Fraunhofer
IKTS

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

ANNUAL REPORT
2010
2011

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Fraunhofer Institute for
Ceramic Technologies and Systems IKTS

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FOREWORD

Dear friends of the IKTS,

We are glad to report that we – now jointly – were able to continue our successful development at our institute branches in Hermsdorf and Dresden. The figures presented on the following pages speak for themselves: with an operating budget of about 32 million euros (without investments) we earned 27 million euros in external funds, mainly from direct industry revenues. Our total profit rate is once again well above 80 percent – at both branches!

As in previous years, last year was marked by special challenges, not least because of the integration activities at both branches. The cooperation in form of joint projects is well on its way and very promising in all research fields. Our established site-spanning organization structures significantly contribute to this process. The process of growing together will of course continue to be a priority, as it holds a great potential from which our customers can benefit.

We have consequently kept on developing our competencies in the fields of structural and functional ceramics. In our projects and partnerships we particularly benefit from the fact that we can rely on closed added value and technological chains – from materials to components or systems – and that we can produce larger quantities. This helps us to make headway in research fields that are new to us, such as storage technologies. Besides lithium ion batteries we also deal with NaS and redox flow batteries. Ceramic cathode materials and manufacturing technologies are in the focus of our activities in the field of lithium ion batteries. Especially plant engineering is a field in the European market which shows significant deficits and we would like to help close the gaps.

In addition to further investments in our technological equipment and plants we also expanded our modeling activities. Now, we are able to simulate complete fuel cell systems in real time, allowing for a further acceleration of our developments. We currently work on the completion of different fuel cell systems of various power classes of a few watts for portable applications, e.g., 1 kW for decentralized combined heat and power generation, and 5 to 20 kW for biogas conversion. We have also reached a top position in membrane technology where we cover the complete spectrum of mixed

conducting, high-density and porous membranes. Various demonstration systems for liquid filtration or oxygen production run in our laboratories or have already been transferred to the customer's site.

In addition to the research fields of energy and environmental technologies, which keep rapidly growing, our project activities in the field of mechanical, electrical, medical and automotive engineering continue to increase. Thus, we serve a broad range of markets and look optimistically into the future. Our competent and highly motivated staff is our most important success factor. We cannot thank them enough for their contribution. Keep up the good work! Of course, we would also like to give a special thanks to our partners for their confidence in us. We will continue with our efforts to achieve optimal project results and to support our partners in developing new innovations. As always, we would like to invite you to make use of our outstanding services and to continue the collaboration.

The present report summarizes some of our highlights. Enjoy reading our annual report.

Alexander Michaelis

Bärbel Voigtsberger

March 2011

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FRAUNHOFER IKTS PROFILE

BRIEF PORTRAIT

The work of the Fraunhofer Institute for Ceramic Technologies and Systems IKTS covers all aspects of technical ceramics from preliminary basic research to application. More than 140 well-equipped laboratories and pilot-scale facilities on nearly 20,000 square meters of usable floor space at the two locations Dresden and Hermsdorf are available for this. At Fraunhofer IKTS, high-performance ceramics know-how forms the basis of development work spanning the entire value chain up to prototype manufacture. With threefold expertise – in materials know-how, production technologies, and system/product integration – chemists, physicists, and materials scientists are supported by experienced research engineers and technicians in activities focused equally on structural and functional ceramics technology platforms.

Project partners are found among both manufacturers and users of ceramics. With extensive expertise and numerous contacts, Fraunhofer IKTS serves as a "one-stop shop" for all ceramics-related problems. Our mission is to bring together different technology worlds to give our customers access to the entire range of innovative solutions provided by ceramics.

Fraunhofer IKTS possesses a number of unique capabilities:

Complete production lines from material to prototype

All standard processes for mix preparation, shaping, heat treatment, and finishing of structural and functional ceramics are available. A key area of expertise in functional ceramics is paste and film technology. We manufacture functional ceramic prototypes using the hybrid and multilayer ceramics lines in our in-house clean rooms.

Multiscale development

Developments can be scaled up from laboratory to pilot scale. In our technological production chains, we can manufacture the quantities required for market introduction. Thus, we can minimize retention cost risks and time to market.

Synergies between structural and functional ceramics

By combining different technology platforms, we enable innovative ceramic products with extended functions and considerable added value to be manufactured.

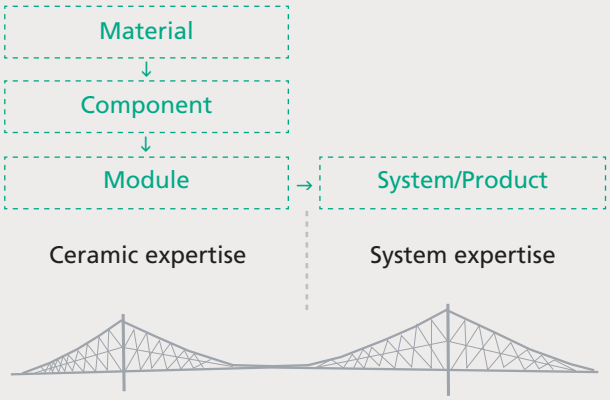
Network formers

We are currently collaborating in projects with more than 450 national and international partners. Fraunhofer IKTS is also active in numerous networks and alliances, within the Fraunhofer-Gesellschaft, for example, in the Fraunhofer Group for Materials and Components – MATERIALS.

In addition, the role of spokesperson for the Fraunhofer High-Performance Ceramics Alliance, made up of seven institutes specialized in ceramics, is held by Fraunhofer IKTS. We facilitate network formation to drive product development and obtain the necessary external expertise.

This pioneering work is made possible by a wealth of experience, extensive knowledge, and constant focus on the interests of our partners.

The Fraunhofer IKTS as "one-stop shop" for ceramics



We bring worlds together

ORGANIZATIONAL CHART

Institute Director

Prof. Dr. habil. Alexander Michaelis

Secretary: Maria Kirschner

Deputy Institute Directors

Dr. Bärbel Voigtsberger

Dr. Michael Zins

Head of Administration

Dr. Michael Zins

Staff, Internal Services and Facility Management, Controlling and Finances, IT Management, Press and Public Relations, Marketing, Quality Management

Materials

Dr. habil. Andreas Krell
- Oxide Ceramics
- Hardmetals and Cermets

Dr. Hagen Klemm
- Nitride Ceramics
- Carbide-, Filter Ceramics and Biogenic Ceramics
- Precursor-Derived Ceramics

Sintering and Characterization

Dr. habil. Mathias Herrmann
- Thermal Analysis and Thermal Physics*
- Heat Treatment
- Ceramography and Phase Analysis
- Powder and Suspension Characterization*
- Quality Assurance Laboratory* and Mechanics Laboratory
- Chemical and Structural Analysis
- Mechanical Testing

* accreditation in accordance with DIN EN ISO/IEC 17025

Micro and Energy Systems

Dr. Mihails Kusnezoff

Materials and Components
- Joining Technology
- High Temperature Electrochemistry and Catalysis
- Ceramic Energy Converters

Dr. Matthias Jahn

Modules and Systems
- Modeling and Simulation
- Energy Conversion and Storage
- Energy Process Engineering
- Electrochemistry

Dr. Uwe Partsch

Hybrid Microsystems
- Thick Film Technology and Photovoltaics
- Microsystems, LTCC and HTCC
- Ceramic Tapes and Functionalized Multilayers
- Systems Integration

Processes and Components

Dr. Michael Stelter
- Powder Technology
- Shaping
- Component Development
- Finishing
- Thermal Spraying
- Pilot Manufacturing High-Purity Ceramics
- Oxide and Polymer-Ceramic Components
- Process Technology and Silicate Ceramics

Environmental Engineering and Bioenergy

Dr. Ingolf Voigt
- Water Technology
- Bioenergy
- Mixed Conductors and Catalysis
- Nanoporous Membranes
- Process Technology and Modeling

Smart Materials and Systems

Dr. Andreas Schönecker
- Dielectric Ceramics and Composites, Piezoceramics
- Functional Layers for Microelectronics and Wear Protection
- Piezosystems

TU Dresden,
Institute for Materials Science

Inorganic-Nonmetallic Materials

Prof. Dr. habil. Alexander Michaelis
- Instrumented Powder Compaction
- Combinatorial Microelectrochemistry on Ceramic Surfaces

Friedrich Schiller University of Jena

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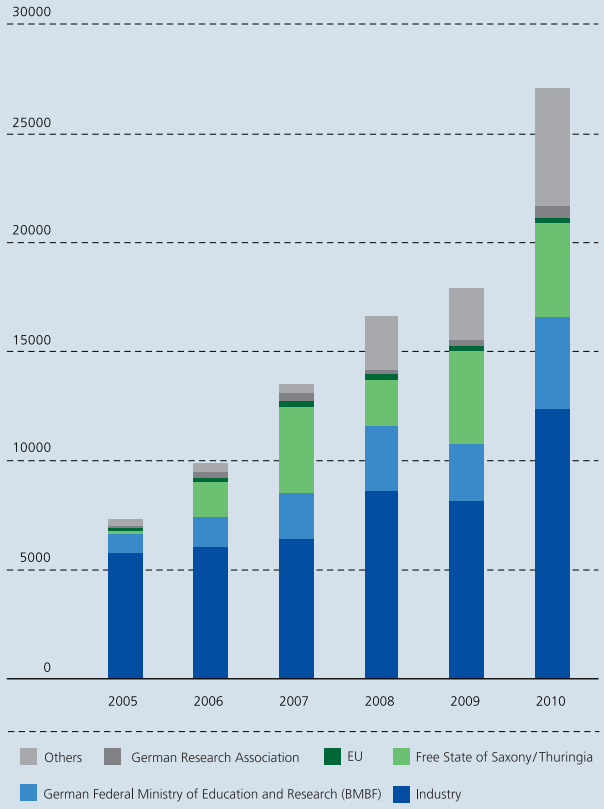
FRAUNHOFER IKTS IN FIGURES

Revenue developments (in thousands of euros) at Fraunhofer IKTS for the budget years 2005-2010



Developments of operating budget (in thousands of euros) at Fraunhofer IKTS for the budget years 2005-2010

Operating budget and figures

2010 is the first year in which the operating budget comprises the figures of both institute branches. For this reason, all graphs show a significant growth. 21.5 million euros of the operating budget of 31.7 million euros fall to the Dresden branch, and 10.2 million euros to the Hermsdorf branch. Additionally, 3.3 million euros were invested in the expansion of laboratories and pilot plants at both sites. Together we earned 27.1 million euros from customers. As the year before, the industrial revenues constitute 45 % of this sum. With a revenue of 4.9 million euros, the Hermsdorf branch has significantly contributed to this success.

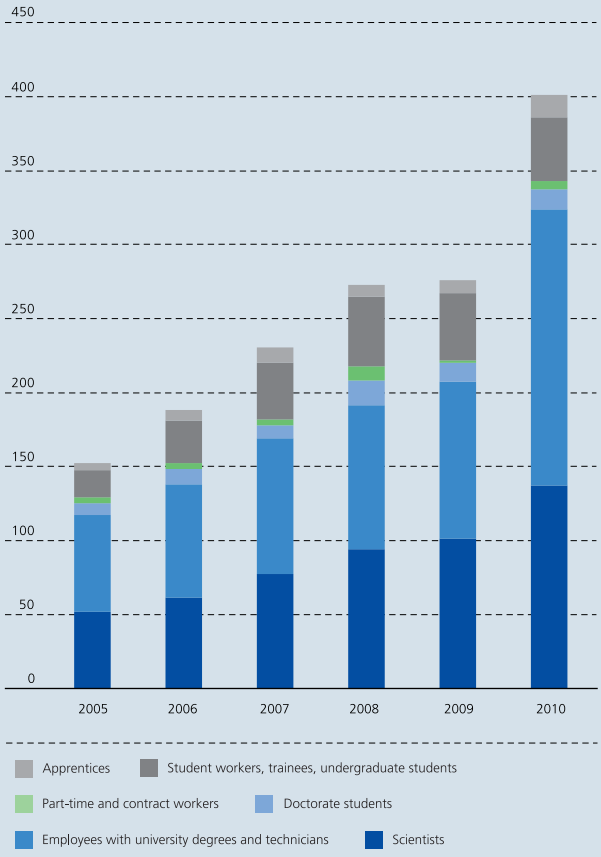
The infrastructure in Dresden has been improved using funds of an economic stimulus package. Thus, we can facilitate new work-places which are essential for 2011.

Expansion of research basis

Through investments in the "Development Center for Energy Efficiency Systems", Fraunhofer IKTS was able to strengthen its position in the fields of fuel cells, thin-film photovoltaics, biomass conversion, thermoelectric generators (TEG) and storage technologies (Lithium ion batteries). Using alliances with strategic partners the offered services have been extended from powders to systems. The integration of existing test equipment of the "Environmental Engineering and Bioenergy" research field into a biogas plant in Pöhl helps us to test ceramic technologies and components. Fraunhofer's research programs significantly facilitate the generation of its own IP rights and thus, the long-term opportunity to acquire new industry projects.

At Fraunhofer IKTS new technologies for the characterization of battery materials and components have been developed

Personnel developments at Fraunhofer IKTS
Number of employees 2005-2010, full-time equivalents
Personnel structure on December 31 of each year



and introduced to different industry consortia. As Fraunhofer IKTS has pilot scale competencies in battery powder preparation and processing technologies it becomes more and more attractive to industry partners in this sector. The institute increasingly acts as a network builder between industry partners, and thus contributes to Fraunhofer's electromobility systems research project.

Personnel development

The integration of the Hermsdorf branch results in a significant increase of staff including scientists, employees with university degree and technicians. With more than 400 full-time positions, Fraunhofer IKTS further increased its special status in the field of technical ceramics. Compared to 2009, the number of employees in Dresden remained almost constant, whereas the number in the Hermsdorf branch slightly increased. The activities at the cooperating chair of IfWW, Institute for Materials Science at TU Dresden, were significantly expanded. In the long term, this alliance will secure the strategic expansion of workforce. Currently, 50 doctoral theses are supervised.

In 2010, 15 apprentices were trained. As before, all apprentices who finished their apprenticeship could continue their employment at the Fraunhofer IKTS. By training apprentices the quality of our laboratory work will be further improved, and knowledge transfer between the working groups is supported. Regular exchange between the institute branches is an increasingly important factor.

BOARD OF TRUSTEES

The president of the Fraunhofer-Gesellschaft has appointed the following people to the board of trustees at Fraunhofer IKTS:

Dr. G. Gille
Chairman of board of trustees
H.C. Starck GmbH & Co. KG, Goslar
Manager of central department research and development

Dr.-Ing. S. Blankenburg
Hermes Schleifkörper GmbH, Dresden
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Managing director

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Rauschert GmbH, Judenbach-Heinersdorf
Managing director

Dipl.-Ing. P. G. Nothnagel
Saxony Economic Development Corporation, Dresden
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Endress+Hauser GmbH & Co. KG, Maulburg
Head of business sector sensor technology

Dr. W. Rossner
Siemens AG, Munich
Central department technology, ceramics
Department head

Dr. K. R. Sprung
German Federation of Industrial Research Associations
CEO

Dr.-Ing. G. Uhlmann
Dresden

Prof. Dr. P. Woditsch
Solar World Innovations GmbH, Freiberg
Board spokesperson

THE FRAUNHOFER-GESELLSCHAFT

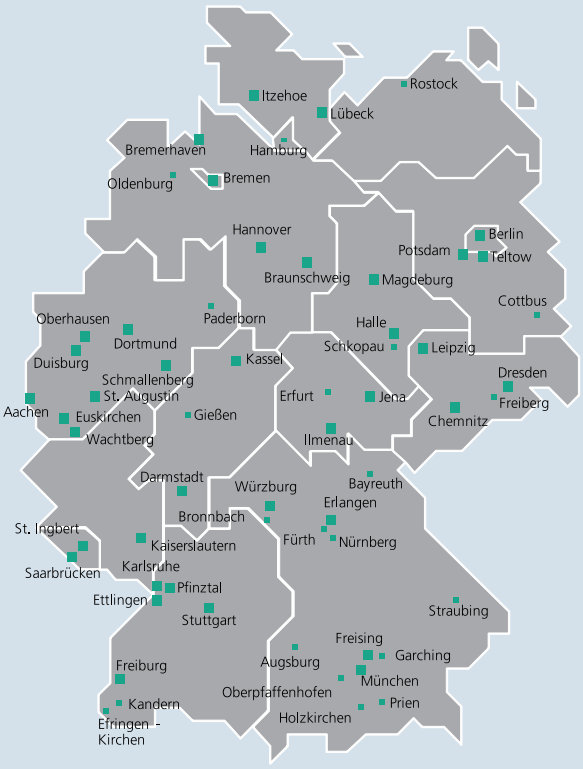
Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual 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. Of this sum, more than €1.40 billion 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.

Locations in Germany



As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

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.

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

MATERIALS

Department head:
Dr. habil. Andreas Krell, Dr. Hagen Klemm

Profile

The core competency of the "Materials" research field lies in the development of new or modified ceramic materials and ceramic-metal composites (hardmetals and cermets) with the use and generation of state-of-the-art technologies.

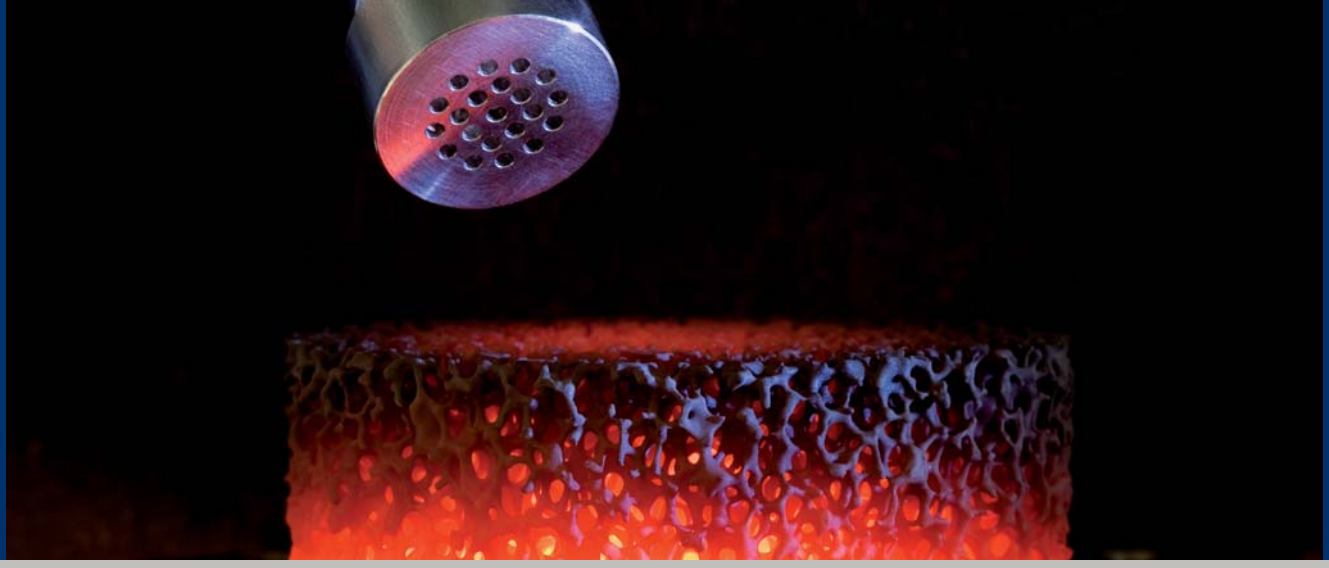
Our offering ranges from targeted synthesis of raw materials from ceramic precursors or renewable raw materials and application-oriented materials development to technological trials and manufacture of prototype parts and systems, including characterization and testing. Material-specific and technological aspects for industrial applications and safety-/health-related aspects are considered.

One focus of materials qualification is the development of low-defect and low-cost processes. Our wide range of capabilities encompasses powder processing technologies for simply structured ceramic materials as well as fiber processing and coating technologies for composite materials and functional coatings for solar applications.

The successful development of new application fields through targeted combination of structural and functional properties in ceramics and ceramic-metal composites is reflected, for example, in the development of high-temperature materials, electrically conducting ceramics, thermoelectric materials, forming tools, transparent components, functional ceramic coatings, and filters.

