 nm) if correspondingly small particles can be dispersed in the cement mortar. For this purpose microsilicas are used which are a by-product of silicon manufacturing. They consist of amorphous silicon dioxide (SiO_2) in the form of spherical particles with diameters of approx. 30 to 600 nm *(Fig. 1, left)*. They are mixed into the cement mortar and bind with the calcium hydroxide ($Ca(OH)_2$) from the cement (pozzolanic reaction).

Perhaps even more suitable for further optimizing the packing density are SiO_2 particles of defined size, which can be produced synthetically in sizes from 50 nm to 1 µm in the Stöber process *(Fig. 1, middle and right)*. As the Stöber particles



1µm

1 *Scanning electron microscope images of microsilica - left: commercial microsilica; middle and right: synthetic microsilicas (Stöber particles) of various sizes (Photo: ISC)*

synthesized in the laboratory were initially only available in small quantities, cement mortar samples (2-cm cubes) were produced for the first tests. Although they did not match the usual standard prisms (4 x 4 x 16 cm), their properties were comparable with those of corresponding reference samples. The results were, however, below expectations. The reason could be that under the conditions of mortar production the particle agglomerates had not been completely broken down. Alternative methods are therefore being used to attempt to disperse the microsilica and Stöber particles to the optimal particle sizes in the nanometer range also in the set mortar. A reduction of porosity would make the set mortar stronger and more resilient. Tests on the resulting strength, porosity and corrosion stability are being conducted in cooperation with the University of Kassel (Faculty of Civil Engineering, Building Materials and Construction Chemistry). The aim is to produce an improved mortar which can be used in applications for which concrete is not or only limitedly suitable, e. g. in pipes for heavily corrosive waste water.

Encapsulation of inorganic phase-change materials

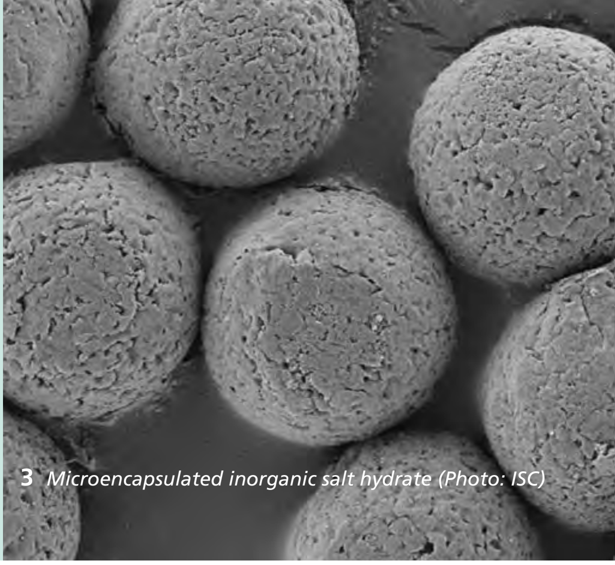
Energy efficiency in buildings makes a significant contribution to reducing CO_2 emissions. The aim is therefore to reduce the heating energy required, by means of thermal insulation materials or by using thermal storage materials.

The simplest way of storing energy is to increase the temperature of a heat-storage medium which is then able to release thermal energy as it cools down again – the principle of a conventional hot-water heating system. However, another, more efficient form of thermal energy storage exists. It makes use of the fact that some materials can absorb or release energy during transition into a different phase, for example into a liquid aggregate state. This energy is referred to as latent heat, and the substances used for this type of thermal storage are referred to as latent heat storage materials (or phase-change materials, PCMs). This storage method is very efficient because the temperature of the substance does not change during the phase transition and there is therefore no need for elaborate insulation.

In order to utilize this storage method, various concepts have been developed in recent years for different applications and temperatures. The first step is to choose a latent heat storage material that is suitable for the particular temperature range. For example, an application such as waste heat recovery requires a material with a much higher melting point than would be required for a building air-conditioning system. As the latent heat storage materials change their aggregate state during »charging« and »discharging«, suitable containers are required. These have to be liquid-tight and possibly also corrosion-stable. The size of the containers is adapted to the specific application and ranges from large tanks to microcapsules. The latter offer the possibility of integrating the storage material in other materials, such as plasters or mortars. Up to now reliable microencapsulation was only possible if the latent heat storage medium was based on water-insoluble organic materials, e. g. paraffin. Inorganic storage materials are, however, much more attractive for many applications. They are non-combustible and generally have a higher storage capacity. The disadvantage of this materials group is their water solubility. Special challenges are also posed by materials under consideration for applications at room temperature. This mainly relates to salt hydrates, which even under normal environmental conditions do not exhibit adequate stability. They release their water of hydration too easily or absorb additional water, which changes their physical properties detrimentally.

Fraunhofer ISC has therefore developed a novel process for encapsulating inorganic latent heat storage materials. Owing to the water solubility of salt hydrates as mentioned above, however, the encapsulation method has to meet special requirements. Many of the customary polymerization techniques used for encapsulation cannot be used for water-soluble substances.

2 *Cube samples of set cement mortar before (left) and after (right) measurement of the compressive strength (Photo: ISC)*



3 *Microencapsulated inorganic salt hydrate (Photo: ISC)*

On the basis of ORMOCER®s, which have already been successfully used as barrier materials in microelectronics, the working group led by Dr. Uta Helbig and Dr. Ruth Houbertz has succeeded in developing an encapsulation material and an associated polymerization technique which enables salt hydrate melts to be enclosed in a hybrid polymer shell. Thanks to continuous further development of the technique over the past two years, the microcapsule wall and diameter have been optimized. The microcapsules produced have been analyzed, including with newly developed locally resolved spectroscopic methods, which for the first time permit non-destructive cross-sectional imaging of the microcapsule. It has thus been proved that this technique produces microcapsule diameters which typically measure about 40 µm and that the wall thickness of the microcapsule shell is below 5 µm. This small wall thickness is particularly advantageous for the application. The proportion of active material by volume increases and a rapid transfer of heat can take place across the microcapsule wall. The underlying polymerization mechanism is currently being intensively researched. In addition, tests on the mechanical stability and barrier effect of the microcapsule wall need to be conducted.

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CENTER SMART MATERIALS CESMA

Roller actuator

Smart materials is the generic term for a highly inhomogeneous family of materials which include polycrystalline solids, switchable liquids and elastic polymers. With their ability to very quickly and efficiently convert electrical energy into mechanical energy and vice versa, and to change their geometry or rigidity in the process, smart materials open up completely new applications. Their individually tunable range of properties with regard to resulting forces, paths traveled or dynamics holds great potential for new technical and design solutions. The myriad of new applications results from the fact that new types of construction become possible for e. g. couplings, actuators and sensors. The diversity of materials and design possibilities opens up solutions for complex systems in virtually all sectors of industry.

The basic idea behind CeSMa is to be able to respond quickly to new market needs for better, lighter and cheaper technical products. These needs are anticipated and channeled into the development of new and enhanced materials and into the design of prototype actuators, sensors and converters.

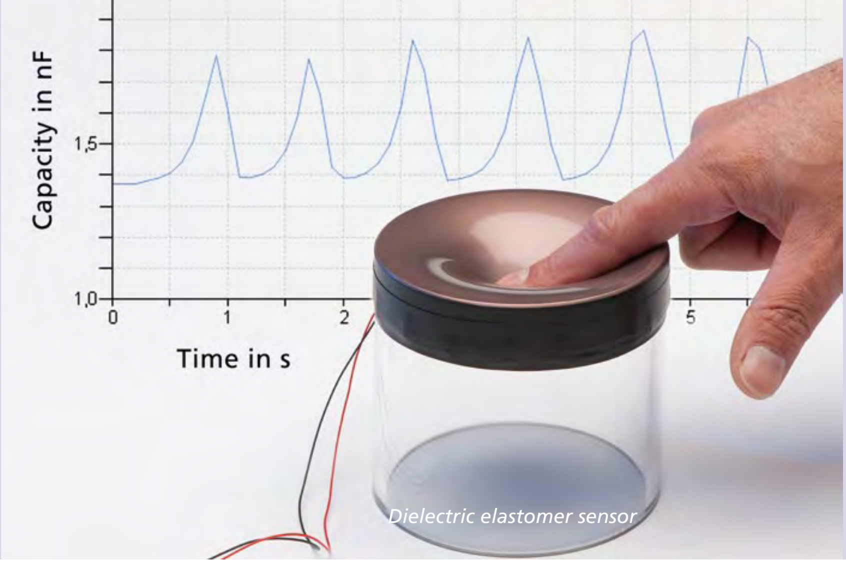
The forces driving the use of smart materials are resource and energy efficiency, functional integration to reduce the number of components, and the use of new functionalities, e. g. tunable damping elements and integrated sensor/actuator functions.