Services offered

- Integrated materials and process development for novel high-performance ceramics and hardmetals
- Development and supply of raw materials, trial parts, and complex components
- Expert opinions on production and application problems
- Materials testing (mechanical, tribological, electrical, and corrosive properties at room and high temperatures)
- Damage and failure analysis of components and tools
- Evaluation of safety and health risks from use of fine powders and materials
- Characterization of wetting behavior of coatings and surface tension of liquids
- Characterization of corrosion behavior under realistic application conditions (hot gas corrosion)



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Precursor-Derived Ceramics
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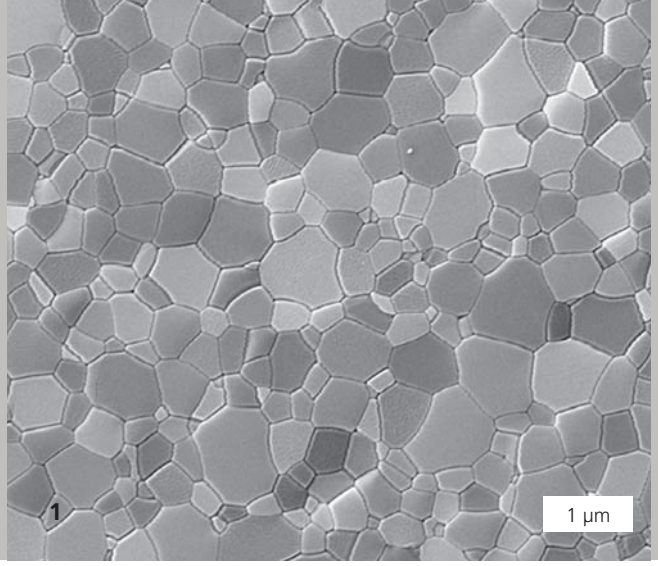

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2

DEVELOPMENT OF LARGER IR TRANSPARENT ALUMINA DOMES

Dr. Jens Klimke, Dr. Andreas Krell

Motivation

Ceramic materials are commonly being used in areas subjected to extremely high mechanical stress like in aerospace industry. So far, single-crystalline Al_2O_3 (sapphire) has been the preferred material for infrared-transmittant windows subjected to thermal stress. In addition to suitable IR transmittance, sapphire exhibits an excellent resistance against erosion by rain or sand combined with high thermal shock resistance. However, the sapphire single-crystals have to be grown as boules in a time-consuming process. Final machining of the massive sapphire boules is complex and expensive because of their high hardness.

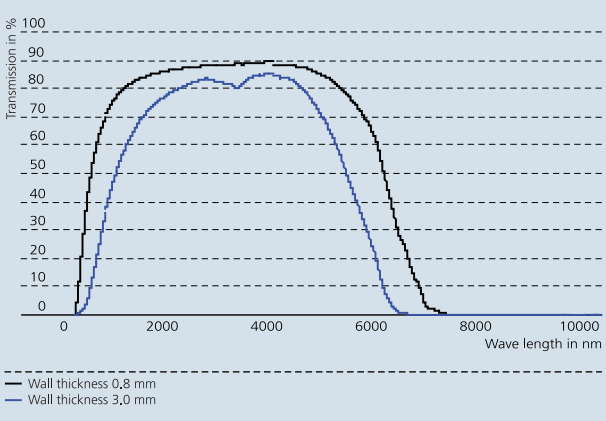
Better material properties of ceramics

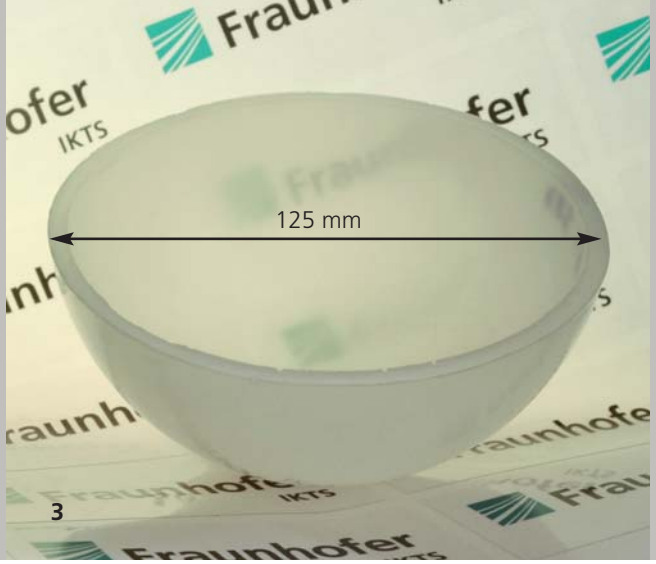
Fraunhofer IKTS developed IR transparent polycrystalline corundum as ceramic alternative to sapphire. Unlike the single crystalline corundum, the polycrystalline corundum exhibits no anisotropy of the material properties. Figure 1 shows an electron micrograph of a crystalline sub-µm microstructure. Top values of the mechanical properties were achieved thanks to the low mean grain size of the virtually pore-free dense-sintered microstructure. Compared with the mean values of sapphire, the IKTS corundum ceramics have a higher fracture toughness of 3.5 MPa√m (sapphire: 2.4 MPa√m), a higher hardness HV10 of > 20 GPa (sapphire: 14 to 15 GPa) and an improved strength (four point bending) of > 650 MPa (sapphire: 400 MPa; ±100 MPa orientation dependent).

High IR transmission

A special treatment of the corundum powder and a low-defect ceramic technology result in a nearly defect-free microstructure. Thus, light scattering at pores and grain boundaries can be largely prevented. In the IR region of 4 to 5 µm wavelength, interesting for sensor applications, the transparency of the ceramics is near the theoretical maximum (diagram below) as reflection at the surfaces reduces maximum transmission by about 11 % in this spectral range. The spectra show the in-line transmission of samples of different wall thickness polished on both sides.

IR transmission spectra of sub-µm corundum ceramics (polished on both sides)





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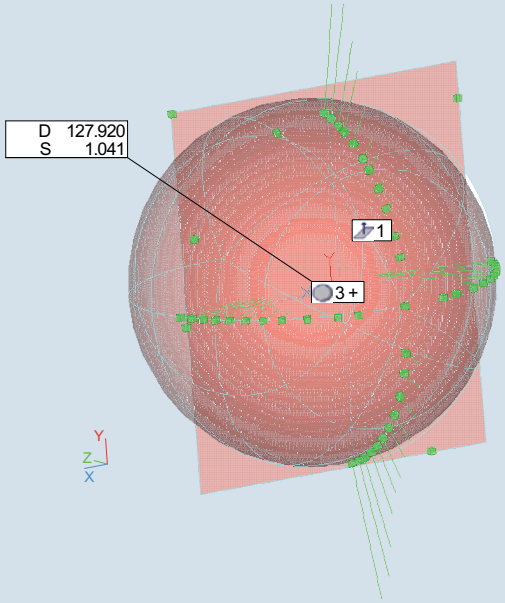
Cost-effective production

Ceramics, in contrast to single crystal, can be manufactured "near to netshape". For that reason, liquid corundum slurry is poured into a specific mold, polymerized and then demolded. Figure 2 shows the demolded ceramic hemisphere with a diameter of about 160 mm (left) and the reduced translucent hemisphere (right) caused by sintering shrinkage. If needed, a machining of the unsintered body by e.g. grinding or milling is possible. The opposite diagram shows the three dimensional size parameter plot of the sintered unpolished hemisphere with a wall thickness of about 4 mm (figure 3). The deviation of the circularity without any post-processing is < 1 %. The IR transparent corundum ceramics offer improved mechanical properties and cost advantages as compared with sapphire. The ceramic processing is particularly suited for small scale production.

Three-dimensional size parameters of a sintered hemisphere



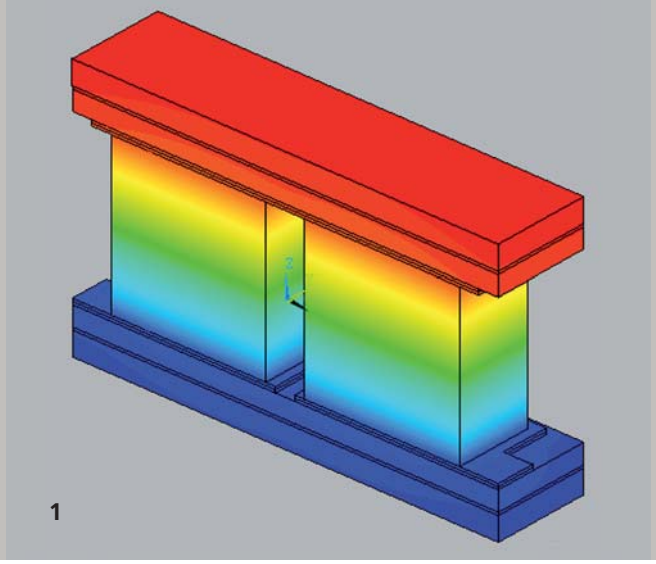
Services offered

- Production of test samples and small-scale production
- Development of materials
- Optimization of material properties
- Measurement of optical transmission

1 *Sub-µm corundum microstructure.*

2 *Ceramics before and after sintering.*

3 *Corundum dome (unpolished).*



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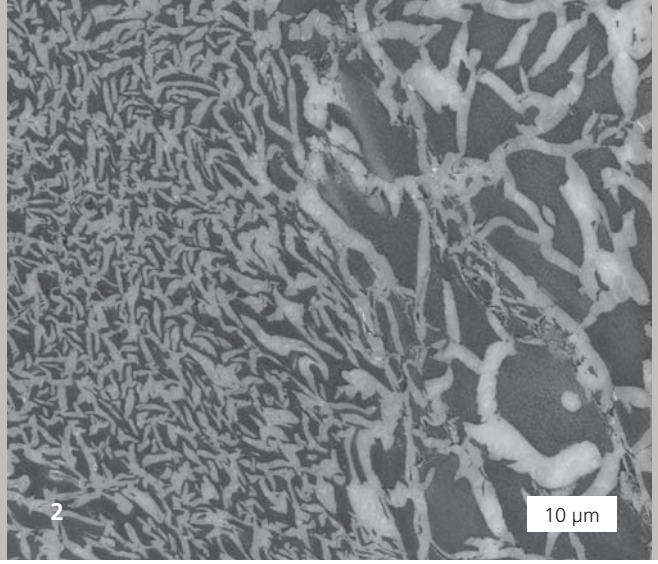


2

THERMOELECTRIC GENERATORS BASED ON CERAMIC TECHNOLOGIES

Dr. Hans-Peter Martin, Dr. Isabel Kinski, Dr. Jochen Schilm

In many technical processes only half of the applied primary energy is directly used. The waste energy typically occurs as peripheral heat. Thermoelectric generators (TEG) are able to transform thermal energy into electrical energy. This contributes to a favorable energy balance of processing. The operation of TEG is based on a solid state physics effect, named after Seebeck. Due to this effect energy transformation by TEG does not produce vibrations or emissions and therefore requires only a minimum of maintenance.

Optimized materials in combination with a temperature gradient allow to use the Seebeck effect for converting thermal energy into electrical energy. The energetic efficiency of a TEG depends on process temperature and TEG properties such as materials efficiency, contact losses, electronic components and system integration aspects. The influence of the process temperature results from the Carnot efficiency meaning that the efficiency of energy conversion increases with process temperature. The efficiency of the material can be calculated from the Seebeck coefficient (S), the electrical conductivity (σ) and the thermal conductivity (κ) resulting in Z which is multiplied by temperature T to obtain the dimensionless figure of merit.

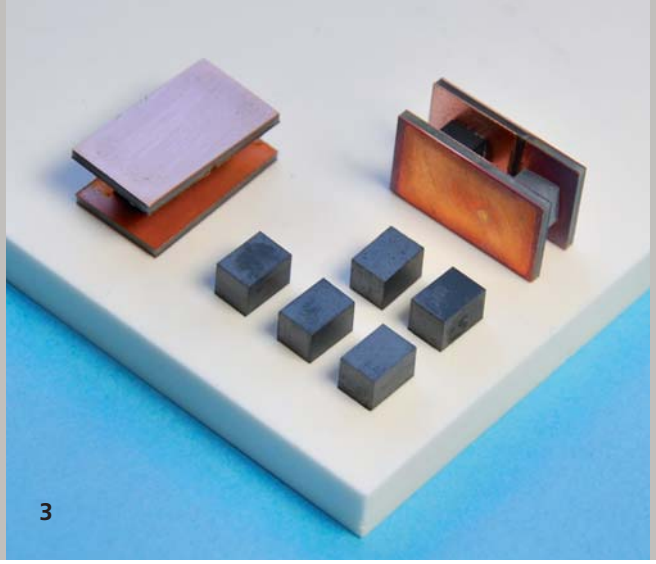
$$ZT = \frac{S^2\sigma}{\kappa}T$$

Electrical voltage which is generated by thermoelectric materials is fairly small since the best thermoelectrics deliver a thermopower between 100 and 300 µV/K within their optimal temperature range. As a consequence thermoelectric elements (legs) are sequentially mounted in modules to generate higher voltages. n-doped and p-doped legs are alternately connected to combine their thermopower. Such modules need to be integrated efficiently into a host system (waste heat source) in terms of thermal and electrical boundary conditions in order to generate a significant economic benefit.

A technological and economic solution for thermoelectric systems requires the interdisciplinary approach of materials science (material synthesis and design), materials technology, joining technology, module mounting technology, thermal management, electrical engineering and finally the integration in existing systems. Competencies in materials science, component manufacturing, joining technology and energy systems are interlinked between the different departments of Fraunhofer IKTS to solve the complex and interdisciplinary challenges of thermoelectrics.

Fraunhofer IKTS is focused on its own core competencies within the field of thermoelectrics, e.g. ceramic thermoelectrics like titanium suboxides, mixed oxides, carbides and non-oxide mixed compounds are developed and optimized. Their good availability, low material costs and suitability for high-temperatures make them attractive for such applications.

The thermopower (S) may be increased without decreasing the electrical conductivity if titanium suboxides are produced from precursors. A defined nanostructuring of the material enables the decoupling of these related properties (figure 2). A significant increase of the electrical conductivity up to a range that is usual for thermoelectrics may be achieved with super stoichiometric boron carbide. The thermopower of boron carbide stays on an extraordinarily high level because of the nano-



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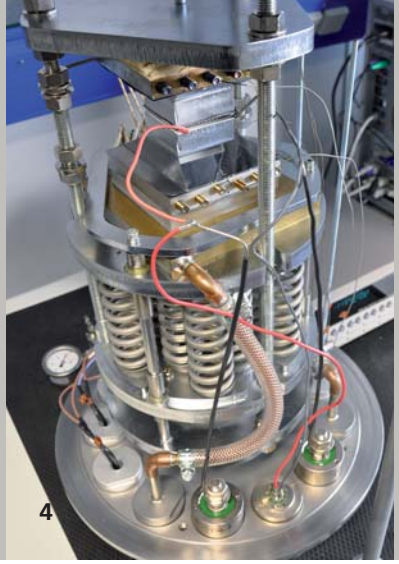

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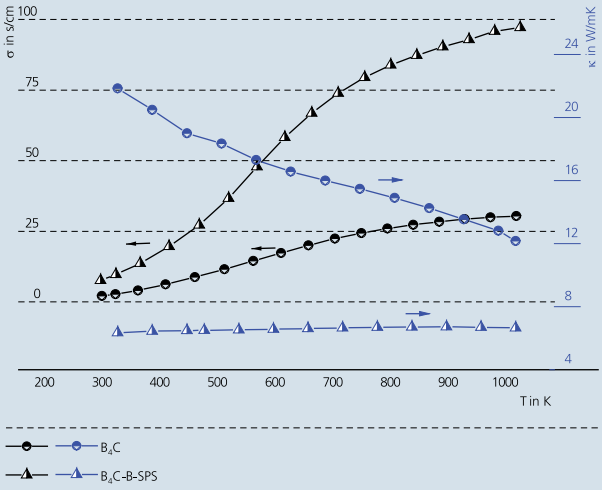
structural nature of the stoichiometric modification. To catch up with the established thermoelectrica it is the goal to reach a ZT value of 1 for ceramic thermoelectrics. It is evaluated how sintering processes such as gas pressure assisted sintering, inert gas sintering, hot pressing and spark plasma sintering influence relevant materials properties. To reach high-level ZT values it is necessary to make high-temperature assembly and joining technologies available. The suitability of technologies is always related to the specific properties of the used materials. Established joining technologies are fitted to titanium suboxides and carbide type materials for thermoelectric applications. Preliminary test samples have already been manufactured from titanium suboxide as n-doped legs and B_4C/SiC as p-doped legs. Substrates have been prepared from metalized AlN plates (figure 3).

The integration of TEG modules is supported by the "Simulation" and "Energy Systems" research groups. Additionally, Fraunhofer IKTS cooperates with external partners of the Fraunhofer-Gesellschaft as well as research institutions in the region of Dresden in the fields of material synthesis and system integration.

Thermal and electrical conductivity of B_4C and super stoichiometric B_4C



Services offered

- Manufacture and characterization of ceramic thermoelectric materials (bulk and layers)
- Design of thermoelectric properties in materials
- Characterization of assembly and joining technologies for ceramic und metallic materials
- Simulation of material and system performance of TEG

1 *Temperature gradient simulation of a TE leg pair.*

2 *Nanostructured texture of a precursor-derived titanium suboxide.*

3 *Pair of legs produced by Fraunhofer IKTS in 2010.*

4 *Test stand for TEG characterization up to 600°C.*

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

PROCESSES AND COMPONENTS

Department head:
Dr. Michael Stelter

Profile

The research field "Processes and Components" encompasses manufacturing processes for ceramic components and assemblies. Prototype solutions are generated on laboratory and pilot scale, small batches are produced and, if required, scaled up to pilot technologies. The value chain ranges from modification of commercial powders and raw materials to shaping, sintering, machining (green and sintered bodies), and to joining and integration technologies. The equipment enables scale-up of all individual technological processes to industrial standards, readily transferrable to the customer's site.

Design of ceramic and metallic materials as well as composite materials and their precursor products form the heart of our powder technology. Silicate and polymer ceramics are additional core areas of materials expertise. Our component design group employs a broad range of plastic and thermoplastic shaping and casting technologies as well as powder pressing. Component surfaces are treated using plasma spray processes.

The technology chains are completed with a capable and innovative green machining and finishing center. Our high standard of quality is supported by a first-class QM system and numerous certifications and expert audits.

Overall, the research unit offers outstanding possibilities for component manufacturing, system integration, and advanced materials. Prototypes and small batches can be delivered quickly, reliably, and cost effectively. We offer a flexible handling and rapid response in order to help our customers to reduce the time to market.

Services offered

- Development of ceramic processes, components and systems on a pilot scale
- Contract research and joint projects
- Services related to manufacturing processes
- Technology transfer
- Design of scientific equipment
- Feasibility studies
- Consulting and training courses

In conjunction with other research fields at Fraunhofer IKTS, namely materials development and simulation, we offer competent advice and excellent R&D to our partners. We can draw on the expertise of other institutes in the Fraunhofer High-Performance Ceramics Alliance to extend our scope. The Fraunhofer Demonstration Center AdvanCer provides a wide range of services.

www.advancer.fraunhofer.de

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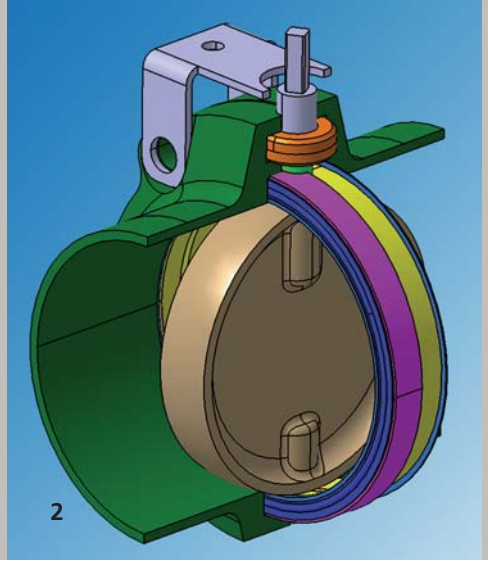


2

HIGH-PERFORMANCE COMPONENTS FOR AUTOMOBILES – CERAMIC EXHAUST FLAP

Dipl.-Ing. Jens Stockmann

State-of-the-art

Since a few years metal exhaust flaps have been used for noise reduction in automotive exhaust systems. Such elements can also be used to reduce emissions. Materials which withstand high temperatures and corrosive environments occurring close to the engine are a prerequisite. Technical ceramics with their outstanding properties are perfectly suited for such requirements.

Development of ceramic prototypes

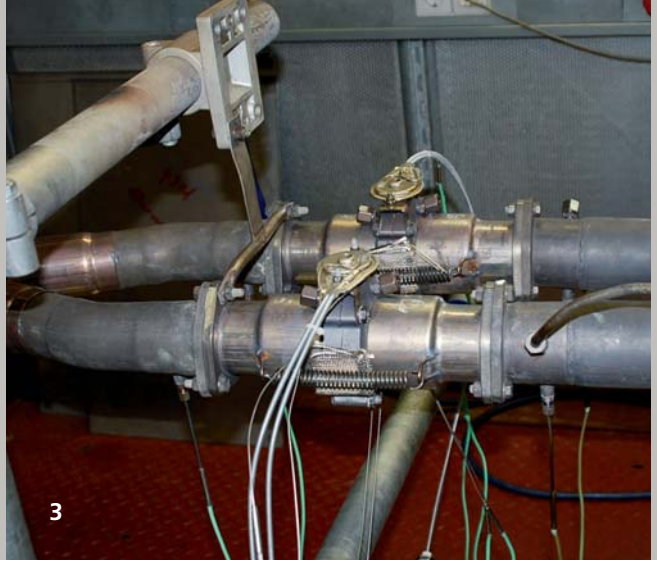
On behalf of Friedrich Boysen GmbH & Co. KG, a leading developer and manufacturer of exhaust systems, all-ceramic exhaust flap prototypes were developed at Fraunhofer IKTS consisting of a baffle plate with bearing pin, adjusting lever and a two-part bearing ring. It was the aim of the project to develop a nearly gas-tight, controllable bypass to protect catalytic components having a lower thermal stability. Silicon nitride was chosen as material on account of its very good mechanical and thermal properties. Prototypes were manufactured by isostatic pressing, green machining (milling) and gas pressure sintering. It was a specific challenge to grind the outer contour of the baffle plate (spherical washer) and the inner contour of the two-part bearing ring (spherical) with high precision in order to guarantee the smallest possible gap for minimal leakage losses when closed.

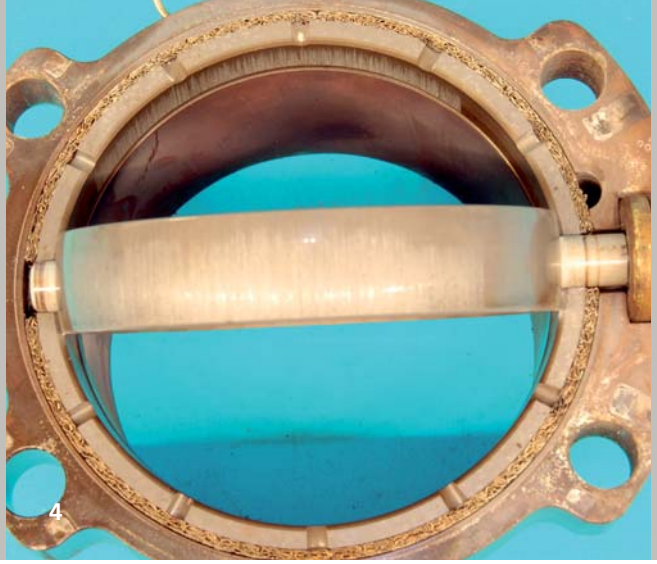
Testing of assemblies

At a test stand at Boysen $5 \cdot 10^5$ switching functions were realized during a test period of 305 h within 1100 temperature cycles, i.e. heating from < 100 to 875°C and cooling. A burner was used to generate high temperatures. The gas throughput was around 450 kg/h. The assemblies withstood the tests without damage. Depending on the ground-in clearance – in the range from 0.05 to 0.1 mm – leakage losses between 10 and 40 l/min were measured. With similar assemblies made of steel the leakage flow rates are significantly higher than 100 l/min.

Prospects

With the ceramic exhaust flap system NOx catalysts can reliably be used to store nitrogen oxides when the combustion engine is operated in partial load. However, these catalysts may not be used at temperatures above 650°C. Operating at higher revs the exhaust gas mixture is passed through a bypass to the three-way catalyst by actuating the exhaust flap. In future, diesel engines can also be equipped with this efficient system for NOx reduction.

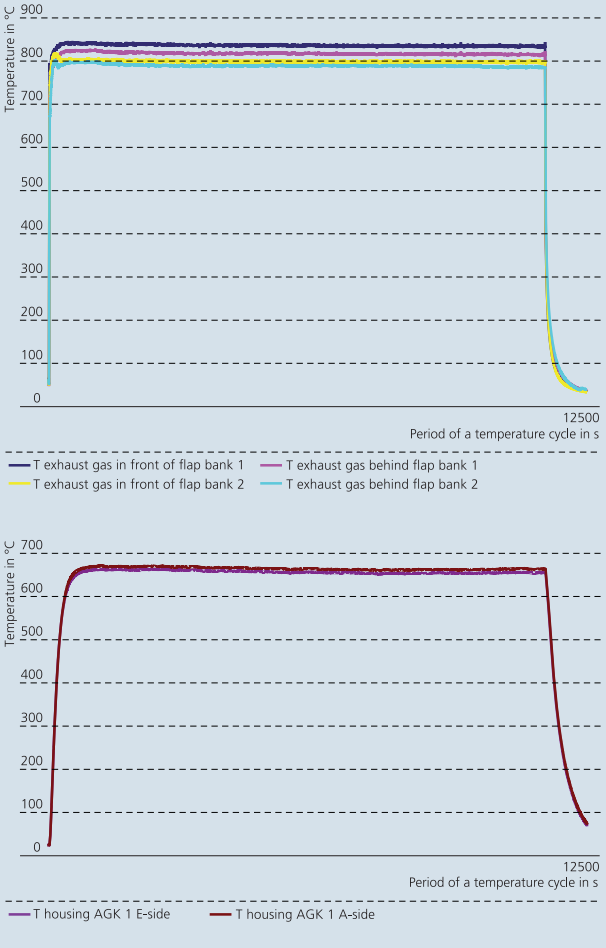




Services offered

- Consulting on materials as well as ceramic-aware design
- Development of prototypes and small batches for functional tests and sampling
- Support in setting-up large-scale ceramic production lines

Temperature-time curve during functional tests
(source: Friedrich Boysen GmbH & Co. KG)

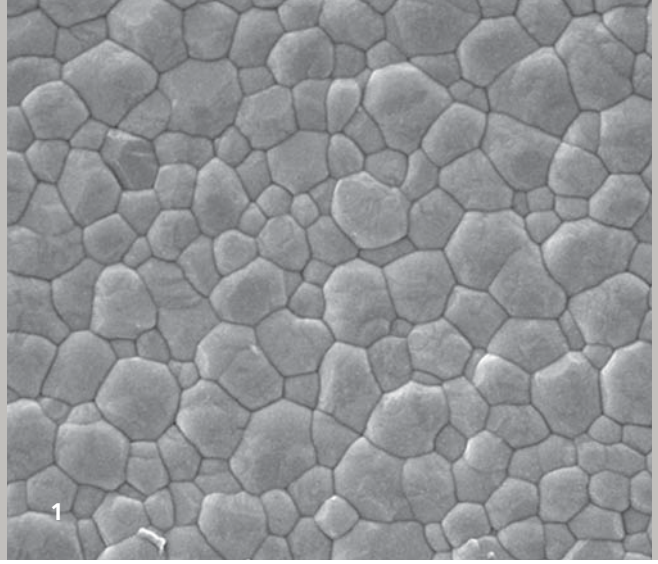


1 *Ceramic assembly, ground.*

2 *3D sectional view through assembly (source: Friedrich Boysen GmbH & Co. KG).*

3 *Test stand for functional test with integrated exhaust flap (source: Friedrich Boysen GmbH & Co. KG).*

4 *Ceramic assembly after testing (source: Friedrich Boysen GmbH & Co. KG).*



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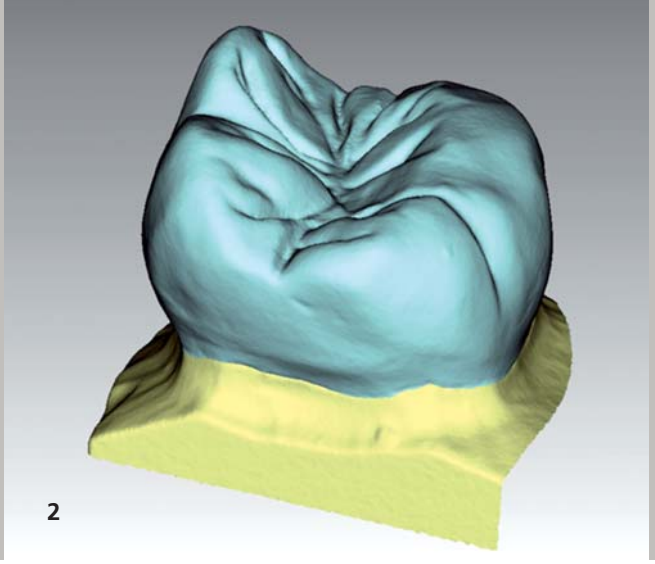


2

VENEERING OF ZIRCONIUM OXIDE WITH LITHIUM DISILICATE GLASS CERAMICS

Dipl.-Chem. Martina Johannes, Dr. Roland Ehrt

Motivation

Yttrium stabilized zirconium oxide has become more and more important for dentistry in recent years. High mechanical strength, fracture toughness and a good translucency make the material suitable for crown and bridge substructures. On account of beauty aspects a veneering of the ceramic substructure is required. The weak points are both, the poor mechanical strength of the ceramic veneering system and possible edge chipping on the veneering system when the layer thickness becomes too large. By increasing the bending strength as well as improving the bonding between ceramic substructure and ceramic veneering system, edge chipping can be avoided.

Approach

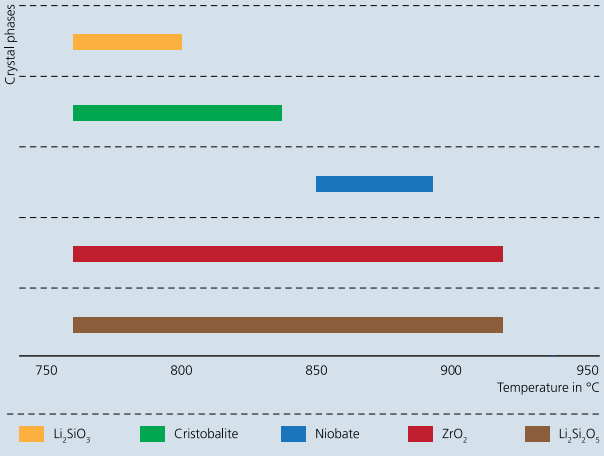
The combination of a crown substructure with an anatomically reduced tooth shape made of yttrium stabilized zirconium oxide with a lithium disilicate glass ceramic veneering system could be an attractive approach for restorative dentistry. Lithium disilicate glass ceramics have very good esthetic as well as mechanical, chemical and optical properties. The represented ceramic veneering system corresponds to the system $M^{I}_{2}O$-$M^{III}_{2}O_{3}$-$Nb_{2}O_{5}$-ZrO_{2}-SiO_{2}. $M^{I}_{2}O$ applies to lithium oxide and sodium oxide, and $M^{III}_{2}O_{3}$ applies to boric oxide and aluminium oxide.

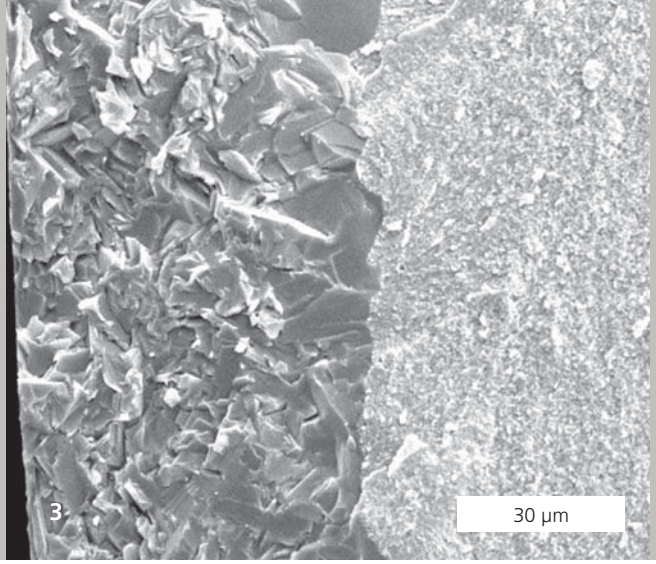
Crystallization behavior of the veneering system

Lithium disilicate ($Li_{2}Si_{2}O_{5}$) is the main crystal phase of the veneering system. Lithium metasilicate ($Li_{2}SiO_{3}$) crystallized in the temperature range from 760 up to 800°C, and cristobalite crystallized up to 840°C as shown in the diagram below.

The ceramic veneering system can be applied as powder or suspension. It is assumed that nucleation is controlled by the grain boundaries of the glass ceramic powder and not by the zirconium oxide crystals. By adding niobium oxide the surface quality of the veneering system can be improved.

Cristallization behavior of the ceramic veneering system

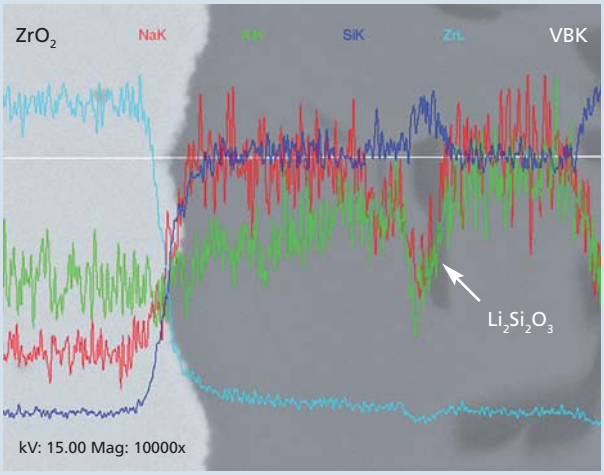




Interface between substructure and veneering system

The bonding between substructure and veneering system was examined by means of SEM microscopy in combination with EDX (linescan). After annealing at 800°C the crystalline phase of the veneering system is grown to the substructure interface. At 890°C a zirconia rich glassy phase is formed at this interface resulting in an intensive bond between substructure and veneering system. The thickness of the intermediate phase may reach 4 µm and the zirconium content increases up to a factor of 4.
The reasons for the formation of the glassy interface may be the crystal growth of lithium disilicate and the diffusion behavior of the lithium ions.

Line scan of interface between ceramic substructure and veneering system



Surface of the veneering system

During the formation of lithium disilicate crystallites the niobium oxide is forced into the glass matrix phase. The Nb_2O_5-content in the glass phase is increased by a factor of 1.5.
The increased niobium oxide content provides the formation of a thin glass layer on the surface of the veneering glass ceramics during the process of controlled crystallization.

Acknowledgments

The Federal Ministry of Economy and Technology is gratefully acknowledged for supporting this project.

Services offered

- Development of glass ceramic materials including customization and characterization of oxide ceramic components
- Shaping of oxide ceramics, e.g. slip casting

1 *SEM structure of a yttrium stabilized zirconium oxide.*
2 *Crown substructure with an anatomically reduced tooth shape.*
3 *SEM image of substructure and veneering interface.*

1

2

LARGE-SIZED PLASMA-SPRAYED CFRP/GFRP COMPONENTS

Dipl.-Ing. (FH) Bernd Gronde

Motivation

Energy-efficient light-weight construction with carbon or glass-fiber reinforced plastics (CFRP, GFRP) is of increasing importance for many industry sectors such as automotive industry or mechanical engineering.

CFPR and GFPR components are produced by near-net-shape techniques as complex parts or as laminated semi-finished products such as cylinders, plates or molded paddings. They are high-strength and light components, but less stable against chemical and tribological stress.

Ceramic coatings can significantly improve surface stability and quality of CFPR and GFPR components. This includes:

- Wear protection of components subjected to frictional and sliding stress
- Non-stick effect against liquids and solids
- Resistance against environmental influences
- Electric insulation (also in combination with improved wear protection)
- Thermal insulation

The surfaces are coated by atmospheric plasma spraying (APS). As we have many years of experience in this field, we succeeded in holding the thermal stress at a subcritical level. A number of ceramic and metallic materials as well as cermets can be applied on the surface without additional heat treatment. The resulting material composites solve the conflict between light, high-strength components and high surface stability as well as surface quality.

In practice, the weight was reduced by a factor of ten by using CFRP components with ceramic sprayed coatings.

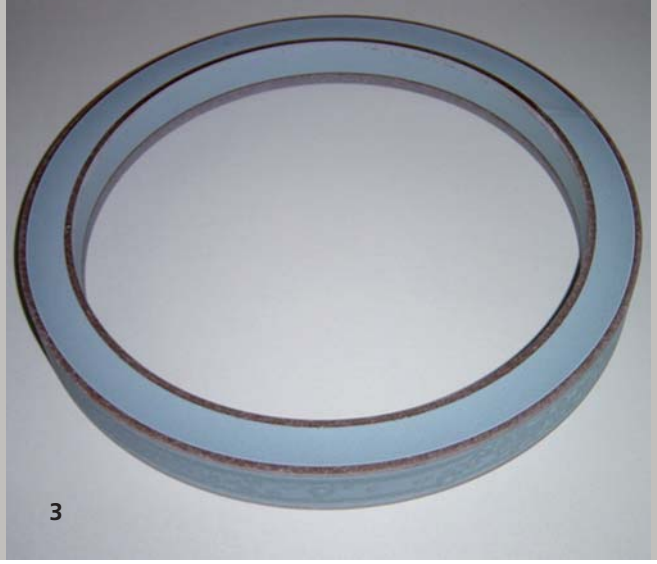
Results

Adhesion between ceramics and plastics plays a decisive role for many coating systems. The ALBOCER® adhesion system developed at Fraunhofer IKTS allows one to apply coatings on CFRP and GFRP surfaces having an adhesive strength of up to 25 N/mm².

This adhesive strength may be realized for sample surfaces as well as for very large-sized components. In the development period the adhesive strength of 25 N/mm² was measured at an alumina coated cylinder with a diameter of 380 mm and a length of 4000 mm. No deviations from the sample components were detected.

The layer thickness ranges from 0.01 to several millimeters. The layer formation rate may amount up to 40 g/min with an economically attractive adhesive rate of up to 80 %.

In the future, even components with complex geometries can be coated. For the first time an inside coating was realized on GFRP bushings at Fraunhofer IKTS.