The portfolio of materials will continue to be systematically expanded. It extends from highly dynamic piezoelectric ceramics through magneto- and electrorheological fluids to highly elastic electro- and magneto-active elastomers. Driven by market needs, a new material was created in the form of metallo-polyelectrolytes with the aim of qualifying them for use in rapidly switching smart windows.

Smart Windows

Switchable transmission has been a long-cherished dream for building and vehicle air-conditioning because it can achieve energy savings of up to 30 %. In the past a series of smart window developments failed to lead to the desired goal, and others needed a very long time to get onto the market. The reasons are many and varied, but essentially the implementation difficulties are attributable to the complex structure consisting of five und more functional layers and the inadequate long-term behavior (switching stability) over many years.

In a collaborative research project funded by the German Federal Ministry of Education and Research (BMBF), Fraunhofer ISC and four research partners are pursuing an innovative approach, starting with the synthesis of switchable substances, followed by their complete characterization and measurement in realistic application scenarios, and culminating in the construction of test windows and their subsequent assessment in climate tests. A new class of materials will help to remedy the defects of the concepts tried up to now. They are the metallo-polyelectrolytes (MEPE) from the working group led by Prof. Dr. Dirk Kurth, Chair for Chemical Technology of Material Synthesis at the University of Würzburg, where the metallo-polyelectrolytes are synthesized. The tests on the structural configuration before, during and after switching are handled by the Federal Institute for Materials Research and Testing (BAM) in Berlin. The Institute of Materials for Electrical and Electronic Engineering IWE Karlsruhe is studying and modeling the interfacial reactions. Fraunhofer ISC is developing leak-proof MEPEs, assessing them over more than 100 switching cycles and building and testing the laboratory demonstrators. The partners aim to have a fully tested demonstration window ready by the end of the two-year project term, with which they can convince interested parties in industry of the applications potential of this technology.



Dielectric elastomer sensor

In MEPEs, metal ions determine the color of the material. Their oxidation state can be switched electrically, which produces the color effect. If for example divalent iron ions release electrons, the blue color disappears and the complex no longer absorbs in the visible range of light. The change is reversible. The decisive factor, however, is that these switching events happen very quickly and only require low voltages of 1 to 1.5 V.

The structure of a smart window with MEPEs is relatively simple. It consists of two panes of glass, the facing sides of which are coated with a thin, transparent electrode. The gap is filled with MEPEs. A stable edge joint (insulating between the panes of glass and completely sealed) ensures that the MEPEs remain permanently switchable. Optimization of the edge joint is part of the project.

Dielectric elastomer actuators

Dielectric elastomer actuators (DEA) are electroactive polymers which change their size and shape when an electric field is applied. The special thing about this young class of polymer actuators is that they achieve elongations which are two orders of magnitude greater than the known piezoceramic actuators. DEAs hold great applications potential because, in addition, they have relatively high activation frequencies and therefore respond more quickly to electrical signals. Economic advantages derive from their low density in connection with the use of lightweight polymers and their potentially low production costs.

Up to now work in this field has mainly focused on special types of actuators and possible applications. The range of materials suitable for DEAs is, however, very limited and the disadvantages of present DEAs preclude their use in further applications. Very high electric field strengths are still needed to activate them, and too little knowledge exists about the service life of the new actuators. For this reason, CeSMa is focusing on the development and optimization of DEA materials with a distinctly improved performance profile. Work is currently being conducted into development projects funded by the German Federal Ministry of Education and Research (BMBF) – BelievE and INFUNK – on significantly lowering the operating voltage and determining and improving the reliability of the actuators. The aim is also to demonstrate the performance capability achieved using the example of a mini-valve.

To produce elastic DEAs with a reduced switching voltage, the materials used must be changed in such a way that they have a higher permittivity. The team has already succeeded in considerably increasing this property, which is also referred to as the dielectric constant. This success shows the potential which can be exploited for future industrial applications through the further development of DEA materials.

Dielectric elastomer sensors

Like the DEAs, dielectric elastomer sensors (DES) are a new class of mechanical sensors with which deformations, forces and pressures can be measured relatively easily. They exhibit particularly high elasticity and can therefore be integrated in structures which are subjected to severe deformations.

Dielectric elastomer sensors are of simple design. They consist of a very elastic elastomer film which is coated on both sides with highly flexible electrodes. The sensor effect derives from measuring the electrical capacitance.

Color variants of metallo-polyelectrolytes (MEPE) (© Dirk Kurth, Chair for Chemical Technology of Material Synthesis, University of Würzburg)

Under compression or tensile loading, the thickness of the sensor film is reduced while the surface area expands, producing an increase in capacitance.

DESs have a wide range of application. By measuring the change in capacitance they can be used, for example, as footstep sensors in floors, for measuring stock levels by weight, and for the continuous pressure measurement of gases and liquids. In each case the various applications require a different properties profile of the dielectric elastomer or a different sensor design. The CeSMa research group has the multidisciplinary expertise required to adapt the composition of the materials, the film geometry and the sensor design to the needs of each specific application and the customer's requirements.

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FURTHER INFORMATION ON THE PROJECTS PRESENTED ON THE PREVIOUS PAGES

Business Unit Surfaces and Coatings

Permanent mold release agent coating based on hybrid nanocomposites (Perma Trenn)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 03X2511F
Coordinator: Intier Automotive Eybl Interiors GmbH
Partners: Intier Automotive Eybl Interiors GmbH, Intier Automotive Näher GmbH, ACMOS Chemie KG, Nanogate AG, Fichtner & Schicht GmbH, WIS-Tooling GmbH
Project term: December 2006 – November 2009

Innovative coating systems for special optical fibers based on nanoscale hybrid-polymer layer systems (BEOS)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 03X0031C
Coordinator: FiberTech GmbH
Partners: FiberTech GmbH, SurAChemicals GmbH, Institut für Photonische Technologien e. V.
Project term: April 2007 – March 2010

Functionalization of fleece materials for deep filtration with water-based inorganic-organic coating sols
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)/AiF
Grant Number: 261 ZBG
Coordinator: Sächsisches Textilforschungsinstitut e. V.
Partners: Sächsisches Textilforschungsinstitut e. V. (STFI), Chemnitz, Institut für Luft- und Kältetechnik gGmbH (ILK), Dresden
Project term: July 2007 – March 2010

Environment-friendly corrosion protection
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)/AiF
Grant Number: IGF-08/05 ZBR 07361/08
Coordinator: Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik (IWU) Dresden
Partners: Fraunhofer IWU, EFDS - Europäische Forschungsgesellschaft Dünne Schichten e. V.
Project term: May 2009 – October 2011

Innovative gradient layers with nanoscale hybrid polymers (INGRAD)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 03X0099D
Coordinator: SurA Chemicals GmbH
Partners: SurA Chemicals GmbH, Heiche Oberflächentechnik GmbH, Ritzi Lackiertechnik GmbH,
MAT Medizintechnik, Fraunhofer ISC, Fraunhofer FEP
Project term: June 2010 – May 2013

Business Unit Energy Technology

Energy storage technology/Materials Development (MALION)
Fraunhofer Systemforschung Elektromobilität:
www.elektromobilitaet.fraunhofer.de/schwerpunkte/energiespeichertechnik
Coordinator: Fraunhofer ISC
Partners: Fraunhofer ITWM, ISIT, ICT, IGB, IZM, IKTS, IAP, IWM, IFAM, IWS, IMS
Project term: May 2009 – June 2011

High-performance storage devices for renewable energy applications (EnergyCap)
Project funded by Bundesministerium für Wirtschaft und Technologie BMWi
(Federal Ministry of Economics and Technology)
Grant Number: Az 0327822B
Coordinaor: BMW Forschung und Technik GmbH, Munich
Partners: 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
Associated partner: ENERCON GmbH, Aurich (no funding)
Project term: July 2009 – June 2012

FURTHER INFORMATION ON THE PROJECTS PRESENTED ON THE PREVIOUS PAGES

Lithium-ion battery innovation alliance KoLiWIn: New materials concepts for electrochemical energy storage devices
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Coordinator: Fraunhofer ISC
Partners: Philipps-Universität Marburg, Fachbereich Chemie; Universität Ulm, Abteilung Anorganische Chemie I; Universität zu Köln, Institut für Anorganische und Analytische Chemie; Universität Münster, Institut für Anorganische und Analytische Chemie; Karlsruhe Institut für Technologie, Institut für Werkstoffe der Elektrotechnik;
Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Dresden;
Fraunhofer-Institut für Werkstoffmechanik IWM, Freiburg
Project term: July 2009 – June 2012