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Serives offered

- Coating of prototypes with ceramic protective and functional layers
- Development and characterization of coatings in terms of morphology, physical and mechanical properties as well as life tests
- Coating of small components (5 to 120 mm in diameter, 10 to 300 mm in length)
- Coating of medium-sized components with standard geometries (max. 500 mm in diameter, max. 2400 mm in length, with a max. weight of 1 t)
- Coating of large-sized components, specialization on rotation symmetrical components and flat components (max. 700 mm in diameter, max. 5000 mm in length, with a max. weight of 1 t)

1 *CFRP cylinder after coating.*
2 *CFRP cylinder for corona application.*
3 *Ring made of DoTherm® with ceramic coating.*
4 *Sleeves with ceramic coating.*

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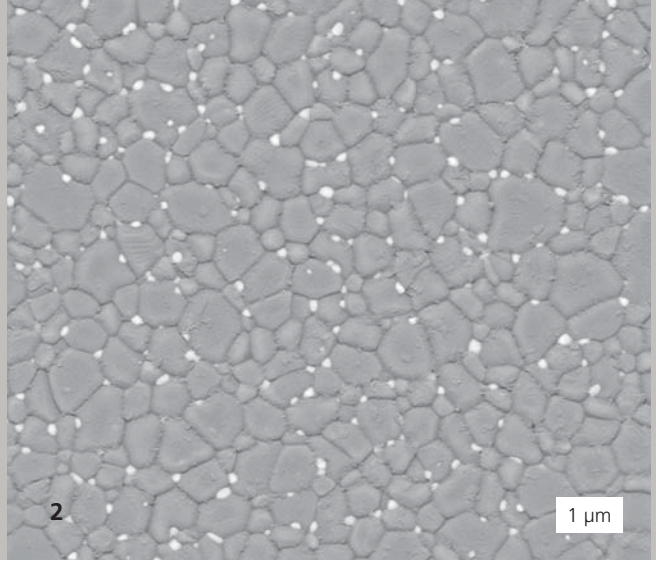


2

HIGH-STRENGTH AND NON-AGEING ZTA CERAMICS FOR IMPLANT APPLICATIONS

Dipl.-Ing. Henry Ludwig, Dr. Uwe Reichel, Dipl.-Ing. Uta Oberbach

Initial situation

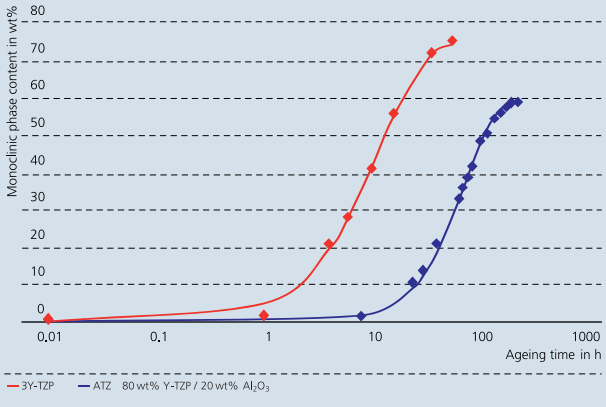
Due to the excellent mechanical qualities and the unique biocompatibility in particular, the interest in ceramic materials permanently grows in the field of medical engineering. Alumina and zirconia ceramics have successfully been used as biomaterials for joint endoprosthesis for many years. The advantages of the single-phase ceramic materials Al_2O_3 and ZrO_2 can be combined by producing a dispersing ceramic material. So, the particular disadvantages of both individual materials can be compensated. Here it is important to distinguish mixtures with a higher alumina amount (zirconia toughened alumina, ZTA) from dispersions with a higher zirconia amount (alumina toughened zirconia, ATZ).

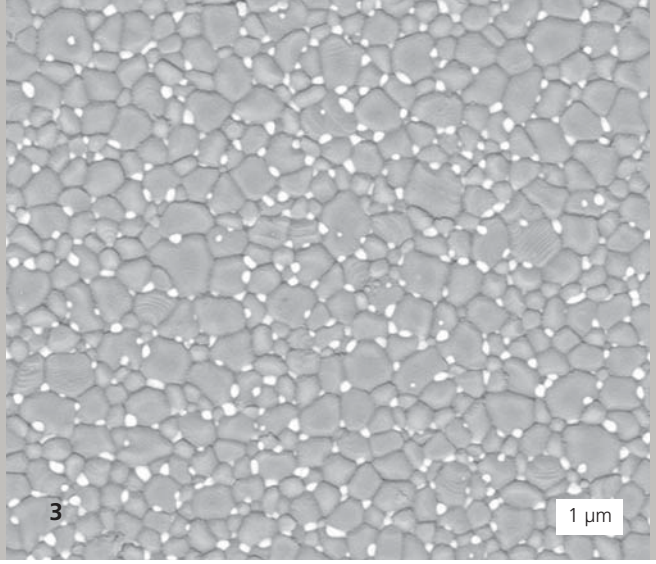
Our materials developments for hard-hard implants (combination ceramic/ceramic) currently focus on using dispersion ceramics. It is the aim to develop high-strength ceramic materials with strength properties that are better than these of pure alumina ceramics. Unfortunately, the conventional dispersion ceramics ZTA and ATZ as well as the pure yttrium stabilized zirconia show an ageing tendency reducing the mechnical properties in vivo (diagram on the right). This ageing described as low temperature degradation (LTD) primarily depends on the zirconia content of the used dispersion ceramics and on the stabilization component as well. The higher the zirconia content in the material, the higher are mechanical strength and fracture toughness of the material, but the lower is the ageing resistance.

Approach

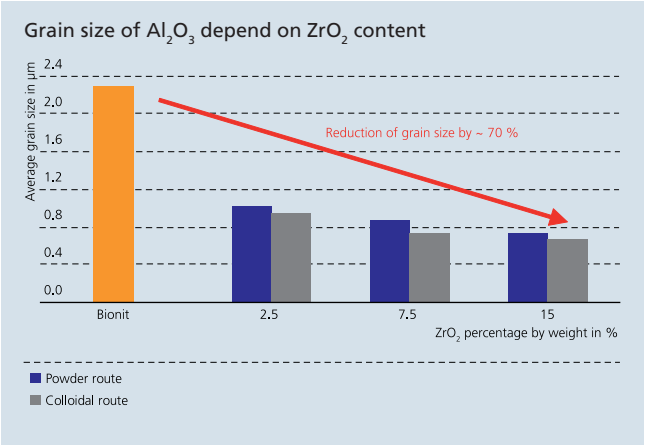
By mixing high-purity alumina powders of different qualities (d_{50} = 0.7 and 0.15 µm) with unstabilized nano zirconia powders (d_{50} < 30 nm) dispersion ceramics were prepared. One method starts with a standard powder mixture, another one uses co-precipitation (mixing of alumina slurries with zirconia precursors) and slip casting. The doping content was between 2.5 and 15 wt% of zirconia. Both methods resulted in dense, highly disperse microstructures. The homogeneous microstructure was free of pores. Using 15 wt% of ZrO_2 the Al_2O_3 grain size was reduced by 70 % compared with the state-of-the-art (diagram on the right). The bending strength was > 1000 MPa (4-point bending test) depending on the used alumina powder quality and the ZrO_2 content. The highest Vickers hardness (HV2) values were achieved with mixtures produced through co-precipitation. The ageing behavior of the dispersion ce-

Low temperature degradation (LTD) of Y-TZP/ATZ
(Vapor water 134°C, 2 bar)





ramics is investigated by determining the bending strength before and after treating the samples in the autoclave (134°C, 2 bar) as well as by phase analysis (XRD). Once a favored material composition has been found (fulfillment of the target criteria/material characteristics) a manufacturing method including granulation and cold isostatic pressing (CIP) is developed. Wear tests were carried out in the hip joint simulator for commercially available standard ZTA ceramics. The tests will be continued with the newly developed material.



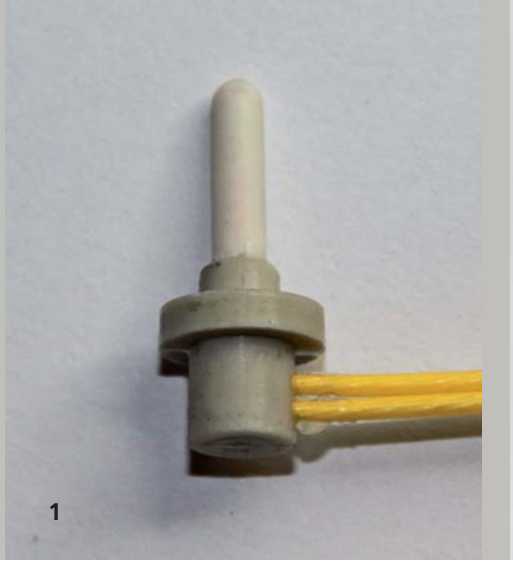
Acknowledgments

The introduced work is result of a current joint project with Mathys Orthopädie GmbH Mörsdorf. The project is funded by the Federal Ministry of Economics and Technology (No. IW 091081).

Services offered

- Development of oxide and dispersion ceramics
- Slip casting of ceramic components
- Development of ZTA or ATZ granules
- CAD/CAM process chain for manufacturing of medical implants

1 *Parts of ceramic hip joints.*
2 *Microstructure of ZTA (Al_2O_3 with 5 wt% ZrO_2).*
3 *Microstructure of ZTA (Al_2O_3 with 15 wt% ZrO_2).*



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2

FUNCTIONALLY MODIFIED INORGANIC-ORGANIC COMPOSITE MATERIALS

Dipl.-Chem. Ralph Schubert

Materials with distinctive functional properties such as high electrical or thermal conductivity or adjustable dielectric conductivity are required for the production of powerful components used in e.g. sensor technology, mechanical egineering, communication technology, or power engineering. Furthermore, these materials should exhibit flexible processing properties including complex plastic shaping techniques or the potential of integration into composites.

A concept of an inorganic-organic composite material based on filled silicium-organic polymers was developed at Fraunhofer IKTS. These composites combine ceramic-like properties (e.g. high thermal stability) and plastic-like properties (e.g. simple processing including plastic shaping techniques such as injection molding and no need of high-temperature treatment).

The results of current investigations reveal that functionalized composites can be realized using special filler systems, and additional thermal treatment in a temperature range between 200 and 900°C, if necessary. Applying electrically conductive fillers electroconductive composites could be produced,

Adjustment of electrical conductivity

System	Electrical conductivity/S·cm^{-1}
Polysiloxane/SiO_2	10^{-12} - 10^{-15}
Polysiloxane/Al	4 - 6
Polysiloxane/Cu	23 - 55
Polysiloxane/TiC	13 - 17
Polysiloxane/C	10 - 12

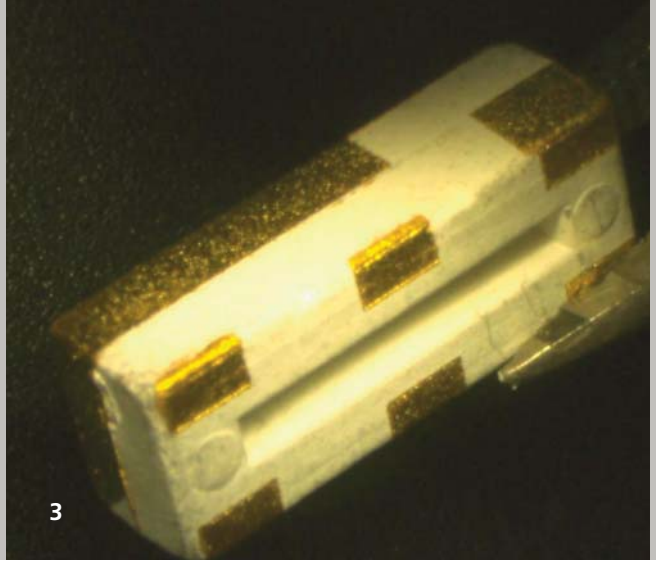
Adjustment of thermal conductivity

System	Thermal conductivity/W·m^{-1}·K^{-1}
Foamed polysiloxane/SiO_2	0.2 - 0.7
Polysiloxane/Al_2O_3	1.1 - 3.8
Polysiloxane/BN	5.0 - 12.0
Polysilazane/AlN	2.2 - 8.5

whereas the application of nonconductive fillers like SiO_2 resulted in insulating materials even at temperatures up to 1000°C (table on the left).

Using thermoconductive fillers as well as polysilazanes as matrix forming polymers and applying a heat treatment process causing a partial ceramization of the composite matrix the thermal conductivity of the composite could be increased significantly. In contrast thermally insulating materials can be produced by foaming the composite matrix in plastic state during processing (table above). Applying fillers with high dielectric conductivity composites with adjustable dielectric constants could be manufactured (figure 1).

Ongoing investigations are targeting the examination of the application potential of the newly developed functionalized composite materials. The composites with modified electrical conductivity are to be tested as sensor housings, electrodes, bipolar plates in fuel cells, and components for electromagnetic shielding. Heat-conductive materials may be used in components of metal processing (e.g. wire drawing nozzels) or as joining systems in heating units. Composites with adjusted



dielectric constants are used in miniature high-frequency antennas.

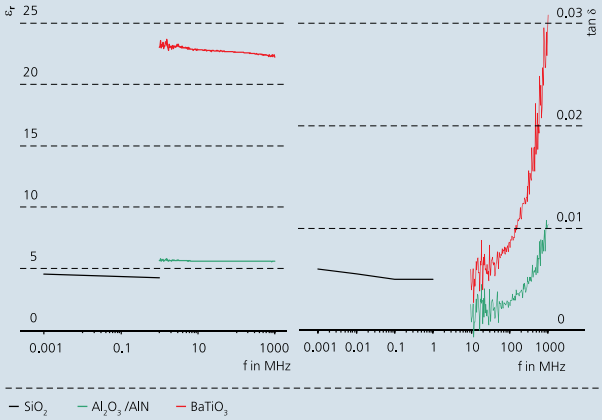
Acknowledgments

The presented results have been particularly obtained within the funded R&D projects INNOWATT IW070216 and INNOKOM VF090024.

Services offered

- Development of functionalized composite materials and appropriate processing technologies
- Supply of composite materials
- Development of application samples

Dielectric properties of functionally filled composite materials based on polysiloxane matrix



1 *Temperature sensor with thermally stable composite housing.*

2 *Bipolar plates made of electroconductive composite material.*

3 *Miniature HF antenna made of HDK composite.*

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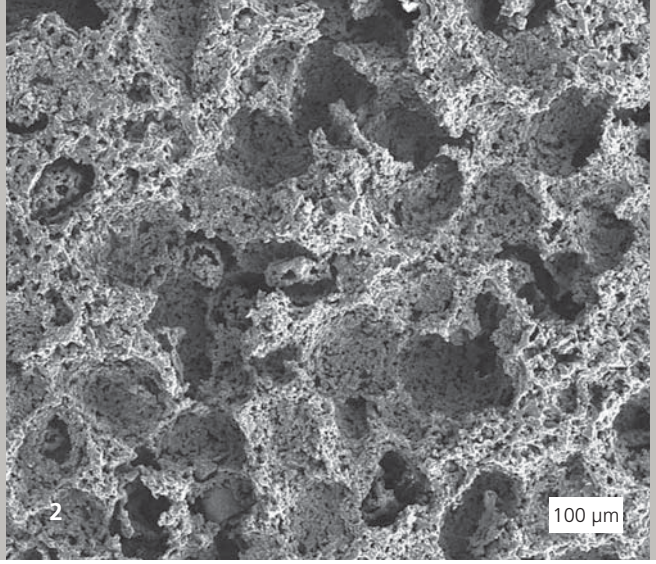


2

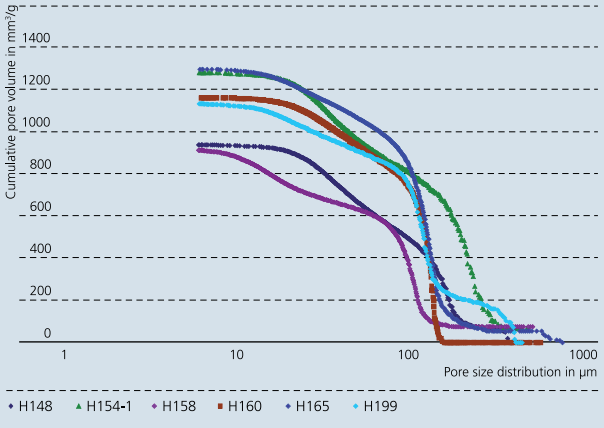
CERAMIC FILTERS FOR CLEANING LPG

Dipl.-Ing. Steffen Lauenroth

Initial situation

LPG (liquefied petroleum gas) is a mixture of propane and butane liquefied under pressure which is generated during oil and natural gas production as well as in oil refineries. Due to its chemical composition LPG can be used as alternative fuel for gasoline engines. The different gas qualities, particularly as far as unwanted components are concerned, cause technical problems when used in gasoline engines. In measurements up to 200 different organic compounds (with trace level) were identified in the LPG. The accumulation of long-chained hydrocarbons in conventional paper filters is problematic as a swelling up followed by obstruction of the gas flow may result in a reduced operability or in filter failure.

Pore size distribution of selected test filters



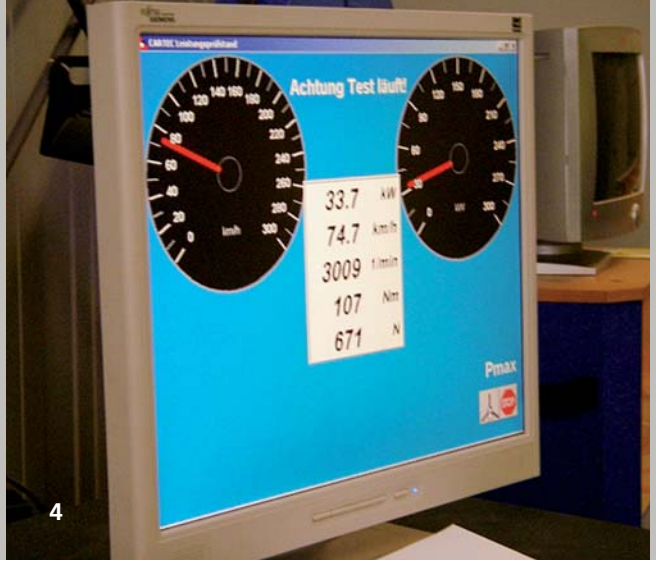
Requirements on filter porosity

The structure of the pore system must fulfill two main requirements: On the one hand, a high open porosity with comparatively large pores is necessary to prevent gas flow limitations in the filter. On the other hand, long-chained hydrocarbons are to be separated selectively by a labyrinth-like pore system and fine-structured pore surfaces.

Results

Particularly good results can be obtained with a cordierite system. By using combustible natural (classified nutshell flours) and synthetic pore forming agents (waxes, graphite) the existing porosity of this material can be increased. The pore size and open porosity can be changed in a wide range by varying type, shape, size and quantity of the pore forming agents. The developed filters offer open porosities of up to 75 % and mean pore sizes > 100 µm.

3



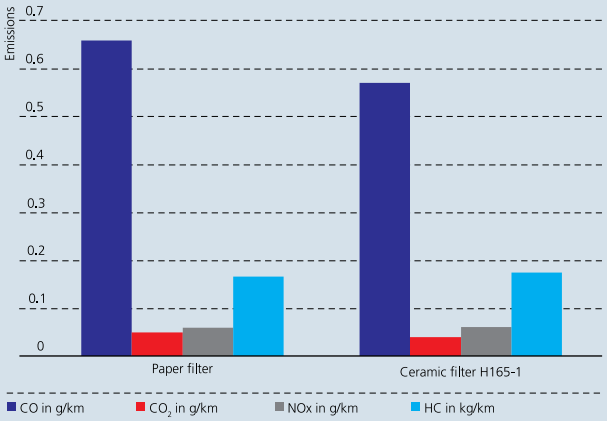
4

Application

Two identically constructed cars of type VW Caddy from Autogastechnik Triptis GmbH were used for testing the filters. Performance tests realized by the TÜV Thüringen on test stands at the University of Applied Sciences Zwickau led to the selection of filters without influence on engine performance. The selected filters were analyzed in terms of their influence on exhaust emission.

Since October 2010 the filters have been tested in traffic. After completing a defined road performance the filters are removed and the filter residue will be examined by IR spectroscopy.

Exhaust emissions with selected filters



Acknowledgments

The presented results were obtained within a publically funded project (BMWi, FKZ. IW090053).

Services offered

- Development of ceramic elements for filtration applications or as carrier for microorganisms or catalysts
- Manufacturing and analysis of test samples and small batches

1 *Conventional paper filter, filter housing, ceramic filter (from right to left).*
2 *SEM image of the pore structure of a ceramic LPG filter.*
3 *Test stand at the University of Applied Sciences Zwickau.*
4 *Instantaneous display during performance test.*

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

ENVIRONMENTAL ENGINEERING AND BIOENERGY

Department head: Dr. Ingolf Voigt

Profile

The research field "Environmental Engineering and Bioenergy" encompasses the development of materials, technologies, and systems for the efficient, safe, economical generation, conversion, transportation, storage, and utilization of energy, especially bioenergy. Technologies and processes are also being developed for water and air purification.

At the core of the research activities are ceramic membranes for liquid filtration, pervaporation, vapor permeation, and gas separation as well as catalysts for exhaust gas purification and wet chemical catalysis. Powerful process technologies for comminution and disintegration of biogenic substrates as well as membrane modules and systems for substance separation and reaction are also being developed. The integration of these technologies into existing technologies (e.g., for biogas and bioalcohol generation) results in a significant increase in efficiency and offers new approaches for process development.

For environmental protection and resource conservation, innovative solutions for substitution or economical use of chemical additives are designed and efficient technologies for recovery and reuse of resources developed.

Services offered

The services we offer range from development, optimization, and planning to scientific support in the installation of facilities and transfer to continuous industrial operation. Innovative treatment technologies and extensive know-how in ultrasonic treatment, biological catalysis, and fermentation are used to enable highly efficient use of natural raw materials and biogenic waste materials.

- Situation and systems analysis at customer site and in laboratory
- Innovative process development and specification for biomass treatment
- Determination of gas potential of biogenic substrates
- Optimization of reaction kinetics for anaerobic breakdown processes
- Processes for wastewater purification and water treatment in municipal and industrial plants
- Ultrasonic application for degassing and disintegration
- Energy optimization of stirring processes
- Membrane development and testing
- Application and piloting of membrane processes
- Catalyst development and testing
- Supply of samples of ceramic membranes and catalysts for pilot and demonstration systems
- Membrane system development and prototype manufacture
- Engineering of biogas plants using new, innovative process steps
- Provision of expert opinions and reports

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EVALUATION OF MIXING PROCESSES BY MEANS OF PROCESS TOMOGRAPHY

Dr. Eberhard Friedrich, Dr. Karin Jobst, Dipl.-Wirt.-Ing. Annett Lomtscher

Initial situation

Despite progress in dimensioning stirring systems using computational fluid dynamics (CFD) the requirements for mixing techniques are only partially fulfilled in many industry sectors. Particularly for highly viscous, non-Newtonian fluids previously used models for CFD lead to incorrect interpretation. This can be referred to insufficient consideration of the real existing properties as well as the lack of an experimental evaluation of mixing and flow processes. Thus, for example, the efficiency of biogas reactors is limited. Besides dead storages floating and sinking layers inhibit an optimal biogas production.

Approach

Using process tomography existing at Fraunhofer IKTS, a visualization and quantitative evaluation of mixing processes of opaque substances can be realized for the first time.

Operating principle

By applying a defined current between a pair of electrodes on each level a potential field is built up which is influenced by the different electrical conductivities of the multiphase system. As a result, the distribution of conductivity and the volume concentration of the disperse phase in the reactor system can be determined. For further evaluation of mixing and flow processes the mixing quality is calculated and the velocity profile is determined.

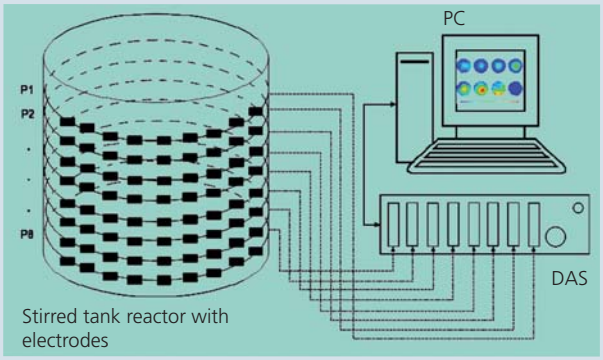
Mixing quality of biogas digesters

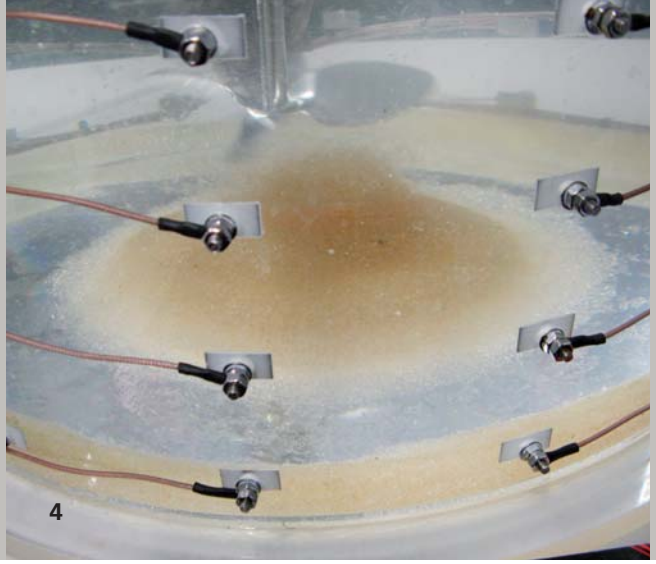
Considering the reactor geometry of large-scale biogas plants the mixing of pretreated straw into digester effluent using horizontal propeller mixers was evaluated by process tomography. Previously conducted studies show that the reactor volume, which is actively stirred, is only between 60 and 85 %.

Effect of particle size distribution

The mixing quality and the energy required for mixing are significantly influenced by the substrate pretreatment and the resulting particle size distribution of the biogenic substrates. The reduction of viscosity due to the pretreatment improves mass transport.

Visualization of mixing processes





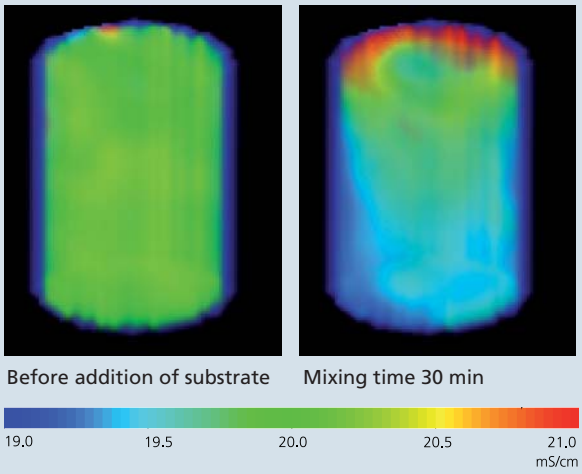
Prospects

Continuing these studies significant statements for design and operation of stirring systems especially being used for highly concentrated, non-Newtonian fluids can be derived.

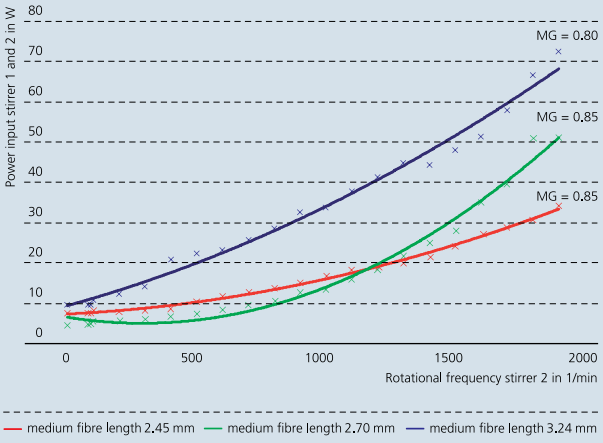
Services offered

- Evaluation of mixing processes for Newtonian and non-Newtonian fluids
- Evaluation of mixing processes for opaque substances
- Aeration of liquid

Change in electrical conductivity due to mixing in pretreated wheat straw

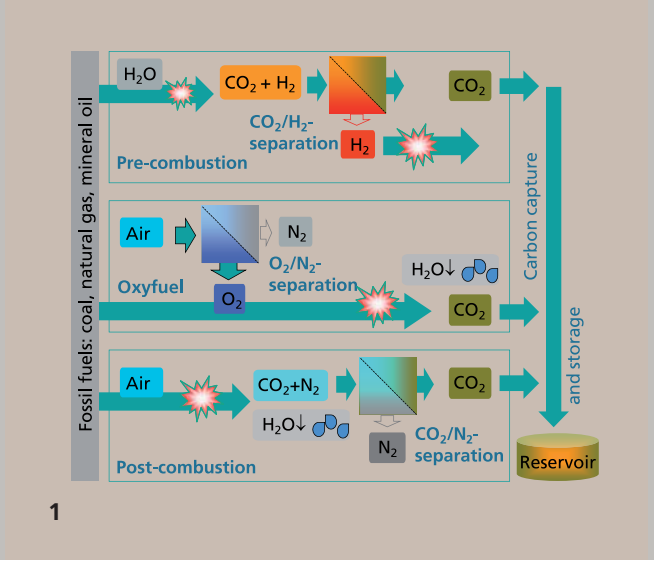


Effect of the reduction ratio of wheat straw on mixing quality (MQ) and the required electrical power of the stirrer



Europa fördert Sachsen.
EFRE
Europäischer Fonds für regionale Entwicklung
Finanziert aus Mitteln der Europäischen Union und des Freistaates Sachsen.

1 *Mixing of maize silage.*
2 *Arrangement of the stirring system.*
3 *Process tomography test stand.*
4 *Formation of sinking layers.*



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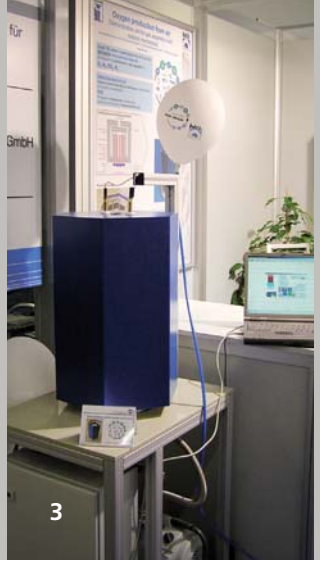


3

CERAMIC MEMBRANES FOR EMISSION-FREE POWER PLANTS

Dr. Ingolf Voigt, Dr. Ralf Kriegel

Membranes for gas separation

Despite of the planned increase of renewable energy sources a considerable part of electrical power production has still to be realized by the combustion of fossil fuels in the near future. For CO_2 separation in power plants different process routes called pre-combustion, oxyfuel and post-combustion are used. The separation of H_2/CO_2, O_2/N_2 and CO_2/N_2 is an essential element in these processes shown in figure 1. In general, membrane separation processes are characterized by lower energy consumption as compared to thermal processes or gas scrubbers, but membranes suited for gas separation in fossil power plants are currently not available. Therefore, the development of such membranes is the target of the Helmholtz Alliance Mem-Brain where Fraunhofer IKTS plays a decisive role.

Demonstration unit for O_2/N_2 separation

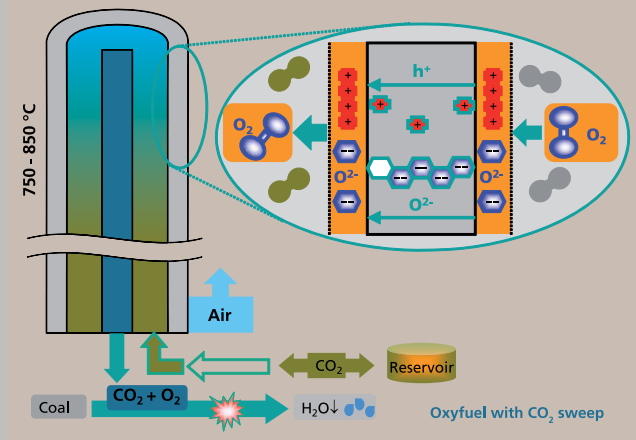
In addition to the development and characterization of membrane materials as well as the preparation of membrane components, the focus of Fraunhofer IKTS was on building up a demonstration unit proving the technical feasibility of gas membrane separation. O_2/N_2 separation was selected as an energy-efficient alternative to conventional techniques for O_2 production. Based on previous, substantial developments for the production and optimization of mixed conducting membrane components shown in figure 2, a device concept was developed and discussed with the project partners. Afterwards the demonstration unit was designed and built up as a portable stand-alone device firstly presented at the Achema trade fair and Hannover Messe in 2009 (figure 3).

Results

The demonstration unit generates 170 l (STP) oxygen per hour at 850°C using a membrane surface of 0.2 m^2. Cyclic operation for 27 heating and cooling cycles as well as long-term operation for more than 1700 hours at 800°C and 850°C were completed without failures of the membrane components or peripheral device parts. Continuous acquisition of operation data provides useful insights on the behavior of the membranes used. Correspondingly, a reliable data base for scaling up the oxygen membrane separation process is available. The electrochemical separation process uses the combined transport of oxide ions and charge carriers within the mixed conducting membrane material BSCF ($Ba_{0.5}Sr_{0.,5}Co_{0.8}Fe_{0.2}O_{3-\delta}$). Therefore, a very high selectivity is reached.

Oxyfuel with CO_2 sweep

Production of oxygen using mixed conducting membranes at high temperature is schematically drawn in figure 4. The use of oxygen separated in an oxyfuel power plant can be realized with or without flue gas sweeping. The first route results in a lower oxygen partial pressure at the permeate side followed by a higher driving force for the oxygen transport. According to that, the energy consumption of the process using flue gas sweeping is decreased as compared to a process without flue



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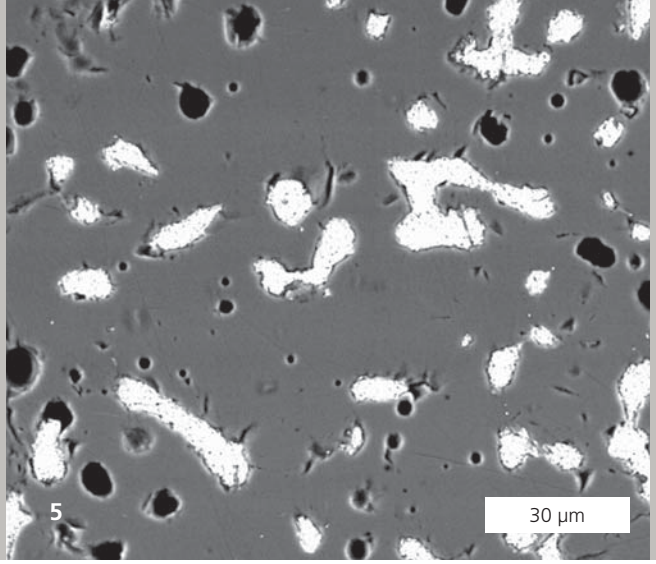

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gas sweeping. Mixed conducting membrane materials with high oxygen permeation are mainly based on earth alkaline cobaltites belonging to the perovskite type like $Ba_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$, $BaCo_{1-y}Fe_yO_{3-\delta}$ and $SrCo_{1-y}Fe_yO_{3-\delta}$ with Co and Fe partly substituted by further elements. As expected, the high earth alkaline content and CO_2 sweep operation results in the formation of blocking carbonate layers. Therefore, membrane materials stable in CO_2 will be developed within the joint research project MEM-OXYCOAL using the following main routes:

- Protection of known, CO_2 instable materials with high O_2 permeation by coating and chemical substitution
- Increase of O_2 permeation of known CO_2 stable materials by chemical substitution and preparation of asymmetric membranes (thin separation layer on porous support)
- Development of new materials stable in CO_2 with high O_2 permeation

Selected results are shown in the opposite diagram containing the oxygen permeability for SCFT ($SrCo_{0.72}Fe_{0.18}Ti_{0.10}O_{3-\delta}$, $SrCo_{0.48}Fe_{0.12}Ti_{0.40}O_{3-\delta}$) and a ceramic metal composite ($Ce_{0.8}Sm_{0.2}O_{1.9}$/Ag) operating in air/CO_2.

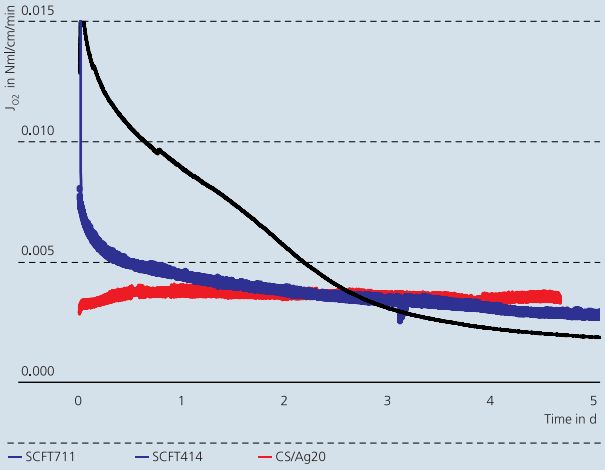
Obviously, the oxygen permeability of SCFT described as stable in CO_2 decreases with increasing Ti substitution. In addition, a steep drop of the oxygen permeability with time is observed. By contrast, the composite based on ceria with approx. 20 vol% silver (comparable to figure 5) shows a stable behavior.

It has to be kept in mind that an economic operation needs higher oxygen fluxes, e.g. by minimization of the membrane thickness. Furthermore, a substitution of the noble metal electron conductor by an oxide semiconductor seems to be meaningful.

Services offered

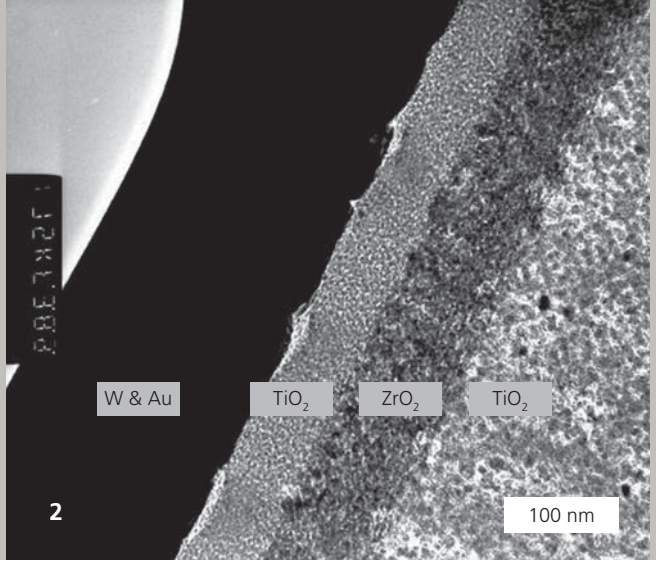
- Characterization of oxygen permeable membranes
- Production and supply of membrane samples for testing
- Consulting for the design of membrane plants on customized specifications

Oxygen permeability of Ti substituted SCF and $Ce_{0.8}Sm_{0.2}O_{1.9}$/Ag composite (air/CO_2, 850°C)



1 *Process routes for CO_2 emission-free coal power plants.*
2 *Oxygen-permeable membranes for demonstration unit.*
3 *Demonstration unit for oxygen separation.*
4 *Principle of oxygen membrane separation with CO_2 sweep.*
5 *CSFM5528/Ag composite, SEM, polished section.*

1



2

CERAMIC NF MEMBRANES FOR WASTE WATER TREATMENT AND PRODUCT SEPARATION

Dr. Ingolf Voigt, Dr. Hannes Richter, Dipl.-Chem. Petra Puhlfürß

Initial situation

Water will become much more important in the future as a resource for industrial processes as well as a basis for human life due to the climatic changes. Waste water treatment will be applied as process-integrated treatment, partial flow treatment and implementation of closed water cycles. Process integration also means high temperature as well as higher concentration of aggressive substances. In case of membrane technology ceramic membranes are advantageous. In addition to waste water treatment effective separation processes are required for product separation and product cleaning.

Membrane development

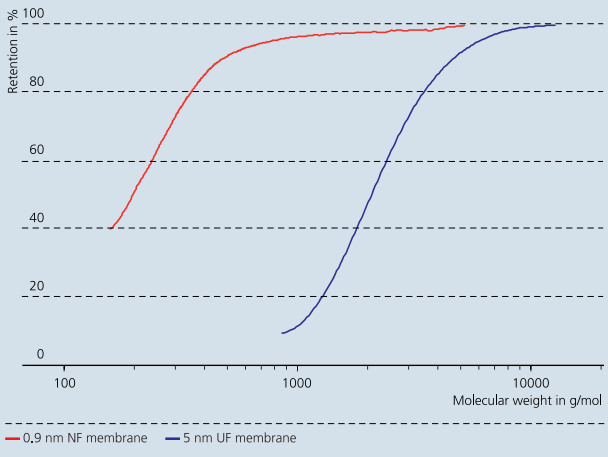
Ceramic nanofiltration membranes (NF membranes) enable the filtration of soluble substances as well as salts. They are applied as thin layers on top of a porous ceramic substrate using the polmeric sol-gel technique. The layer thickness is only about 50 nm, so that a high-quality support as well as defined intermediate layers are needed to adjust the pore size as well as the surface roughness step by step to the requirements of the NF membrane. The last two intermediate layers consist of TiO_2 with a pore size of 5 nm and ZrO_2 with a pore size of 3 nm. Both layers can also be used as ultrafiltration membranes (UF). The NF membrane layer consists of amorphous TiO_2 with a pore size of 0.9 nm and a molecular weight cut-off (MWCO) of 450 D (corresponding to 450 g/mol). In contrast to the UF membrane layers, the pores have a cylindrical shape showing a lower blocking tendency.