Business Unit Glass and Ceramics

ENITEC - Efficient low-energy debinding and sintering technology in ceramic production
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 02PO2025
Coordinator: CeramTec AG
Partners: CeramTec AG, Lapp Insulators GmbH & Ko. KG, BCE Special Ceramics, Eisenmann Maschinenbau KG,
FCT Systeme GmbH, Fraunhofer IWM, Freiburg
Project term: July 2009 – June 2012

Business Unit Construction and Environment

Cold-hardening ceramics through nanotechnological microstructure optimization
Project funded by Bundesministerium für Bildung und Forschung BMBF (Federal Ministry of Education and Research)
within the WING-Program: Nanotechnologie im Bauwesen – Nano Tecture
Grant Number: 03X0067E
Coordinator: BASF Construction Chemicals GmbH
Partners: BASF Construction Chemicals GmbH, Universität Kassel Fachbereich Bau- und Umweltingenieurwesen,
Verein Deutscher Zementwerke e. V., FEhS – Institut für Baustoff-Forschung e. V.
Chemiewerke Bad Köstritz GmbH, Woellner GmbH & Co. KG, Remmers Baustofftechnik GmbH,
PigTek Pig Equipment Group, CTB
Project term: June 2009 – May 2012

Multi-source Energy Storage System Integrated in Buildings (MESSIB)
EU funded project within the 7th framework program
Grant Number: 211624
Coordinator: Acciona Infraestructuras S. A.; Javier Grávalos
Coordinator within Fraunhofer: Fraunhofer ISE
Project term: March 2009 – February 2013

Center Smart Materials CeSMa

Development and research of durable, long-life material systems of dielectric elastomer actuators (BelievE)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 13N10635)
Coordinator: Prof. Schlaak, TU Darmstadt
Project term: August 2009 – July 2012

Integration of novel functional construction materials and their application in a miniaturized valve assembly (INFUNK)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 16SV3725
Coordinator: Fraunhofer ISC
Project term: November 2008 – December 2011

SmartWin-Mepe: Joint Project: Smart Windows based on Metallo-Polyelectrolytes, ISC Subproject: Build-up and test of ECW-hybrid-synthesis and characterization (MEPE)
Project funded by Bundesministerium für Bildung und Forschung BMBF
(Federal Ministry of Education and Research)
Grant Number: 13N11284
Coordinator: Fraunhofer ISC
Project term: September 2010 – August 2012

FRAUNHOFER

The Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains more than 80 research units in Germany, including 60 Fraunhofer Institutes. The majority of the more than 18,000 staff are qualified scientists and engineers, who work with an annual research budget of 1.65 billion euros. Of this sum, more than 1.40 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

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The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

EDITORIAL NOTES

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ANHANG / APPENDIX

INHALTSVERZEICHNIS ANHANG

WISSENSCHAFTLICHE VORTRÄGE UND VERÖFFENTLICHUNGEN

Bachelor-Arbeiten

Brand, Bastian:
Verifikation einer Methode zur in-situ Viskositätsmessung von Glasschmelzen.
Fachhochschule Würzburg-Schweinfurt

Deinhardt, Anika:
Entwicklung eines Glaslotes für einen Glas-Metall-Verbund für solare Anwendungen.
Fachhochschule Jena

Rauscher, Thomas:
Herstellung und Charakterisierung von alpha-Aluminiumoxidgrünkörpern.
Bayerische Julius-Maximilians-Universität Würzburg

Master-Arbeiten

Herzog, Benjamin:
Vergleichende Untersuchung verschiedener Prüfverfahren an Rohren aus faserverstärktem Material.
FH Jena

Diplomarbeiten

Arnold, Michael:
Aufbau und Untersuchung eines dielektrischen Elastomer-Aktors.
Fachhochschule Würzburg-Schweinfurt

Back, Franziska:
Siebdruckfähige Sol-Gel-Materialien mit einer temperaturbeständigen Sperrschutzschicht.
Bayerische Julius-Maximilians-Universität Würzburg

Biechteler, Katja:
Herstellung und Charakterisierung von magnetorheologischen Elastomeren mit chemisch an die Elastomermatrix angebundenen Partikeln.
Fachhochschule Würzburg-Schweinfurt

Engel, Pascal:
Entwicklung eines energieverbrauchsarmen Funksensorknotens für den Einsatz in energieautarken Sensorsystemen.
Fachhochschule Würzburg-Schweinfurt

Kouhi Anbaran, Yalda:
Entwicklung von parametrischen Lautsprechern auf Basis von Piezoelektrischen Dünnschichtwandlern.
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Müller, Jana:
Untersuchungen zur Silizium-Infiltration von C/C Preformen.
Justus-Liebig-Universität Gießen

Obel, Kerstin:
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Otto, Christoph
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Schibelgut, Angelina :
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Schott, Marco:
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Somorowsky, Ferdinand:
Herstellung und Charakterisierung von nanoporösen Vycor-Gläsern mit einstellbarer Porosität für Bauanwendungen.
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Väth, Andreas:
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Wagner, Arne:
Der Einfluss von Dotierung auf das Verdichtungsverhalten (Diffusion) von Al2O3-Keramiken.
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Götzendörfer, Stefan:
Synthesis of copper-based transparent conductive oxides with delafossite Structure via Sol-Gel Processing.
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Kumbar, Suresh:
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Above ~ 1600° C different class of materials required
Approach
Energy Radiated To Space
Heat Flux
Energy Transfer

Geschäftsfeld Oberflächen und Schichten
Business Unit Surfaces and Coatings

Aktive, schaltende Schichten
Active switchable coatings

Innovative switchable shading appliances based on nanomaterials and hybrid electrochromic device configurations (EU)

Entwicklung von Klebstoffen mit Hochbarriereeigenschaften auf Basis nanoskaliger Hybridpolymere (BMBF)

Flexibles Energieversorgungssystem für energieautarke Mikrosysteme (BMBF)

Innovative Gradientenschichten mit nanoskaligen Hybridpolymeren (BMBF)

Funktionalisierung von Vliesstoffen für die Tiefenfiltration mit wasserbasierten anorganisch-organischen Beschichtungssolen (AiF/BMBF)

Korrosionsschutz durch hybride Nanomaterialien zur Substitution Chrom(VI)-haltiger Systeme (AiF/BMBF)

Aktive Schichten für den Korrosionsschutz (MPG/FhG)

Entwicklung, Erprobung und inline-Qualitätssicherung von flexiblen Ultrabarrierefolien im Pilotmaßstab für die Anwendung in fotoelektronischen Systemen (FhG)

Saubere / leicht zu reinigende Schichten
Self-cleaning / easy-to-clean surfaces

Atmospheric Plasmas for Nanoscale Industrial Surface Processing (EU)

Erhöhung der aktiven und passiven Sicherheit von Fahrzeugen durch neuartige multifunktionelle Nanobeschichtungen (BMBF)

Herstellung von organisch-anorganischen Nanokompositbeschichtungen für Bildschirm- und Mobiltelefonoberflächen zur Selbstreinigung von Fingerabdrücken (BMBF)

Permanente Trennmittelbeschichtung auf Basis hybrider Nanokomposite (BMBF)

Innovative Plasmatechnik zur Erzeugung aktiver, hybrider Schichten (VDI/BMBF)

Hybride Nanokomposite für die elektrolytische Abscheidung (FhG)

Optisch-funktionale Schichten
Optical functional coatings

Entwicklung abriebbeständiger Antireflexschichten für hochtransparente Verglasungen im Baubereich (BMBF)

Innovative Beschichtungssysteme für optische Spezialfasern (BMBF)

T-Rex – Transparente, kratzfeste Schichten mit niedrigem refraktivem Index sowie hoher Transmission im sichtbaren, UV- und IR-Bereich (BMWI)

UV-härtbare Digitaldruckfarbe auf Hybridpolymerbasis zur Bedruckung von Glas (FhG)

Barriereschichten
Barrier coatings

Development and integration of processes and technologies for the production of organiclow cost and large-area flexible electronics (EU)

Plasmaaktivierung und plasma-unterstützte Beschichtung von Kunststoff-Folien für Anwendungen in der Elektrotechnik (BMBF)

Entwicklung der Grundlagen für eine polymere Low-Cost-Elektronik im Rahmen der Marktorientierten Vorlaufforschung MAVO (FhG)

Multifunktionale Membrankissenkonstruktionen (FhG)

Umweltmonitoring und präventive Konservierung
Environmental monitoring and preventive conservation

Climate for Culture: Damage risk assessment, macroeconomic impact and mitigation strategies for sustainable preservation of cultural heritage in the times of climate change (EU)

MEMORI: Measurement, Effect assessment and Mitigation of Pollutant Impact on Movable Cultural Assets. – Innovative Research for Market Transfer. (EU)

NET-HERITAGE/ERA-NET: – European network on Research Programme applied to the Protection of Tangible Cultural Heritage (is the first significant initiative ever attempted to coordinate national RTD programmes of European countries and support the European RTD Programmes in the field of research applied to the Protection of Tangible Cultural Heritage) (EU)

Dom zu Merseburg – Konzept der konservatorischen und restauratorischen Maßnahmen an Metallsarkophagen in der Fürstengruft des Domes zu Merseburg (KUR)

Entwicklung und modellhafte Erprobung von energetisch optimierten Schutzverglasungen für anthropogen umweltgeschädigte historische Verglasungen am Beispiel des Xantener Domes (DBU)

Wege in die Moderne – Schadenspotential von Licht auf Museumsartefakte (SAW)

Plasmatechnologie Kulturerbe: Plasmatechnologie - eine innovative Technologie zur Konservierung und Restaurierung von Kulturgütern und öffentliche Präsentation der Forschungsallianz Kulturerbe (FhG)

Entwicklung transparenter Lacke zur Konservierung von Glas, Metall, Industriedenkmälern etc.