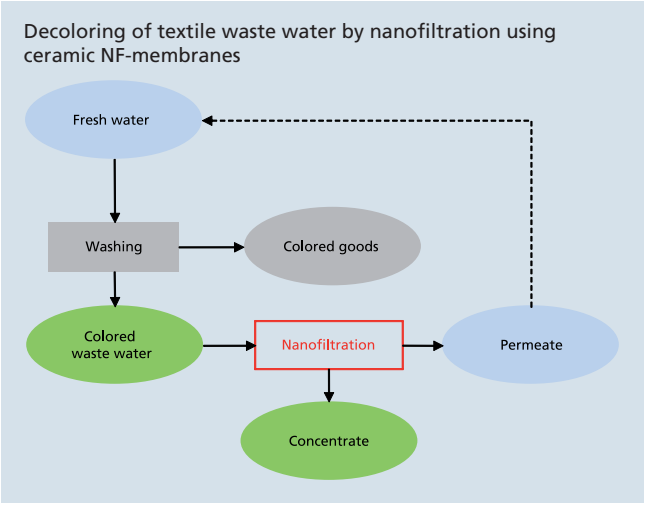
Application

Ceramic NF membranes with a cut-off of 450 D have proven successful in many applications. The first plant was built by Andreas Junghans in 2002. With a membrane area of 25 m^2 it was used for the decoloring of textile waste water at Riedel Textil GmbH. In 2005, this plant was expanded to 62 m^2 because of the increased amount of waste water. The complete plant has been running up to now without replacing the membranes. Permeate fluxes of 100 to 200 l/(m^2h) are obtained at a transmembrane pressure of 10 to 20 bar.

Besides waste water treatment ceramic NF membranes are successfully applied to clean products by diafiltration. One example is the cleaning of inutec® at BENEO-Orafti, which is

Retention of ceramic NF membranes in comparison to UF membranes





formed by transformation of inulin in NMP (n-methylpyrrolidone). During the diafiltration process NMP is replaced by water and the product is concentrated. In this case, a stability against NMP is required as well as a high retention to prevent product losses. Today, ceramic NF membranes are commercially produced by our cooperation partner Rauschert under the brand name inopor® membranes.

Further development of ceramic NF membranes is focused on an application-specific surface modification as well as the reduction of the cut-off. Correspondingly, the wetting by organic solvents can be improved by coupling silanes to the membrane surface. This is the basis for the application of ceramic NF membranes in chemical processes.

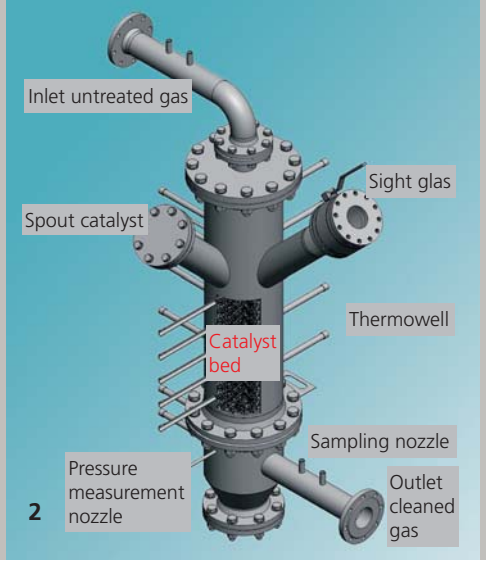
Within the "Nanomembrane" project (BMBF, FKZ: 03X0080L) the molecular weight cut-off of the ceramic NF membrane is to be further reduced down to 200 D.

Services offered

- Development of application-specific membranes
- Supply of membranes for testing
- Customer-specific testing of membranes in our laboratory and pilot plants
- Execution of field tests
- Production of membranes for pilot and demonstration plants

1 *Module with ceramic membranes.*
2 *TEM cross section of a ceramic NF membrane.*
3 *62 m² NF membrane plant for the cleaning of textile waste water.*
4 *37 m² NF membrane plant for diafiltration.*

1



2

CATALYST AND O_2 CARRIER SYSTEM FOR THE PROCESSING OF TAR-CONTAINING GASES

Dr. Jörg Richter, Dr. Ralf Kriegel

Initial situation

The gasification of biomass allows the combined generation of electricity and heat with high overall efficiencies in small, decentralized systems which can provide a significant contribution to the realization of local supply structures. Particularly during the one-step gasification in small-scale plants hydrocarbons with high boiling points (e.g. tars) are generated which seriously limit the utilization of these gases in combined heat and power plants. Currently, the required gas quality cannot or can only be achieved by installing additional technical equipment and costly process steps, e.g. by catalytic oxidation with air or by methanol washing. The applied catalysts tend to coking and the introduction of nitrogen decreases the heating value. Furthermore, the handling of toxic solutions and by-products places high demands on the plant safety.

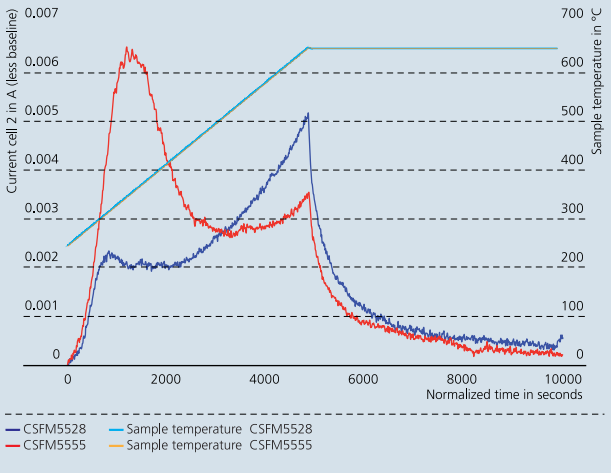
Approach

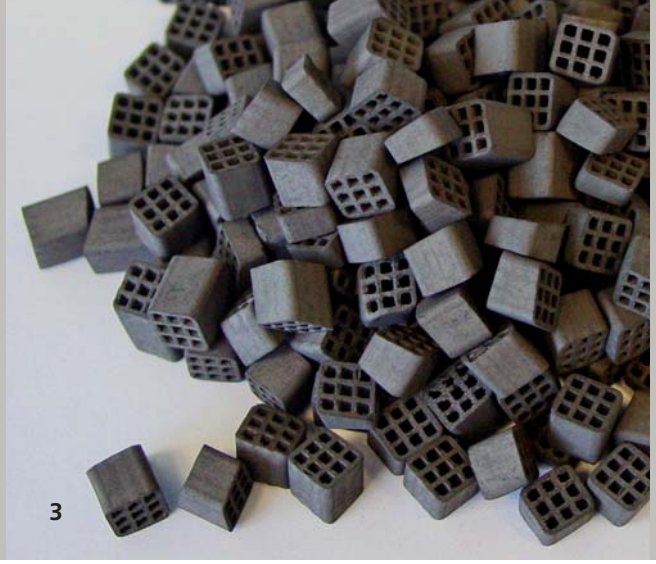
At Fraunhofer IKTS ceramic oxygen storage materials (OSM), which are covered with ceramic catalysts, are used. Thus, the necessary oxygen for partial oxidation of tar is released exactly at the location of its demand. Hence, the additional introduction of nitrogen and the decrease of the heating value can be avoided. Due to the time-dependent depletion of the OSM the process is cyclically run using parallel reactors. The partial oxidation of tar occurs in the first reactor, while the oxygen depleted OSM will be recovered by purging the second reactor with air. Modeling shows that tar components condense at the material surface. The released oxygen primarily oxidizes the tar components, while the components of the fuel gas contributing to the heating value of the gas remain unaffected.

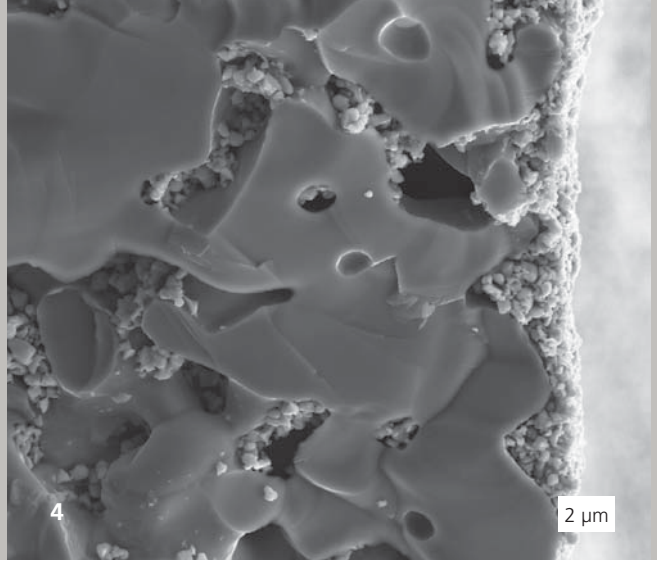
Development of oxygen storage materials (OSM)

Perovskite materials are preferably used as OSM since their oxygen exchange properties (uptake and release) can be adjusted to the expected process conditions. Potential candidate OSM have been characterized by O_2 TPD (temperature programmed desorption) and TG (thermogravimetry). Selected materials have been shaped to mini-honeycombs (miniliths) by extrusion and can be used as packed bed for future pilot plant scale tests.

Temperature programmed desorption:
Comparison of two oxygen storage materials







Development of catalyst materials

Perovskite catalysts have already proved to be the appropriate solution for miscellaneous oxidation reactions. Their catalytic activity can be adjusted in a certain range. Naphthalene ($C_{10}H_8$) was chosen as model substance for tar.

The conversion of naphthalene was recorded by FTIR (Fourier transformed infrared spectroscopy) and MBMS (molecular beam mass spectroscopy) for different oxidation catalysts.

A catalyst made of $LaCoO_{3-\delta}$ has already shown naphthalene conversions of more than 80 % at 500°C. The naphthalene conversion increases to 90 % at 600°C and to 100 % at 700°C.

Development of the catalyst and O_2 carrier system

Miniliths of a chosen OSM were coated with a perovskite catalyst material. In this process the fine-grained catalyst granules infiltrate into the pores of the OSM. No reactions between these two materials were observed during the necessary annealing process. Further coatings of oxygen storage materials with different catalyst are prepared for technical tests on the pilot plant of the Technical University of Dresden.

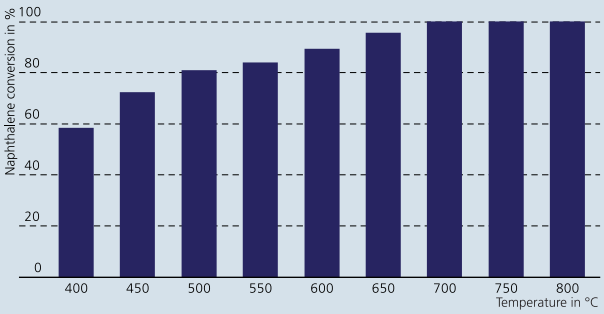
Acknowledgments

This project was funded by Deutsche Bundesstiftung Umwelt (AZ 27087).

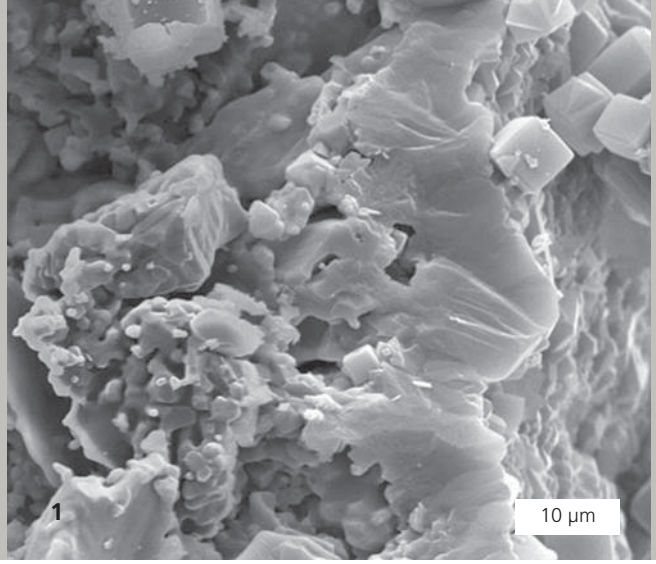
Services offered

- Development of oxygen storage materials
- Development of ceramic catalysts for total and partial oxidation
- Characterization of the oxygen storage behavior

Naphthalene conversion of a $LaCoO_{3-\delta}$ catalyst (characterized by molecular beam mass spectrometry)



1 *Reactor for biogas production at TU Dresden.*
2 *Diagram of a reactor with catalyst bed.*
3 *Miniliths of an oxygen storage material.*
4 *SEM image of a minilith with catalyst coating.*



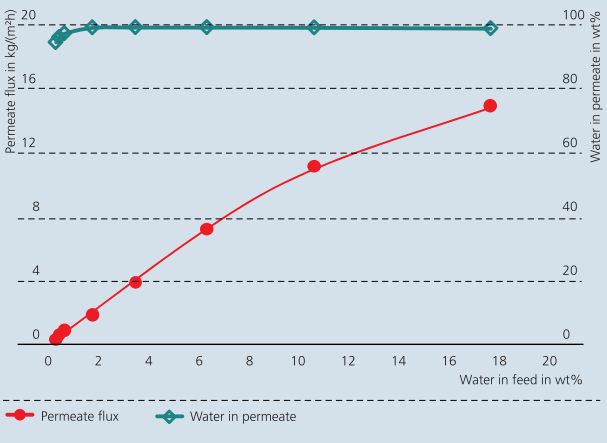
EFFICIENT PRODUCTION OF BIOETHANOL USING ZEOLITE MEMBRANES

Dr. Hannes Richter, Dr. Marcus Weyd, Dipl.-Ing. Jan-Thomas Kühnert

Bioethanol is made of renewable resources and is deemed to be carbon-neutral. By using domestic resources the energy balance of bioethanol is only slightly positive on account of high energy demanding processes. Besides distillation concentration of ethanol from 10 to 96 % (azeotropic point) the further drying of ethanol up to 99.5 % requires huge amounts of energy by using conventional technologies such as adsorption and azeotropic distillation.

Membrane processes with zeolite membranes are an energy saving alternative. Zeolite A is characterized by small pores (pore diameter of 0.4 nm) and a hydrophilic surface. At Fraunhofer IKTS a process was developed to prepare a thin and defect-free layer of zeolite A inside the channels of ceramic supports of high open porosity. By streaming ethanol-water mixtures through the channels of the membrane and applying vacuum on the outside of the tubes only water can permeate through the nanopores of the zeolite layer. Thus, the ethanol is dewatered. This filtration process can be applied in liquid state (pervaporation) as well as in vapor state (steam or vapor permeation) and with ethanol at temperatures up to 140°C.

Dewatering of ethanol by steam permeation at 125°C



Membrane synthesis was scaled up to tubes having a 4-channel geometry and a length of 1.2 m. A sample production line in industrial scale was built up at the Hermsdorf branch of Fraunhofer IKTS. The GFT Membrane Systems GmbH investigated the application of the zeolite membranes in the industrial bioethanol production. The whole process line of bioethanol production was adapted to the potentialities of membrane technology. Using zeolite membranes for ethanol dewatering, the ethanol has only to be concentrated by distillation (rectification) to 85 %.

Thus, the process offers the following advantages:

- Columns with a lower number of separating stages running with lower reflux ratio can be applied in newly constructed bioethanol plants using membrane drying.
- An existing rectification unit can be operated with a higher throughput after retrofitting a membrane drying unit.
- The membrane drying unit can be operated directly coupled with the rectification in vapor permeation. Vapor compression and heat recovery are advantageous.
- After the energetic optimization of the whole ethanol production process the energy demand for ethanol drying can be reduced by up to 90 % as compared to conventional techniques.

3

4

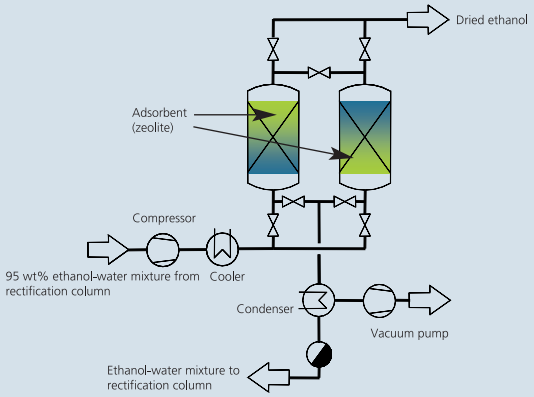
A first demonstration plant for industrial bioethanol drying equipped with a membrane surface of 25 m² was started up in November 2007. A large-scale demonstration plant with a membrane surface of 120 m² started operation in February 2009. Currently, approx. 100,000 l/d ethanol are dried by zeolite membranes of Fraunhofer IKTS. Further plants are under construction.

Finally, the membranes also can be used for the efficient drying of several organic solvents from different industries like chemistry and pharmaceutics. The membranes have already showed convincing results in the dewatering of other solvents (e.g. methanol, tetrahydrofuran and 2-propanol), esters (ethylacetate) and various organics. A first pilot plant is at the planning stage.

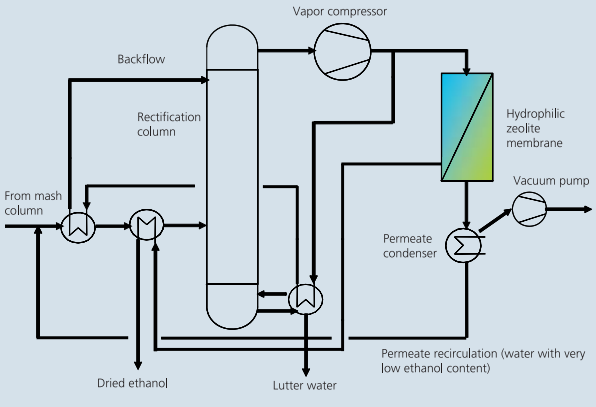
Services offered

- Dewatering and separation tests with customer-specific mixtures in laboratory and pilot plant scale and on-site
- Engineering, construction and equipment of membrane plants

Convential drying by pressure swing adsorption



Drying by vapor permeation with vapor compression and heat recovery

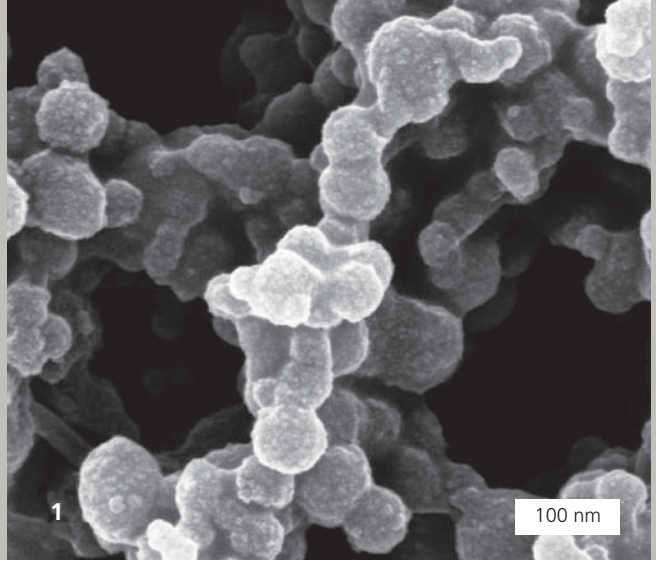


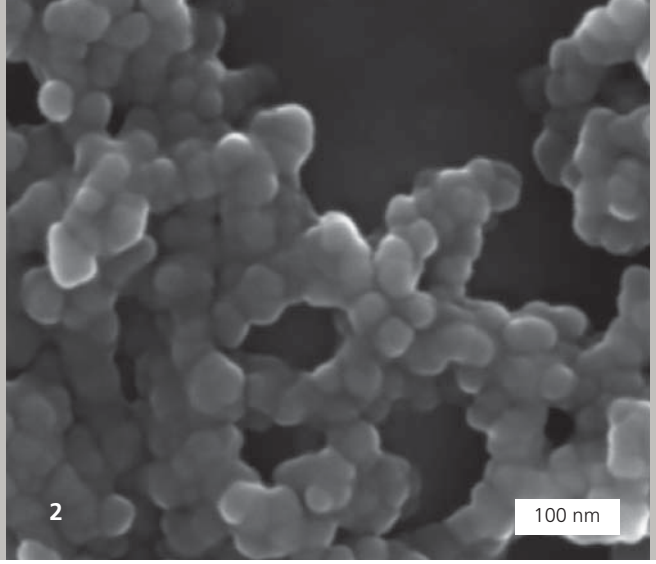
1 *Cross section of zeolite membrane (SEM).*

2 *Membranes in stainless steel module.*

3 *Pilot plant for bioethanol drying.*

4 *Porous ceramic supports made of Al_2O_3.*



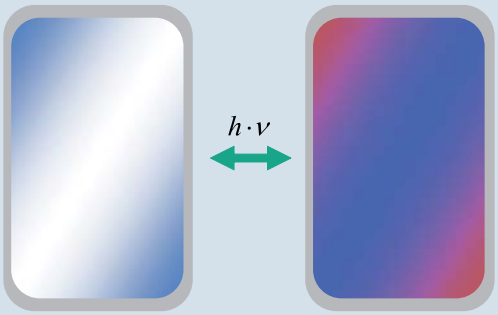


NANOSIZED ZEOLITES AS HOSTS FOR PHOTOCHROMIC DYES

Dipl.-Ing. Oliver Tröber, Dr. Hannes Richter

For a long time, architects have been in search of homogeneous photoswitchable window fronts which change their color quickly and reliably. The present systems are expensive and have a limited range of colors. Furthermore, the photoswitchable behavior is influenced by temperature. Photochromic dyes embedded in a polymer foil of a laminated glass seem to be an alternative.