Klimamessungen im Innen- und Außenraum (Industrie und Denkmalpflege)

Klimasimulation und Schadensanalytik für Industriekunden

Lichtdosimeter zur Bestimmung der Gesamtmenge Licht, die auf ein Objekt/Exponat fällt, z.B. während einer Museumsausstellung

Umweltmonitoring: Umweltwirkungsmessungen, »preventive conservation«, Glassensoren

Forschungen zur nachhaltigen Sicherung von mittelalterlicher Kirchenverglasung
Sustainable conservation of medieval church windows

Conservation materials for stained glass windows – assessment of treatments, studies on reversibility and performance of innovative restoration strategies and products (EU)

Craquelée Schäden: Anwendung innovativer Restaurierungsmaterialien und -methoden zur Sicherung und Konservierung craquelierter Glasmalereien, modellhaft angewendet an Glasfenstern des 19. Jahrhunderts im Kölner Dom (Weltkulturerbe) (DBU)

Geschäftsfeld Energietechnik
Business Unit Energy Technology

Energiespeicherung
Energy storage

EnergyCap – Hochleistungsspeicher für Anwendungen im Bereich der erneuerbaren Energieversorgung, mobilen Bordnetzen und Traktionsanwendungen; Teilvorhaben: Entwicklung und Charakterisierung nanoskaliger Hybridelektroden und dafür abgestimmte Elektrolytsysteme für (BMBF)

Konzeptstudien für neuartige Lithium-Ionen-Zellen auf der Basis von Werkstoff-Innovationen – Koordination und Teilvorhaben: Elektrodenbeschichtung, hybride Elektrolyte und elektrochemische Charakterisierung (BMBF)

Verbundprojekt Fraunhofer Systemforschung Elektromobilität – Schwerpunkt 3: Energiespeichertechnik – Koordination und Teilvorhaben: Materialentwicklung für Li-Ionen Batterien (BMBF)

Schichten
Coatings

Oxide Materials towards a matured post-silicon electronics era (EU)

MEM-OXYCAL Membranen für die Kraftwerkstechnologie – Teilvorhaben: Entwicklung, Charakterisierung und Test nanoskaliger, dichter Membranschichten für die Sauerstoffabtrennung (BMWi)

Mobile Energieversorgung
Mobile energy supply

Autarke Energieversorgung über intelligente Piezogenerator/Polymer-Supercap/Lithium-Polymerakku-Mikrosysteme (BMBF)

Geschäftsfeld Glas und Keramik
Business Unit Glass and Ceramics

Keramische Fasern
Ceramic fibers

SiBNC-Werkstoffe für Produktions-, Energie- und Verkehrstechnik (BMBF)

Simulationsbasiertes Prozessdesign für die Entwicklung innovativer Keramik-Hochleistungsfasern (BMBF)

Entwicklung und Upscaling von Chemie und Technologie für SiC-Fasern (STMWIVT)

Oxidische Ceramic Matrix Composites (BMWi)

Glas
Glass

Kundenspezifisches Spezialglas
Customized special glasses

Flexibles Flachglas-Biegeverfahren (BMBF)

Laserstrahl-Glasfrit-Bonden zum Packaging temperaturempfindlicher Glas- und Siliziumbauteile (BMBF)

Entwicklung der Prozesskette zum thermischen Wiederziehen komplexer Mikrokomponenten aus hochbrechenden Glaswerkstoffen (BMWi)

Entwicklung von Schmelzscreening-Verfahren (Bayerische Forschungsstiftung)

Inhärent sichere Keramikherstellung
Inherently safe ceramics production

C/SiC-Kupplung – Kupplung mit Keramikreibpaarung (StmWIVT)

Herstellung großformatiger Bauteile aus Nichtoxidkeramik durch Einsatz optimierter Formgebungsverfahren und Mikrostruktur-Eigenschafts-simulation (StmWIVT)

Thermoschockbeständiges Keramik-Kompositmaterial für die Wärmetechnik; Materialentwicklung des Keramik-Matrixmaterials (BMWi)

Mikrostrukturentwicklung und Sintern bei Co-Firing von keramischen Mehrschichtsystemen (DFG)
Kontinuierliche Silizierung von Bremsscheiben (Bayerische Forschungsstiftung)

Ressourcenschonung
Sustainable consumption and production

Effiziente Entbinderungs- und Sintertechnik in der Keramikherstellung; Teilprojekt: Entwicklung effizienter Optimierungsmethoden für die Entbinderungs- und Sintertechnik (BMBF)

ECO-Zement – Energieeinsparung und CO_2-Minderung bei der Zementproduktion durch die Herstellung hüttensandreicher Hochofenzemente mit verbesserter Anfangsfestigkeit (BMWi)

Mess- und Prozesstechnik
Measuring and process technology

Aufbau eines Multiplen Hochtemperatur-Prüffeldes für Materialuntersuchungen unter kontrolliertem Sauerstoffeinfluss (MWVLW und ECREF)

MUHOPF – Aufbau eines multiplen Hochtemperatur-Prüffeldes für Materialuntersuchungen unter kontrolliertem Sauerstoffeinfluss; Innovationscluster Metall, Keramik, Kunststoff und Oberflächentechnik des Ministeriums für Wirtschaft, Verkehr, Landwirdschaft und Weinbau und des Europäischen Feuerfestzentrums ECREF

Untersuchung zur Entwicklung eines quecksilberfreien Präzisionsthermometers (AiF)

Ofenbau im Bereich Sonderanlagen

Prototypen-Anlagenbau

Robotik

Softwareentwicklung im Bereich Mess-, Steuerungs- und Automatisierungstechnik

Volumenmesstechnik

Zertifizierter Standardgerätebau im Bereich Volumendosierung, Laborglasjustierung und Thermo-optischer Messverfahren

Geschäftsfeld Mikrosystemtechnik
Business Unit Microsystems

Optische Aufbau- und Verbindungstechnik
Optical packaging

Functionalized Advanced Materials Engineering of Hybrids and Ceramics (EU)

Nanochemistry and self-assembly routes to nanomaterials (EU)

Extrem flache Kamerasysteme für Anwendungen im Automobil (BMBF)

Optische Tranceiver-Module mit in-situ definierbaren spektralen Eigenschaften für optische Zugangsnetze (BMBF)

Optisch erzeugte Sub-100 nm-Strukturen für biomedizinische und technische Applikaltionen: Materialien und Technologien zur Erzeugung kleinster Sturkturen mittels Femtosekundenlaser- induzierter Mehrphotonenpolymerisation (DFG-SPP)

Mikro- und Polymerelektronik
Micro and polymer electronics

Printable pyroelectrical and piezoelectrical large area sensor technology (EU)

Evaluierung der Nano-Imprint Technologie für die Herstellung von »sub 35 nm IC« – Teilprojekt Entwicklung von low-k-Dielektrika für die Nano-Imprint-Lithographie auf Basis von anorganisch-organischen Hybridpolymeren (BMBF)

Aerosolgedruckte Dünnfilmschaltungen für den elektrischen Funktionstest hochperformanter integrierter Schaltungen – Aerosol Printed Loadboard (FhG)

Entwicklung der Grundlagen für eine polymere Low-Cost-Elektronik (FhG)

Nanoparticles and layers of semiconductors and dielectrics, ferroelectrics, piezoelectrics of AIST in and on multifunctional ORMOCER®-matrices and layers including relevant thin-film and micro-technology of ISC (FhG)

Geschäftsfeld Life Science
Business Unit Life Science

Photoinitiierte Mikrostrukturierung von piezoelektrischen Werkstoffen für die Medizintechnik und die Mikrosystemtechnik (FhG)

Diagnostik
Diagnostics

Untersuchungen zur Speicherung von Ladungsträgern in Nanopartikeln und Entwicklung von Infrarotlicht-stimulierten Markern für die Bioanalytik und Diagnostik (DFG)

BioDots für biomedizinische Anwendungen (FhG)

Nanopartikelbasierte multimodale In-vivo-Diagnostik (FhG)

Verfahrensentwicklung zur schonenden Kapselung von Wirkstoffen (FhG)

Regenerative Medizin
Regenerative medicine

EAP mit magnetisch steuerbarer Elastizität zur Interaktion mit Bindegewebszellen (BMBF)

Mikroverkapselung von Wirkstoffen (ZIM)

Physiologisch degradierbare, mittels Zwei-Photonen-Absorption (TPA) strukturierte Hybridwerkstoffe für die Regenerative Medizin (FhG)

Entwicklung eines bioresorbierbaren Kieselgelfaservlieses mit Wirkstoff-Freisetzung zur Versorgung schlecht heilender Wunden

Dentalmedizin
Dental medicine

Entwicklung einer innovativen Werkstofflösung für Zahnkronen (ZIM)

Innovatives dentales Füllungskonzept (ZIM)

Allergenfreies dentales Basismaterial (FhG)

All-in-one Adhäsiv: Einfach applizierbare, langzeitstabile Materiallösung für die Dentalmedizin (FhG)

Chairside-Kronen (FhG)

Prothesenzähne aus Hybridpolymeren - Mechanisch hochwertiger Zahnersatz (FhG)

Dentale Glaskeramiken

Geschäftsfeld Bau und Umwelt
Business Unit Construction and Environment

Nanotechnologie
Nanotechnology

Best practices for IPR and technology transfer in NT-developments (EU)

BMBF-Marketing Nanotechnologie Japan (BMBF)

(Nano)poröse Materialien
(Nano)porous materials

Entwicklung einer Technologieplattform für die Herstellung multifunktionaler Hybridschäume (FhG)

Funktionsfüllstoffe
Functional filling materials

Multi-source energy storage systems integrated in buildings (EU)

Kalthärtende Keramik durch nanotechnologische Gefügeoptimierung (BMBF)

Baustoffe auf Basis von porösen Glasflakes für das Klimamanagement (Bayerische Forschungsstiftung)

Zeolithe mit absorberkatalytischer Wirkung für Formaldehyd in Holzwerkstoffen (FhG)

CeSMa - Center Smart Materials

Einsetzbare adaptronische Module zur Kompensation von Echtzeitfehlern (thermisch und Schwingungen) und zur supergenauen Positionierung in rekonfigurierbaren Hochpräzisions-Werkzeugmaschinen (EU)

Entwicklung von Hochtemperatur-Ultraschallwandlern zur On-line-Strukturüberwachung heißer Dampfleitungsrohre (EU)

Hierarchical and Adaptive smart components for precision production systems application (EU)

The integrated safe- and smart-built concept (EU)

Erforschung betriebsfester und langlebiger Materialsysteme von dielektrischen Elastomeraktoren – Teilvorhaben: Organisch modifizierte Silikonmaterialien für dielektrische Elastomeraktoren (BMBF)

Innovatives Condition Monitoring System zur nachhaltigen Überwachung sicherheitsrelevanter Komponenten (BMBF)

Integration neuartiger Funktions- und Konstruktionswerkstoffe und deren Anwendung in einem miniaturisierten Ventilsystem (BMBF)

Modellgestütztes Structural Health Monitoring für Rotorblätter von Windenergieanlagen (BMBF)

Smart Windows auf Basis von Metallo-Polyelektrolyten (BMBF)

Verbundprojekt Fraunhofer Systemforschung Elektromobilität (FSEM)
- Schwerpunkt 4, Teilprojekt B: Technische Systemintegration, gesellschaftspolitische Fragestellungen und Projektmanagement,
AP 5: Magnetorheologische Motor-Generator-Kupplung (BMBF)

Entwicklung von multifunktionellen Sensoren zum Nachweis der Glasbruchentstehung und zur Ansteuerung von Facility-Management-Systemen (BMWA)

Aufbau und Betrieb eines Centers »Smart Materials« - Entwicklung und Applikation (StMWIVT)

Amberg-Schwab, S.; Halbhuber, A.; Uhl, D.; Haas, K.-H.
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DE 10-2009-013884 A1 Offenlegungstag: 2010/09/30

Amberg-Schwab, S.; Weber, U.; Noller, K. Miesbauer, O.
Herstellung von Hochbarriereverbunden
WO 2010-069958 A1 Offenlegungstag: 2010/06/24

Ballweg, Th.; Gellermann, C.; Hanselmann, D.; Probst, J.
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Ballweg, Th.; Nique, S.
Dialkoxy- oder Dihydroxyphenylreste enthaltende Silane, daraus hergestellte Klebstoffe sowie Verfahren zur Herstellung und Vewendungtidmodifizierter anorganisch-organischer Hybridpolymere für Feuchtemillieu-taugliche Klebungen
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Böse, H.; Ehrlich, J.
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Böse, H.; Ehrlich, J.
Schaltbare magnetorheologische Drehmoment- oder Kraftübertragungsvorrichtung, deren Verwendung sowie magnetorheologische Drehmoment- oder Kraftübertragungsverfahren
DE 10-2009-72909 A1 Offenlegungstag: 2010/08/12

Böse, H.; Gerlach, Th.
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US 2010-0162776 A1 Offenlegungstag: 2010/07/01

Böse, H.; Gerlach, Th.
Blockiervorrichtung mit feldsteuerbarer Flüssigkeit sowie deren Verwendung / EP 2147219 A1 Offenlegungstag: 2010/01/27

Böse, H.; Hesler, A.; Monkmann, G.
Magnetorheologische Kompositmaterialien mit hartmagnetischen Partikeln, Verfahren zu deren Herstellung sowie deren Verwendung
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Böse, H.; Trendler, A.-M.
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EP 1782439 B1 Erteilungstag: 2010/10/13
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Böse, H.; Trendler, A.-M.
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US 2010-0193304 A1 Offenlegungstag: 2010/08/05
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Celik, A.; Schottner, G.; Posset U.; Pagani, G.; Abbotto, A.; Mari, C.; Beverina, L.; Ruffo, R.; Patriarca, G.
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US 2010-0189918 A1 Offenlegungstag: 2010/07/29

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Partikel mit einer lumineszierenden anorganischen Schale, Verfahren zur Beschichtung von Partikeln sowie deren Verwendung
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Glaubitt, W.; Probst, J.
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Götzendörfer, St.; Löbmann, P.; Kapuschinski, M.
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Houbertz-Krauß, R.; Domann, G.; Schmitt, A.; Popall, M.; Stadlober, B.; Haas, U.; Haase, A.
Halbleiterbauelement, Verfahren zu dessen Herstellung und Verwendung von anorganisch-organischen Hybridpolymeren zur Herstellung von Halbleiterbauelementen
EP 1803173 B1 Erteilungstag: 2010/04/07

Rose, K.
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EP 1878760 B1 Erteilungstag: 2010/03/03

Rose, K.; Fernandez-Lafuente, R.; Jaffrezic, N.; Dzyadevych, S.
Biosensor and its use / US 7709221 B2 Erteilungstag: 2010/05/04

Rüdinger, A.; Clade, J.; Spaniol, H.; Sporn, D.
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Spaniol, H.; Krüger, R.; Müller, T.; Rüdinger, A.; Graupner, U.; Fuchs, O.
Flexible und infiltrierbare Bündel aus Keramikfasern mit stark vergröbertem Gefüge und Methode zu deren Herstellung
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Spaniol, H.; Krüger, R.; Müller, T.; Rüdinger, A.; Graupner, U.; Fuchs, O.
Flexible und infiltrierbare Bündel aus Keramikfasern mit stark vergröbertem Gefüge und Methode zu deren Herstellung
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Hochreine, nanoskalige organische Schichtsilikate mit der Struktur des Talk sowie Verfahren zu deren Herstellung
DE 10-2008-031072 A1 Offenlegungstag: 2010/01/07

Wolter, H.; Nique, S.
Phosphorgruppenhaltige Carbonsäurederivate mit polymerisierbaren Gruppen / US 7777080 B2 Erteilungstag: 2010/08/17

Mit Hochschulen
With universities

Academy of Fine Arts, Faculty of Art Conservation, Krakau (PL)

AGH-University of Science and Technology, Krakau (PL)

Albert-Ludwigs-Universität Freiburg

Aristotle University of Thessaloniki (GR)

Bauhaus-Universität Weimar, Fakultät Bauingenieurwesen, Professur Bauchemie

Charité Campus Benjamin Franklin, Berlin

Czech Technical University, Prag (CZ)
- Faculty of Mechanical Engineering

Ecole Nationale Supérieure de Céramique Industrielle, Limoges Cedex (F)