Window switching behavior under UV radiation



Photochromic dyes, however, have a limited chemical stability. For this reason, embedding of dyes in the cages of zeolites is a promising approach to stabilize the pigments. The zeolite hosts have to fulfill the following requirements:

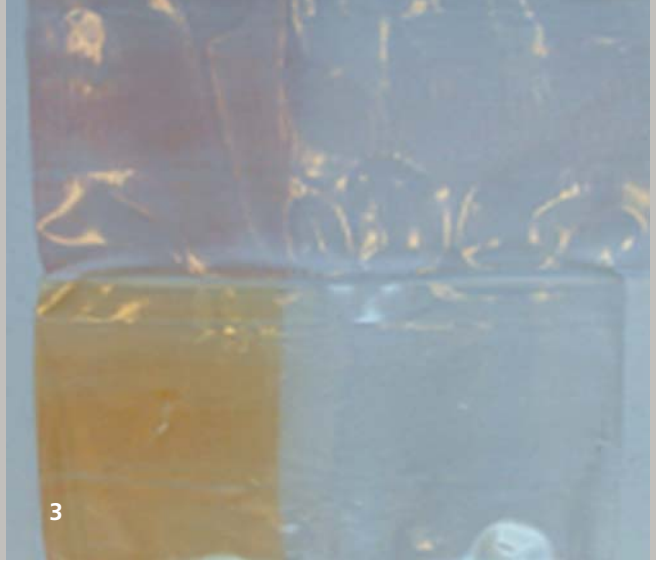
- Sufficient space for the dyes in the pores
- Sufficient polarity for dye-cage connection
- Polarity and space should not affect the switching behavior of the pigments
- Host-guest hybrids must be dispersible in polymers
- Particle diameter less than 150 nm for good transparency

Zeolite Y and MCM-41/48 were chosen as stabilizing cages. The inner room of these silicates has a pore width of 1.2 and 3 nm. Template-assisted hydrothermal synthesis led to milky suspensions with particle diameters from 0.5 to 1.1 µm. Improving the reaction conditions the particle diameter was reduced to 40 to 80 nm.

So it was possible to produce lucent nanosized suspensions of zeolite Y and the MCM materials. However, the crystalline cavities of the as-synthesized zeolites were blocked with organic templates after synthesis. The hosts were treated by a multilevel extraction process to obtain a template free cage for the dye molecules. This process resulted in no significant coarsening of the nanoparticles.

Because of the narrow pores in the zeolite Y the dyes had to be synthesized inside the cages. The dyes were successfully prepared using a "ship-in-bottle" reaction (SIBOR), but steric hindrance and high polarity limited the photochromic behavior inside the zeolite Y. Because of the large pores of mesoporous materials it was possible to synthesize the dye outside the

Schematic structure zeolite Y, MCM-41 and MCM-48 (www.iza-structure.org, Nature 359 and 441)



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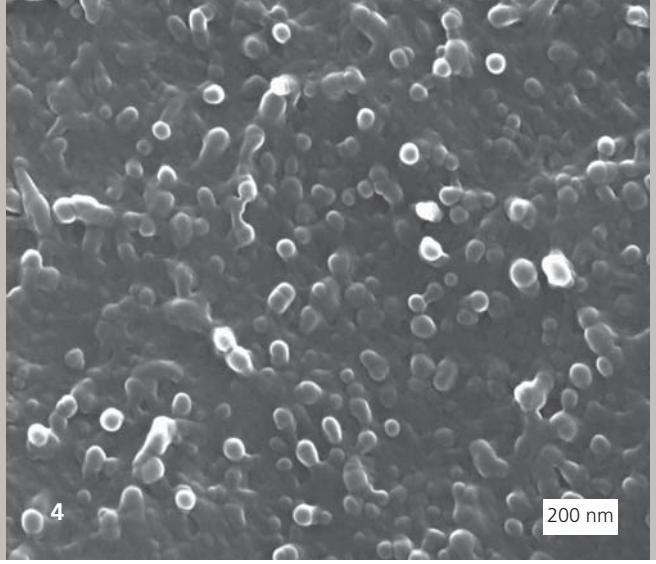

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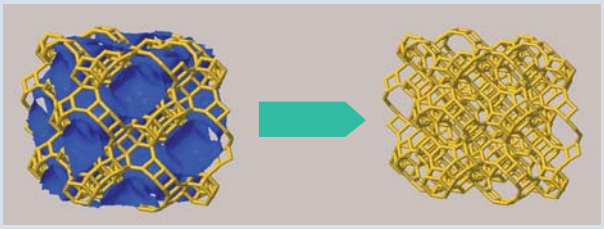
Zeolite Y with filled and empty pores (www.iza-structure.org)

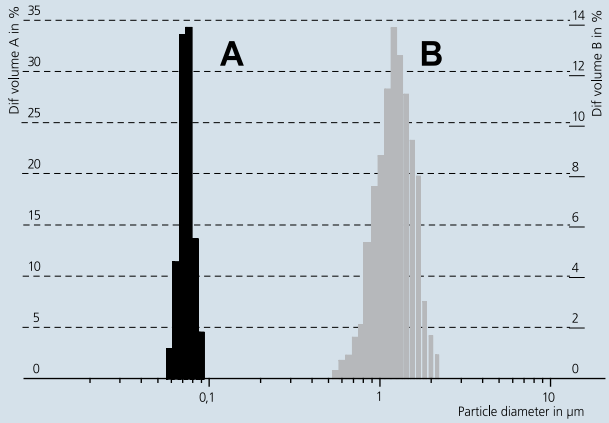


pores and to bring them into the cages by diffusion. The nitrogen-sorption measurement indicated that the dye molecules were located inside the pores of the mesoporous material. The host-guest hybrid showed the desired photochromic behavior and testified to a successful development.

The next step aimed on the embedding of the host-guest hybrid in a polymer matrix and the extrusion of the polymer (polyetylene) composite. It was necessary to functionalize the particles to disperse them homogenously in polyethylene. The extruded composite films showed the same photochromic reaction as the single host-guest hybrid. The color of the dye-MCM-48 composites intensified immediately through ultraviolet radiation and discolored after exposing. So, the feasibility of low-cost and fast photoswitchable windows with a broad range of colors was demonstrated.

Long-term studies, substitution of alternative dyes and an improved anchoring of the guests inside the cages are subject of current research.

Particle size distribution via laser diffraction



A Improved synthesis for nanozeolites **B** Primary hydrothermal synthesis

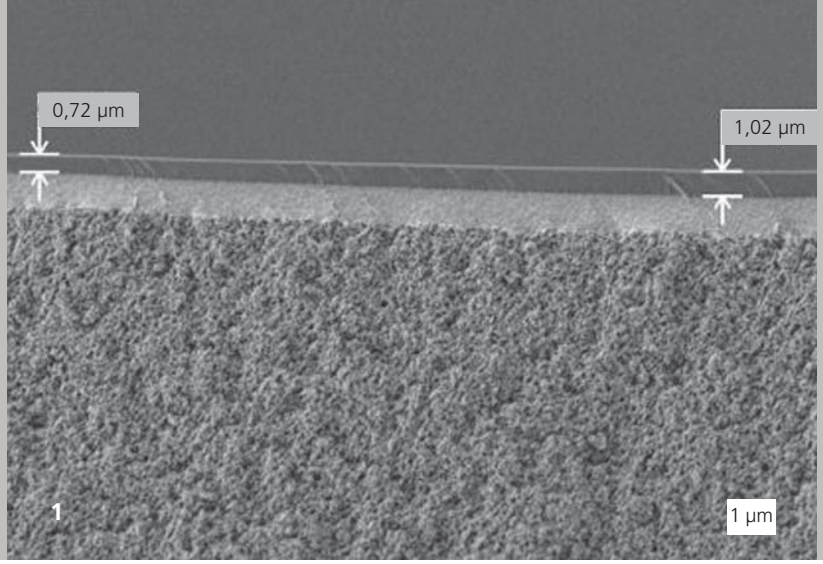
Acknowledgments

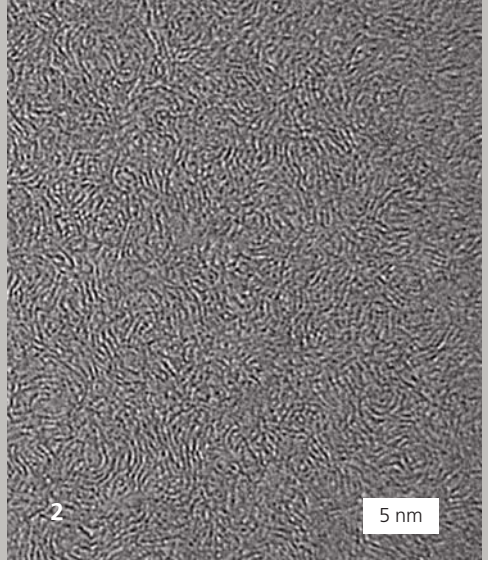
The presented results are a part of a joint project with TU Chemnitz and Innovent e.V. The DFG is acknowledged for financial support (RI930/2-1).

Services offered

- Development and production of template-free, micro and mesoporous nanoparticles in form of suspensions and dispersible powders
- Functionalization of different nanoparticles
- Embedding, segregation and shaping in different matrices

1 *SEM image of zeolite Y nanoparticles.*
2 *SEM image of MCM-48 nanoparticles.*
3 *Photo-switchable polymeric foils after partial UV irradiation.*
4 *SEM cross section of photo-switchable polymer foil.*





ADSORPTION-SELECTIVE CARBON MEMBRANES FOR BIOGAS APPLICATION

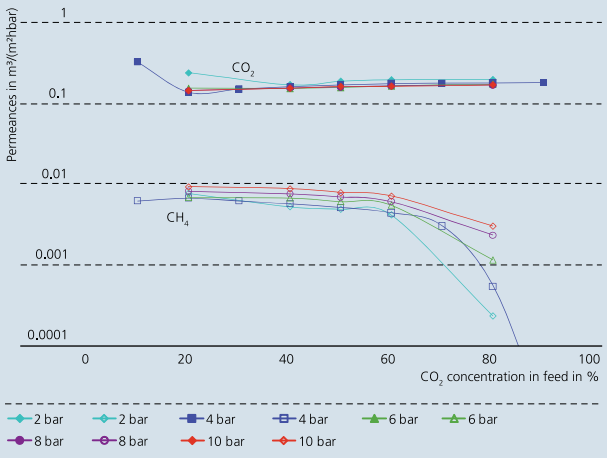
Dr. Nadine Kaltenborn, Dipl.-Ing. Susanne Müller, Dr. Hannes Richter

After synthesis biogas consists of up to 55 % CO_2. For using biogas as a fuel or feeding in natural gas pipes it has to be purified. For this treatment adsorption and wash processes are usually used.

Membrane processes have the advantage of a continuous processing as well as a simple, modular and flexible plant design, which means low cost and low energy demand. Within a project, funded by Deutsche Bundesstiftung Umwelt (AZ 26357-31), ceramic membranes for CO_2 separation from biogas were developed. As membrane material for CO_2/CH_4 separation adsorption-selective carbon membranes were found to be useful. They are formed by deposition of a polymeric precursor material on the inner surface of a porous, ceramic tube and by subsequent pyrolysis. After pyrolysis a paracrystalline or pyrolytic carbon is obtained deviating from the ideal crystal structure. Because of its high open porosity it is suitable for adsorbent as well as membrane material. The disordered aromatic domains in the amorphous matrix cause the free volume and its ultramicroporosity. The mostly slit-shaped pores have pore dimensions between 0.3 and 0.7 nm which is in the range of small gaseous molecules. Adsorption-selective carbon membranes separate gases because of selective adsorption and surface diffusion of one component. So, free valences of carbon atoms can interact with polar molecules like CO_2. In a mixture with less polar molecules, like CH_4, CO_2 permeates through the nanopores when creating a concentration gradient between the front and backside of the membrane (feed and permeate side).

In cooperation with DBI GUT GmbH membranes for CO_2/CH_4 separation were found which showed sufficiently high CO_2 permeation in a wide range of gas compositions and pressure ratios. The relation of CO_2 to CH_4 permeances varied between 15 and 14,000 as a function of test conditions. In any case CO_2 rich or pure CO_2 could be delivered from different CO_2/CH_4 mixtures.

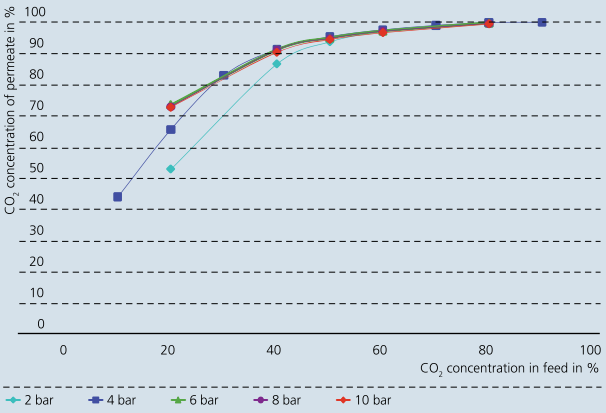
CO_2 and CH_4 permeances as a function of CO_2 concentration of the feed



The membrane preparation was scaled up to a length of 0.5 m. In single gas permeation experiments an adsorption-selective behavior with CO_2 permeances of up to 24 m³/(m²hbar) was determined.

The membranes were tested in a pilot plant of DBI GUT GmbH near a biogas plant working with real biogas. Under different operating conditions concentrated CO_2 was separated from

CO_2 concentration in the permeate as a function of feed composition

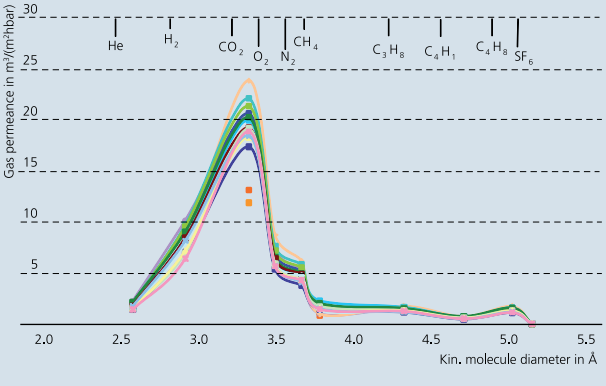


Services offered

- Manufacturing and characterization of carbon membranes in single and gas mixture permeation measurements
- Optimization and development of molecular as well as adsorption-selective carbon membranes for specific applications
- Engineering and equipment of pilot plants

biogas over a period of several weeks. The membranes were very robust when using disturbing gases like H_2O and H_2S. As the varying parameters were limited on the pilot plant, the membranes were again measured in the laboratory after the tests with real biogas. Here, conditions were found under which synthetic 0.5 CO_2/0.5 CH_4 mixtures were concentrated to approx. 95 % CH_4 applying just one membrane step.

Single gas permeances of adsorption-selective carbon membranes with a length of 0.5 m as a function of the kinetic diameter of the molecules



1 *Cross section of a carbon membrane (SEM).*
2 *Microstructure of nanoporous carbon (TEM).*
3 *Carbon membrane (0.5 m) before installation.*
4 *Pilot plant (container) near biogas plant.*

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

SINTERING AND CHARACTERIZATION

Department head:
Dr. habil. Mathias Herrmann

Profile

Extensive sintering and analysis know-how in this research field is concentrated at both the Hermsdorf and the Dresden location. With diverse characterization methods, thermodynamic and kinetic modeling, and extensive furnace equipment from the laboratory to the pilot scale as a basis, targeted development of materials, components, and processes is possible.

Existing methods range from particle and suspension characterization and ceramographic sample preparation using conventional and ion beam-based techniques to quantitative phase and microstructural analysis. In addition, a wide range of thermoanalytical and thermophysical characterization techniques and methods for tribological, mechanical, and electrical characterization are available. Mastery of these sophisticated analytical methods is coupled to detailed process know-how as well as materials and scientific knowledge, enabling well-founded interpretation of results.

We also test electrical devices and equipment in accordance with national and international standards as well as customer-specific requirements and possess a wide range of possibilities for environmental simulation and calibration of measurement systems.

Services offered

Development projects and individual contracts for characterization of powder metallurgical and ceramic feedstocks and materials as well as for heat treatment of materials and components:

- Particle characterization from micro- to nanoscale
- Application-specific suspension characterization for all concentrations
- Determination of thermoanalytical and thermophysical characteristics
- Investigation of sintering behavior of materials and components
- Design, execution, and optimization of heat treatments, including scale-up to industrial scale
- Characterization of materials and components in terms of microstructure, phase composition, and mechanical and tribological properties
- Testing of electrical devices and equipment (CE and GS marks, in cooperation with TÜV and VDE)
- Simulation of environmental effects (temperature, climate, mechanical loads, corrosion)
- Component failure analysis and consulting on use of ceramic materials
- Calibration of measuring devices (length, temperature, electrical measurement parameters)
- Consulting on quality and environmental management systems

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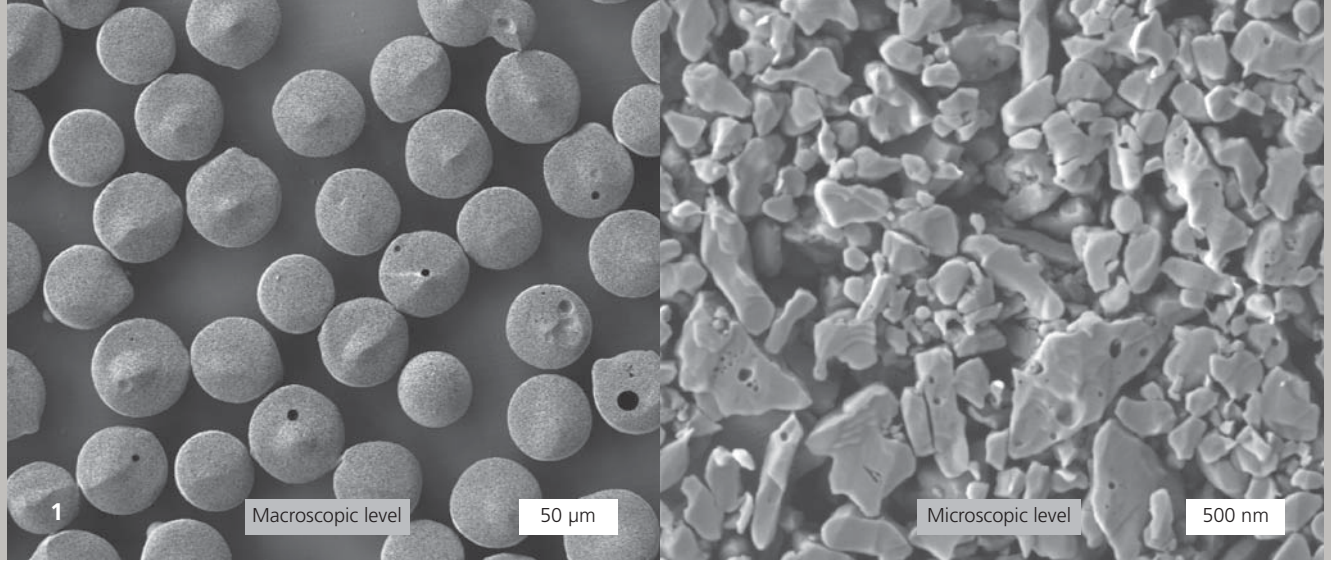


QUANTIFICATION OF INTERNAL STRUCTURES OF CERAMIC SPRAY-DRIED GRANULES

Dipl.-Ing. Sören Höhn, Dipl.-Ing. Susanna Eckhard, Dr. Manfred Fries, Dr. habil. Mathias Herrmann

During processing of ceramic or metallic powders the materials are homogenized and milled in aqueous or organic solvents and spray dried after adding pressing agents. The spray-dried granules need to fulfill specific requirements that are defined by the end-use application. The internal granule structure is an important property. It determines the quality and influences the processing properties of the granule bulk as well as the failure distribution within the resulting compact. For the development of well-founded scientific correlations between process parameters, granule structure and product or processing properties appropriate characterization methods are essentially based on a gentle and reproducible sample preparation as well as structure quantification through image analysis.