Fachhochschule Potsdam, Studiengang Restaurierung, Studienrichtung Metallkonservierung

Fachhochschule Würzburg-Schweinfurt-Aschaffenburg, Fachbereich Informatik

Friedrich-Schiller-Universität Jena

Ghent University (B)
- Department of Geology and Soil Science
- IMEC Center for Microsystems Technology

Glasgow Caledonian University (UK)

Gotland University, Department of Building Conservation, A Baltic Sea Region Network on Indoor Climate in Churches, Visby (S)

Hochschule Anhalt, Medizinischer Gerätebau

Hochschule Regensburg, Fakultät Elektro- und Informationstechnik

Humboldt-Universität zu Berlin, Fakultät Chemie

Institut National Polytechnique de Grenoble, Laboratoire SIMAP (Science et Ingénierie des Materériaux et Procédés), Saint Martin d'Heres (F)

Institute Electronic Structure and Laser, Foundation for Research and Technology, Holography Lab – Laser Applications, Heraklion (GR)

Johannes Kepler Universität Linz (A)

Julius-Maximilians-Universität Würzburg
- Lehrstuhl für Funktionswerkstoffe der Medizin und Zahnheilkunde
- Lehrstuhl für Klassische Archäologie
- Lehrstuhl für Materialsynthese

Karlsruhe Institute of Technology KIT
-Institut für Werkstoffe der Elektrotechnik

Katholieke Universiteit Leuven (B)

Leibniz Universität Hannover

London School of Economics & Political Science, Grantham Research Institute on Climate Change and Environment (UK)

Medizinische Hochschule Hannover, Klinik für Zahnärztliche Prothetik und Biomedizinische Werkstoffkunde

Nagoya University, National Institute of Advanced Industrial Science and Technology AIST, Nagoya (JP)

National Technical University of Athens (GR)
- School of Mechanical Eng.,
Lab. of Heterogeneous Mixtures & Combustion Systems

- School of Civil Engineering, Lab. for Earthquake Engineering

Otto-Friedrich-Universität Bamberg, Institut für Archäologie, Denkmalkunde und Kunstgeschichte

Paris-Lodron-Universität Salzburg (A), Fachbereich Materialwissenschaften und Physik

Philipps-Universität Marburg, Institut für Anorganische Chemie

Polytecnio di Torino (I)

Rheinisch Westfälische Technische Hochschule (RWTH) Aachen
- Institut für Elektrochemische Energiewandlung und Speichersystemtechnik
- Institut für Gesteinshüttenkunde
- Institut für Physikalische Chemie
- Institut für Werkstoffanwendungen
- Klinik für Plastische Chirurgie, Hand- und Verbrennungschirurgie

Sächsisches Textilforschungsinstitut e.V. an der TU Chemnitz

Tampere University of Technology, Tampere (FIN)

Technical University of Denmark, Department of Management Engineering, Kongens Lyngby (DK)

Technische Universität Bergakedemie Freiberg, Institut für Automatisierungstechnik, Freiberg

Technische Universität Braunschweig

Technische Universität Darmstadt

Technische Universität Dresden
- Institut für Festkörperelektronik

Technische Universität Graz (A)
- Institut für Chemische Technologie von Materialien

Technische Universität München, Studiengang für Restaurierung, Kunsttechnologie und Konservierungswissenschaft, München

Technische Universität Wien (A)
- Institut für Angewandte Synthesechemie
- Institut für Nachrichten- und Hochfrequenztechnik

Technische Universiteit Eindhoven (NL)
- Department Technology, Unit Building Physics and Systems
- Department of Applied Physics (Plasma and Materials Processing)

The Royal Danish Academy of Fine Arts, Kopenhagen (DK)
- The School of Conservation

Tokyo Institute of Technology (JP)

Tokyo University of Agriculture and Technology, Ohno-Lab (JP)

Universidade do Minho, Braga (P)
- Grupo de Revestimentos Functionais

Università di Genova (I)

Università Milano-Bicocca, Mailand (I)

Universidad Alicante (E)

Universität Augsburg
- Anwenderzentrum Material- und Umweltforschung

Universitat Autònoma de Barcelona (E)
- Instituto de Ciencia de Materiales

Universität Bayreuth
- Bayerisches Geoinstitut
- Lehrstuhl keramische Werkstoffe

Universität Bremen

Universität Erlangen-Nürnberg
- Institut für Werkstoffwissenschaften
- Lehrstuhl Werkstoffe der Elektrotechnik

Universität Karlsruhe (TH)
- Institut für Werkstoffe der Elektrotechnik

Universität Rostock
- Institut für Biomedizinische Technik
- Kompetenzzentrum für Biomaterialien
- Poliklinik für Zahnärztliche Prothetik und Werkstoffkunde

Universität Rostock
- Medizinische Fakultät, Institut für Biomedizinische Technik

Universität Stuttgart

Universität Ulm

Universität Ulm
- Abt. Anorganische Chemie I

Universität zu Köln, Lehrstuhl für Anorganische Chemie

Universitätsklinikum Würzburg
- Augenklinik und Poliklinik

Université de Haute-Alsace, Mulhouse-Colmar (F)
- Département de Photochimie Générale CNRS-UMR 7525

Université de Picardie Jules Verne, Amiens (F)
- Laboratoire de réactivité et Chimie des Solides LRCS

Université Montpellier (F)

Université Pierre et Marie Curie, Paris (F)

University College of Antwerp, Hogeschool Antwerpen (B)
University of Birmingham (UK)

University of Huddersfield (UK)

University of Leeds (UK)
- Nanomanufacturing Institute

University of Ljubljana (SLO)
- Faculty of Civil and Geodetic Engineering, Chair for Research in Materials and Structures

University of London, Birkbeck College (UK)

University of Manchester (UK)

University of Patras (GR)
- Department of Civil Engineering, Structural Materials Laboratory

University of Pisa (I)
- Department of Chemistry and Industrial Chemistry

University of Sheffield (UK)

University of Thessaloniki (GR)

University of Twente (NL)
- Department of Civil Engineering

University of Valencia (E)

University of Zagreb (CRO)
- Faculty of Civil Engineering

Warsaw University (PL)
- Laboratory of Electrochemical Power Sources

Westfälische Wilhelms-Universität Münster, Institut für Anorganische und Analytische Chemie
Yonsei University Seoul (KO)
- Mechanical Engineering

Mit anderen Forschungseinrichtungen
With other research institutions

Acreo AB, Printed Electronics Group and Interconnect and Packaging Group, Norrköping (S)

Akademie der Wissenschaften der Tschechischen Republik, Prag (CZ)
- Institute of Radio Engineering 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)

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)

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

Electronics and Telecommunications Research Institute (ETRI), Daejeon (KO)
- Optical Interconnection Team
- Basic Research Laboratory

ERANET/NET-HERITAGE

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

Forschungszentrum Karlsruhe GmbH (FZK), Karlsruhe

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

Glasrestaurierungswerkstatt der Dombauhütte Köln

Hermsdorfer Institut für Technische Keramik e.V., Hermsdorf (jetzt Fraunhofer IKTS

Hüttentechnische Vereinigung der Deutschen Glasindustrie HVG, Offenbach

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

Institut de Recherche d'Hydro Québec (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 für Physikalische Hochtechnologie e.V., Jena

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

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

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), St. Martin d' Heres (F)

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)

Zentrum für Sonnenenergie- und Wasserstoffforschung, Ulm

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

Lehrtätigkeit

Teaching activities

Julius-Maximilians-Universität Würzburg

Lehrstuhl für Chemische Technologie der Materialsynthese

Lehrstuhlinhaber: Prof. Dr. Gerhard Sextl

Vorlesungen Sommersemester 2010

Sextl, G., Löbmann, P., Hilbig, A., Bastian, M.
MaterialwiSoSeenschaften II (Die großen Werkstoffgruppen)

Kurth, D., Müller-Buschbaum, K.
Moderne analytische Methoden

Helbig, U.
Von der Biomineralisation zur biologisch-inspirierten Materialsynthese

Löbmann, P.
Sol-Gel-Chemie I: Grundlagen

Helbig, U., Löbmann, P.
Chemische und biologisch-inspirierte Nanotechnologie für die Materialsynthese

Hilbig, A., Drach, V.
Moderne Beschichtungsverfahren und Schichtmaterialien aus der Gasphase

Wolff Fabris, F.
Polymerwerkstoffe 2: Technologie der Modifizierung von Füllstoffen für Polymerwerkstoffe

Raether, F.
Technologie sensorischer und aktorischer Materialien inklusive Smart Fluids

Staab, T.
Eigenschaften moderner Werkstoffe: Experimente und Simulation

Küchler, A.
Hochspannungsisolierwerkstoffe und -systeme

Sextl, G., Kurth, D., Löbmann, P., Hilbig, A., Schwarz, G.
Anleitung zum selbstständigen wiSoSeenschaftlichen Arbeiten

Vorlesungen Wintersemester 2010/2011

Möller, K.-C.
Elektrochemische Energiespeicher und -wandler

Sextl, G., Walles, H.
MaterialwiSoSeenschaften I (Struktur, Eigenschaft und Anwendungen von anorganischen Werkstoffen)

Kurth, D., Schwarz, G.
Molekulare Materialien (Chemische Technologie der Materialsynthese)

Löbmann, P.
Sol-Gel-Chemie 2: Schichten und Beschichtungstechnik

Bastian, M.
Polymerwerkstoffe I: Technologie der Modifizierung von Polymerwerkstoffen

Schwarz, G.
Anwendungsorientierte Charaktersierung von molekularen Systemen

Sextl, G., Kurth, D., Löbmann, P., Hilbig, A., Schwarz, G.
Anleitung zum selbstständigen wiSoSeenschaftlichen Arbeiten

Übungen und Praktika

Sextl, G., Löbmann, P., Hilbig, A., Bastian, M.
Übungen zur Vorlesung »MaterialwiSoSeenschaften II«
SoSe 20010
Kurth, D., Schwarz, G.

Praktikum zu Moderne Analytische Methoden
SoSe 2010

Sextl, G., Löbmann, P., Kurth, D., Hilbig, A., Schwarz, G.
Praktikum Chemische Technologie der Materialsynthese für Studenten der Chemie
SoSe 2010

Wolff Fabris, F.
Praktikum zu Polymerwerkstoffe 2
SoSe 2010

Raether, F.
Praktikum zur Technologie sensorischer und aktorischer Materialien inklusive Smart Fluids
SoSe 2010

Küchler, A.
Übungen zu Hochspannungsisolierwerkstoffe und -systeme
SoSe 2010

Küchler, A.
Praktikum zu Hochspannungsisolierwerkstoffe und -systeme
SoSe 2010

Sextl,G., Kurth, D., Hilbig, A., Schwarz, G.
MaterialwiSoSeenschaftliches Kolloquium
SoSe 2010 und WS 2010/2011

Sextl, G., Hilbig, A.
Übungen zu Vorlesung MaterialwiSoSeenschaften I (Struktur, Eigenschaft und Anwendungen von anorganischen Werkstoffen)
WS 2010/2011

Kurth, D., Schwarz, G.
Übungen zu Molekulare Materialien (Chemische Technologie der Materialsynthese)
WS 2010/2011

Kurth, D., Schwarz, G., Hilbig, A.
Praktikum Molekulare Materialien (Chemische Technologie der Materialsynthese)
WS 2010/2011

Sextl, G., Löbmann, P., Schwarz, G.
Praktikum Chemische Technologie der Materialsynthese für Studenten der Chemie
WS 2010/2011

Möller, K.C.
Praktikum Elektrochemische Energiespeicher und -wandler
WS 2010/2011

Bastian, M.
Praktikum zur Technologie der Modifizierung von Polymerwerkstoffen
WS 2010/2011

Seminare

Löbmann, P.
Seminar zur Vorlesung Sol-Gel-Chemie I: Grundlagen
SoSe 2010

Sextl, G., Kurth, D.
Seminar für wiSoSeenschaftliche Mitarbeiter
SoSe 2010 und WS 2010/2011

Sextl, G., Kurth, D., Löbmann, P.
Seminar für Doktoranden
SoSe 2010 und WS 2010/2011

Staab, T.
Seminar Eigenschaften moderner Werkstoffe: Experimente und Simulation
SoSe 2010

Universität Bayreuth
Lehrstuhl Keramische Werkstoffe des Instituts für Materialforschung
Lehtstuhlinhaber: Prof. Dr.-Ing. Walter Krenkel

Vorlesungen und Veranstaltungen Sommersemester 2010

Krenkel, W.
Hochtemperatur-Leichtbau

Hausherr, J.M.
Hochleistungskeramik

Mucha, H.
Metallinfiltrierte Keramik

Raether, F.
Ringvorlesung des Graduiertenkollegs im Elitenetzwerk Bayern der Universität Bayreuth:
Structure-property relations in materials – from crystal structures to textures to macroscopic properties

Vorlesungen und Veranstaltungen Wintersemester 2009/2010 und 2010/11

Krenkel, W.
Einführung in die MaterialwiSoSeenschaft - Keramik

Krenkel, W.
Verbundkeramiken

Krenkel, W.
Eigenschaften von Verbundwerkstoffen

Hausherr, J.M.
Zerstörungsfreie Prüfmethoden


Hochtemperaturleichtbau – keramische Faserverbundwerkstoffe

GASTREFERENTEN DES ISC-SEMINARS IN WÜRZBURG

GUEST SPEAKERS AT THE FRAUNHOFER ISC

12. April 2010

Prof. Kickelbrick

Oberflächenfunktionalisierte Metalloxo-Cluster und NP als Bausteine für Polymer-Nanokomposite

15. Juni 2010

Prof. Robert R. McLeod

Associate Professor of Electrical, Computer and Energy Engineering, University of Colorado at Boulder

3D single mode, hybrid integrated optics in solid photopolymers

29. Juli 2010

Prof. Dr. Hartmut Hibst

BASF AG Ludwigshafen

Nanocatalysis and Inorganic Solids

Heterogene Katalysatoren für selektive Oxidation am Beispiel der Herstellung von Acrylsäure

3. August 2010

Dr. Friedrich Raether

Fraunhofer ISC

Materialauswahl mit CES – Selector für Kundenberatung, Konstruktion und Identifikation neuer Anwendungsfelder

22. Oktober 2010

Otto F. W. Herrmann

G.R.O.W. Concepts GmbH & Co. KG, Gesellschaft für ganzheitliche Unternehmens- und Personalentwicklung

Die ISO-Familie 9000, Internationales Führungsmodell und Reifegrad-Modell zur Organisations- und Prozessentwicklung

4. November 2010

Prof. Robert R. McLeod

Associate Professor of Electrical, Computer and Energy Engineering, University of Colorado at Boulder

Nonlinear patterning of photopolymers via structured inhibition

17. November 2010

Dipl.-Ing. Dipl.-oek. (BOEK) Oliver Millon

Fraunhofer-Institut für Kurzzeitdynamik Ernst-Mach-Institut EMI

Abteilung Baulicher Schutz und Sicherheitstechnologie

Optimierung von UHPC im Hinblick auf ein besseres Tragverhalten – Stand des Wissens

7. Dezember 2010

Prof. Dr.-Ing. habil. Lutz Mädler

Stiftung Institut für Werkstofftechnik (IWT)

Hauptabteilung Verfahrenstechnik

Fachbereich Produktionstechnik (FB 4)

Universität Bremen

Metalloxide aus der Sprühflamme: Herstellung, Charakterisierung, Anwendung

GASTREFERENTEN »BRONNBACHER GESPRÄCHE 2010«

GUEST SPEAKERS AT THE BRONNBACH BRANCH

20. Januar 2010

Dr. Jörg Paczkowski

Grafschaftsmuseum Wertheim

Glasfenster in Lothringen am Beispiel der Kathedrale in Metz

17. Februar 2010

Dr. Paul Bellendorf

Fraunhofer-Institut für Silicatforschung ISC

Der Einsatz von 3D-Scannern zur berührungslosen Dokumentation von Kunst- und Kulturgut

21. April 2010

Prof. Dr. Gerhard Sextl

Fraunhofer-Institut für Silicatforschung ISC

Was ist Glas -was macht diesen Werkstoff so einzigartig

19. Mai 2010

Dr. Jörn Probst

Fraunhofer-Institut für Silicatforschung ISC

Bioaktive Werkstoffe für die regenerative Medizin

15. September 2010

Dr. Falko Bornschein

Kunstgutbeauftragter des Bistums Erfurt

Die Glasfenster des Erfurter Doms - Bestand und Restaurierung

VERANSTALTUNGEN AM FRAUNHOFER ISC

CONFERENCES AND EVENTS AT THE FRAUNHOFER ISC

Smart Materials für Sicherheit, Haptik und Komfort
Workshop zum Jahrestag der Gründung von CESMA
Würzburg, 5. Mai 2010

Feierliche Grundsteinlegung zum Neubau Technikum III
Würzburg, 16. Juli 2010

Mobile Ausstellung: Der Fraunhofer-Truck
Bayreuth, 20. – 22. September 2010

Girls' Day 2010
Würzburg, 22. April 2010

3. Sol-Gel-Fachtagung Oberflächenveredelung durch Nanotechnologie
Von der Theorie zur industriellen Umsetzung
Technische Akademie Wuppertal
Würzburg, 28.-29. September 2010

Lehrerfortbildung der Nanoinitiative Bayern GmbH
Würzburg, 27. Oktober 2010

Nanoanalytik für Oberflächen und mehr
Clustermeeting des Clusters Nanotechnologie
Würzburg, 16. November 2010

MESSEN UND AUSSTELLUNGEN

FAIRS AND EXHIBITIONS

Photonics West 2010
San Francisco, CA (USA), 26. – 28. Januar 2010

NanoTech 2010
Tokyo (JP), 17. – 19. Februar 2010

Material Innovativ
Augsburg, 24. März 2010

Hannover Messe
Hannover, 19. – 23. April 2010

Sensor + Test 2010
Nürnberg, 18. – 20. Mai 2010

MS Energie Wissenschaft im Dialog zum »Wissenschaftsjahr 2010 – Die Zukunft der Energie«
18. Mai – 7. Oktober 2010

Mechatronics
Karlsruhe, 19. – 20. Mai 2010

Eurolite 2010 – Internationale Fachmesse für Leichtbaukonstruktion
Nürnberg, 8. – 10. Juni 2010

HT-CMC7 – 7th Internation Conference on High Tempe-ature Ceramic Matrix
Composites HT-CMC7,
Bayreuth, 20. – 22. September 2010

denkmal
Leipzig, 18. – 20. November 2010

AUSBLICK MESSEN 2011
FAIRS AND EXHIBITIONS PLANNED IN 2011

Bau
München, 17. – 22. Januar 2011

Photonics West
San Francisco, CA (USA), 25. – 27. Januar 2011

NanoTech 2011
Tokyo (JP), 16. – 18. Februar 2011

Symposium Material Innovativ
Fürth 24. Februar 2011

Hannover Messe
Hannover, 4. – 8. April 2011

MS Gesundheit
19. Mai – 29. September 2011

Mechatronik
Karlsruhe, 25. – 26. Mai 2011

Sensor + Test
Nürnberg, 7. – 9. Juni 2011

Jahreskongress Zulieferer innovativ
Ingolstadt, 6. Juli 2011

Composites Europe
Stuttgart, 27. – 29. September 2011

Productronica
München, 15. – 18. November 2011

ALLIANZEN AND NETZWERKE

ALLIANCES AND NETWORKS

Das Institut in Netzwerken

Das Fraunhofer ISC ist aktives Mitglied in zahlreichen nationalen und internationalen Forschungsnetzwerken. Ziel der Kooperationen ist es, den interdisziplinären Wissensaustausch mit der Industrie und anderen universitären und außeruniversitären Forschungseinrichtungen zu fördern, die eigene Kompetenz einzubringen und neue Partner zu gewinnen.

Innerhalb der Fraunhofer-Gesellschaft führen Mitarbeiter des Fraunhofer ISC die Verbünde »Nanotechnologie« und »POLO – Polymere Oberflächen«. Auf Geschäftsfeldebene bestehen zusätzlich eine Reihe weiterer enger Kooperationen mit Fraunhofer-Netzwerken zu den Themen »Adaptronik«, »Hochleistungskeramik«, »Numerische Simulation von Produkten und Prozessen«, »Optisch-funktionale Oberflächen« und »Photokatalyse« sowie mit zahlreichen Universitäten und Forschungsinstituten außerhalb der Fraunhofer-Gesellschaft.

Das Institut ist Mitglied beim »Wilhelm Conrad Röntgen Research Center for Complex Material Systems« (RCCM) an der Universität Würzburg, auf nationaler Ebene im Kompetenznetz für Materialien der Nanotechnologie (NanoMat) und im Kompetenznetzwerk für Materialforschung und Werkstofftechnik Materials Valley e.V. sowie auf europäischer Ebene im »European Multi-functional Materials Institute (EMMI).

Als Materialentwicklungsinstitut gehört das Fraunhofer ISC dem Fraunhofer-Verbund Werkstoffe, Bauteile an. Vorsitzender ist Prof. Dr.-Ing. Holger Hanselka, Leiter des Fraunhofer LBF. Weitere Mitglieder sind die Fraunhofer-Institute EMI, IAP, IBP, ICT, IFAM, IGB, IKTS, ISE, ISI, ITWM, IWM, IZFP und WKI. Das Institut ist außerdem vertreten in dem als Demonstrationszentrum angesiedelten Themenverbund »AdvanCer« (System development with high-performance Ceramics - Weitere Informationen unter www.advancer.fraunhofer.de).

Das Fraunhofer ISC in weiteren Allianzen und Netzwerken

Fraunhofer-Allianz Polymere Oberflächen (POLO)
Sprecherin der Allianz und Leiterin der Geschäftsstelle: Dr. Sabine Amberg-Schwab, Fraunhofer ISC
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Fraunhofer-Allianz Nanotechnologie
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Fraunhofer-Allianz Bau
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Forschungsallianz Kulturerbe
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Dr. Stefan Simon
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Fraunhofer-Netzwerk »Nachhaltigkeit«
Ansprechpartner
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Beteiligung an den Clustern der Allianz Bayern Innovativ

Cluster Chemie
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Kontakt: herrmann@cluster-chemie.de; felcht@cluster-chemie.de
www.cluster-chemie.de

Cluster Mechatronik & Automation
Sprecher: Prof. Dr.-Ing. Gunther Reinhart und Prof. Dr.-Ing. Klaus Feldmann
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www.cluster-ma.de

Cluster Medizintechnik
Sprecher: Prof. Dr. med. Michael Nerlich
Kontakt: michael.nerlich@medtech-pharma.de
www.cluster-medizintechnik.de/

Cluster Nanotechnologie
Sprecher: Prof. Dr. Alfred Forchel
Kontakt: info@nanoinitiative-bayern.de
www.nanoinitiative-bayern.de

Cluster Neue Werkstoffe
Sprecher: Prof. Dr. Rudolf Stauber und Prof. Dr. Robert F. Singer
cluster-neuewerkstoffe@bayern-innovativ.de
www.cluster-neuewerkstoffe.de

MITGLIEDSCHAFTEN UND MITARBEIT IN GREMIEN

Ad-hoc Advisory Group for Industrial Nanotechnology (EU-Kommission Brüssel)
Academy of Dental Materials (ADM)
AMA Fachverband für Sensorik e.V.
AGEF Arbeitsgemeinschaft Electrochemischer Forschungsinstitutionen e.V.
American Ceramic Society (ACerS) – Fellow
Arbeitsgemeinschaft Wirtschaftsnaher Forschungseinrichtungen in Baden-Württemberg
Arbeitskreis Mikrosysteme für Biotechnologie und Lifesciences e.V. BioMST

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

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
Deutsche Forschungsgesellschaft für Oberflächenbehandlung e. V.
- Fachausschuss Oberflächenbehandlung von Stahl und Multisubstraten
Deutsche Gesellschaft für Materialkunde e.V. (DGM)
- Arbeitskreis Verstärkung keramischer Werkstoffe
- Fachausschuss Biomaterialien
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
Deutscher Verband für Materialforschung und -prüfung e. V. (DVM)
- Arbeitsgruppe Zuverlässigkeit adaptiver Systeme

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
Forum für Medizin Technik und Pharma in Bayern e.V.
Forschungsgemeinschaft Technik und Glas e.V., Bronnbach (FTG)
- Technischer Ausschuss
Forum Elektromobilität
Forum Innovation und Technologie Heilbronn Franken
Fraunhofer-Demonstrationszentrum AdvanCer
- Mitglied des Projektleitungsrats
Fraunhofer Allianzen:
- Adaptronik
- Werkstoffe, Bauteile
- Hochleistungskeramik
- Nanotechnologie
- Numerische Simulation von Produkten und Prozessen
- Polymere Oberflächen (POLO)
- Optisch-funktionale Oberflächen
- Photokatalyse
- Energie
- Elektrochemie
- Netzwerk Elektrochemie

- Netzwerk Batterien
- Bau

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 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 Valley e.V. – Kompetenznetzwerk für Materialforschung und Werkstofftechnik

mst–Netzwerk Rhein Main
- Kompetenznetzwerk Mikrosystemtechnik

Nano and Hybrid Coatings Conference
- Konferenzpräsidium

NanoMat – Netzwerk Nanomaterialien

Nanonetz Bayern e.V.

Nanotech Europe Berlin 2009 Mitglied Programmkommission

Photonics West
- Programme Committee Optoelectronic Interconnects and Component Integration

Quadriga – Associated Network on Organic and Large Area Electronics

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)

Würzburger Forschungsverbund Funktionswerkstoffe