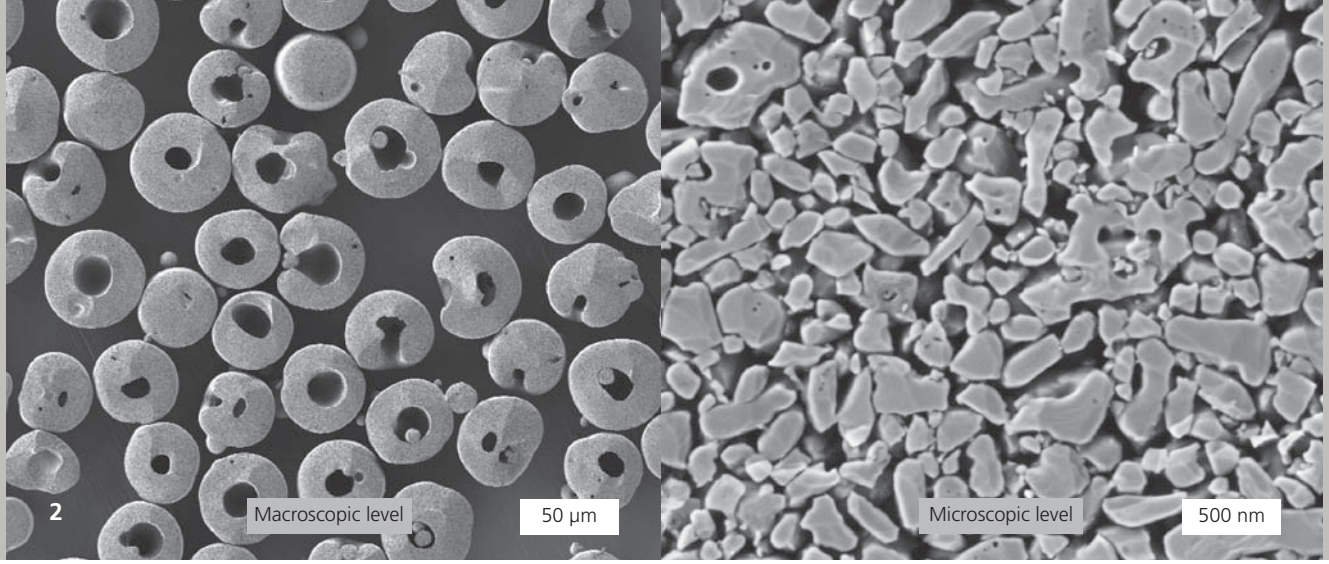
Using ion beam sputtering techniques, it is possible to prepare samples without inducing mechanical stress resulting in damage. The broad ion beam technique with argon ion beam is an ideal method for preparing comparatively large sample surfaces for structure quantification. This method enables the simultaneous exposure of hard ceramic particles and soft organic components. By means of high resolution visualization using a scanning electron microscope (SEM), it is possible to characterize the granule structure up to nanometer scale. Model granules with defined varied structures are the basis for the development and validation of quantification algorithms. Below they are called batch A and batch B. For the investigations a standard ceramic material (Al_2O_3, Nabaltec AG, Al_2O_3 content of 99.7 %) was used. All analytic investigations were done with granules having a size fraction of 45 to 63 µm (~d_{50}). The granule cross section was prepared in the granule center (±10 %). Figures 1 and 2 show SEM images of the internal structure of batch A and B. It can be seen that batch A mainly consists of homogeneous granules whereas batch B contains a high number of hollow granules. Furthermore, it becomes clear that the intragranular porosity, the pore structure as well as the position of primary particles can be well visualized without infiltrating the samples with epoxy resin.

The structure was quantified on a microscopic and macroscopic level (figures 1 and 2). The determined parameters on the macroscopic level (table below) include average shell thickness S, macroporosity P_{macro} and an amount of homogeneous (M_{homo}), hollow (M_{hollow}) and intersection granules (M_{inter}) within the batch.

Macroscopic structure parameters

Sample	M_{hollow} [%]	M_{inter} [%]	M_{homo} [%]	P_{macro} [%]	S [µm]
A	5.7	12.3	82.0	0.2	23.5
B	46.1	27.9	25.9	2.2	19.5

To determine possible gradients in the microstructure (table on the right) various sample positions within the granule cross section were analyzed (figure on the right). In addition to microporosity P_{micro}, a local determination of primary particle size d_P is possible. From microporosity and macroporosity values, a total porosity P_{total} can be calculated. Pore space and particle neighborhood relationship are quantitatively described by analyzing the primary particle surface distances D_{OF}. These distances are calculated on the basis of an algorithm following Voronoi tesselation und Delaunay triangulation. From the re-

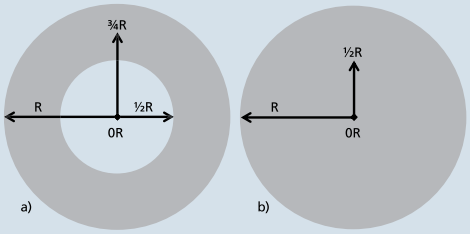


sults the subjective impression of loosely packed microstructures within batch A can be quantitatively confirmed (D_{OF} and P_{micro}). Mobile primary particles, as can be found in batch B, are able to move to the shell during the evaporation process. Therewith more hollow granules and more densely packed areas at the shell are formed as can be proven with the quantification results.

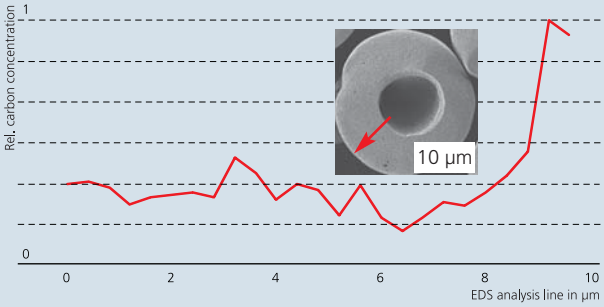
Besides the described microstructural and macrostructural parameters the distribution of organic additives within the granule structure shows a strong influence on the resulting processing parameters. The diagram on the right documents an inhomogeneous distribution of organics within an example granule of batch B. The visualization of gradients of the additive concentration within the granule cross section is possible using EDX analysis on ion-beam polished sample surfaces.

On basis of these results it is possible to develop correlations between process functions, granule structures and resulting product properties.

Analysis positions in the granule cross section



EDX line scan at a granule of batch B



Microscopic structure parameters and P_{total}

Sample	Analysis position	d_p [nm]	D_{OF} [nm]	P_{micro} [%]	P_{total} [%]
A	0	166	115	44.0	
	1/2R	166	118	45.2	
	R	172	114	44.7	
	∅	170	115	44.8	44.9
B	1/2R	169	96	37.6	
	3/4R	176	86	34.6	
	R	149	90	34.8	
	∅	162	90	35.3	36.7

Services offered

- Development of customized spray-dried granules
- Development of adapted preparation and quantification methods for granules, green and sintered objects
- Preparation and quantification on demand

1 *Macrostructure and microstructure, batch A.*
2 *Macrostructure and microstructure, batch B.*

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

MICROSYSTEMS AND ENERGY SYSTEMS

Department head:
Dr. Mihails Kusnezoff, Dr. Matthias Jahn, Dr. Uwe Partsch

DEPARTMENT

MATERIALS AND COMPONENTS

Profile

The "Materials and Components" department is involved in the development and preparation of functional ceramic materials and their application in functional elements.

Traditional fields are thick film technology, glass development, high-temperature fuel cells (SOFCs), and high-temperature chemical sensors. Extensive experience and outstanding technical equipment allow complex requirements and interactions in sophisticated applications such as fuel cells, sensors, microsystems, and packaging in complex materials systems to be controlled.

Close meshing with the "Modules and Systems" and "Hybrid Microsystems" departments ensures the practical relevance of the results. This allows us to give our customers attractive offers for materials, prototypes, and services along the entire process chain.

Services offered

- Development and preparation of pastes for printing and overlay techniques
- Development and preparation of sealing glasses and elements as well as solders
- Development of electrode materials and coatings for Li-ion batteries and supercaps
- Testing and inspection capacity for components (gas sensors, gas chromatography, cells for SOFCs and SOECs)
- Development, manufacture, and testing of SOFC stacks
- Packaging for ceramic systems
- Consulting and materials analysis

DEPARTMENT

MODULES AND SYSTEMS

Profile

The working groups of the "Modules and Systems" department cover all subareas required for development of energy systems with their defined core research areas. Systems for the efficient provision of electricity and heat are designed, constructed, and tested under realistic conditions.

A core technical aspect is formed by concepts utilizing high-temperature fuel cells (SOFCs) as energy converters with electrical outputs of approx. 100 W to several kW. In addition, batteries and supercaps for storage of electrical energy are investigated. Apart from implementation of new materials and manufacturing technologies, characterization and modeling are additional focal points of the work.

The methodical basis for this is formed by extensive activities in the fields of multiphysics modeling and simulation of applications (SOFCs, heterogeneous catalysis) as well as electrochemistry and spectroelectrochemistry.

Services offered

- Component and system layout
- Design and construction of systems
- Investigation of reactions in reactors
- Catalyst development
- Test bench construction according to customer's requirements specifications
- Battery development and characterization
- Functional oxide and metallic coatings for dielectrics, photovoltaics, fuel cell technology, and corrosion protection
- Developments for high-throughput screening for applications in chemical and biochemical analysis
- Investigations on electrochemical machining (ECM)

DEPARTMENT

HYBRID MICROSYSTEMS

Profile

The department "Hybrid Microsystems" is focused on the development of thick-film and multilayer compatible functional ceramic materials, miniaturized components and systems. Fields of applications are electronics packaging, high-power electronics, sensors, and energy technology (e.g. micro-fuel cells and photovoltaics).

For the deposition of functional layers, both classic screen printing technology and additional mask-based (stencil and gravure printing) and digital printing processes (aerosol and inkjet printing) can be used, depending on the application requirements. In addition, a complete ceramic multilayer technology line (LTCCs, HTCCs) is available at Fraunhofer IKTS to manufacture 3D-structured components.

We also offer our customers a wide range of technologies for electrical contacting (soldering, gluing, bonding) and for mechanical and microstructural characterization of electrical connections.

Services offered

- Development, preparation, and characterization of application-specific functional ceramic materials
- Component design, development, and characterization
- Electrical systems integration of ceramic components
- Development of technologies and assessment of scalability

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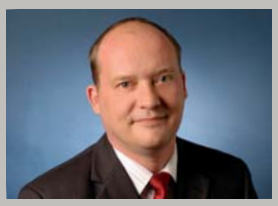

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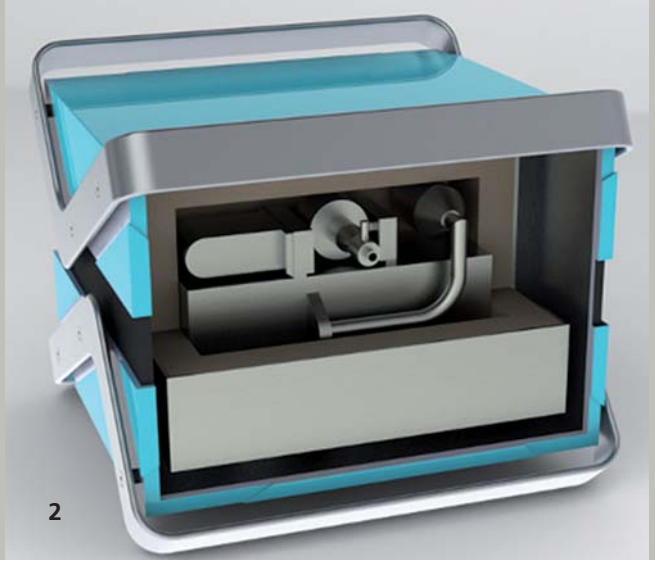


2

PORTABLE ENERAMIC® SOFC SYSTEM

Dr. Wieland Beckert, Dr. Matthias Jahn, Dr. Stefan Megel, Dr. Mihails Kusnezoff,
Dipl.-Ing. Andreas Pönicke, Dipl.-Ing. (FH) Sebastian Reuber, Dr. Mareike Schneider, Dr. Michael Stelter

Based on almost 20 years of experience, Fraunhofer IKTS is developing high-temperature fuel cells and systems in various power classes (P_{el} = 10 W to 1 kW) which can be powered by different fuels (biogas, natural gas, camping gas). Such complex development tasks require numerous interdisciplinary competencies which have been established within the "Micro and Energy Systems" research field allowing us to provide complete solutions for SOFC systems.

It was the aim of the eneramic® project to develop a portable system which works on the basis of a commercially available fuel such as LPG. The eneramic® SOFC system is intended as a remote power supply device for camping and outdoor applications requiring a robust and reliable concept:

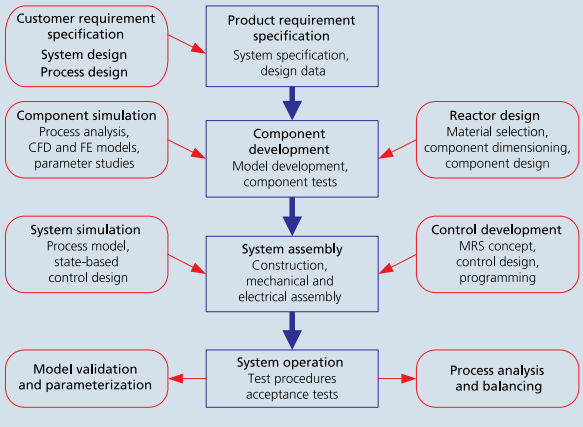
- Net power 100 W at 12 V
- Volume 8 l, weight 8 kg
- Durability 3000 h and 300 start/stop cycles
- Start up time 30 min

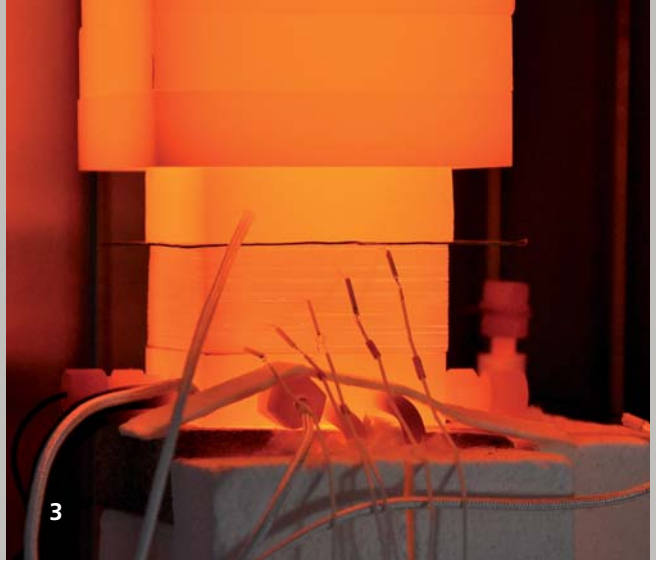
The eneramic® system was developed within the framework of one of the first projects financed by the Fraunhofer Future Foundation. After important technical milestones have already been reached successfully, first steps for commercialization are taken.

A newly developed stack concept based on electrolyte supported SOFC cells is the heart of the eneramic® system. Here, we were successful in reducing the complexity of the stack using a multilayer design for the bipolar plate. Thus, it was possible to reduce the production costs. By means of this new concept, current densities of up to 375 $mA \cdot cm^{-2}$ were achieved. The long-term stability as well as a power of more than 160 W have been experimentally proven.

The high mechanical and thermal level of integration resulting from a small reactor volume and the compact packaging concept is a main challenge of system development. Because of that the system components such as reformer and burner cannot be considered separately. It is rather necessary to consider the interaction of the components in an early stage of the design process. For this purpose, extensive stationary and dynamic simulations at the system level were performed taking the thermal interaction as well as fluidic influences into consideration. These investigations were validated by means of numerous component and system tests at specifically constructed test stands. As a result of this work a system was de-

Flow diagram for system development





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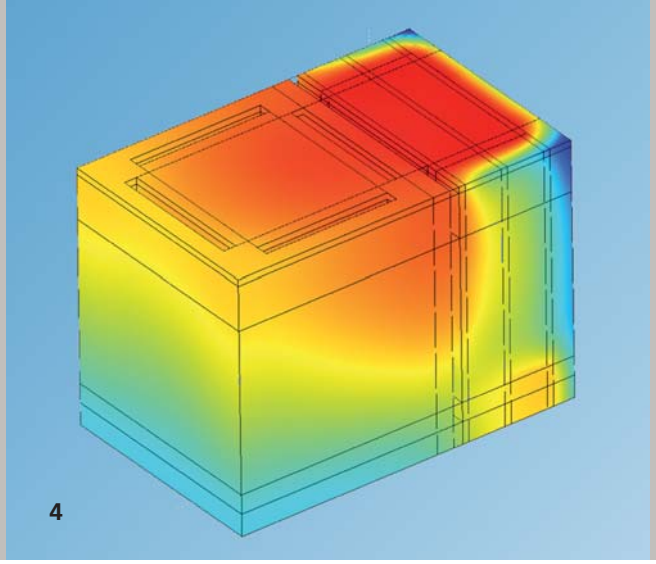

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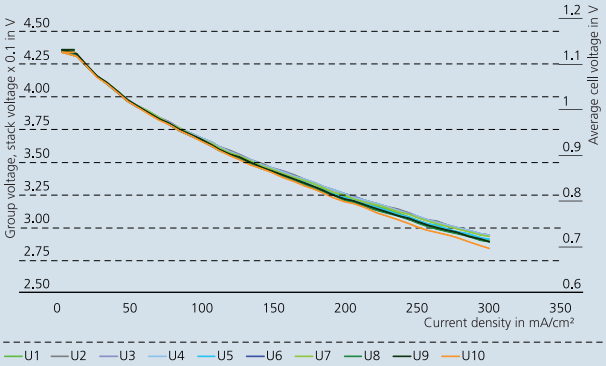
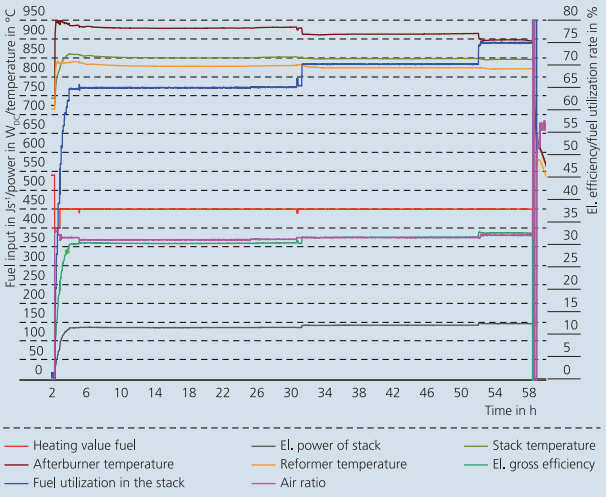
Performance of e100 eneramic stack under simulated system conditions, 140 W at 29 V

Operation with reformate equivalent, 40 cells at 852°C, 70 % fuel utilization rate, 300 mA·cm^{-2}



Influence of fuel utilization rate in the stack on temperature and system performance



veloped that is extensively tested at present. Some test results which prove a gross efficiency of 33 % are summarized in the diagram above. Now, the independent and secure operation is to be guaranteed based on a robust, fail-safe operating concept which is realized by a specially developed system control. Its reliability and realization are currently studied.

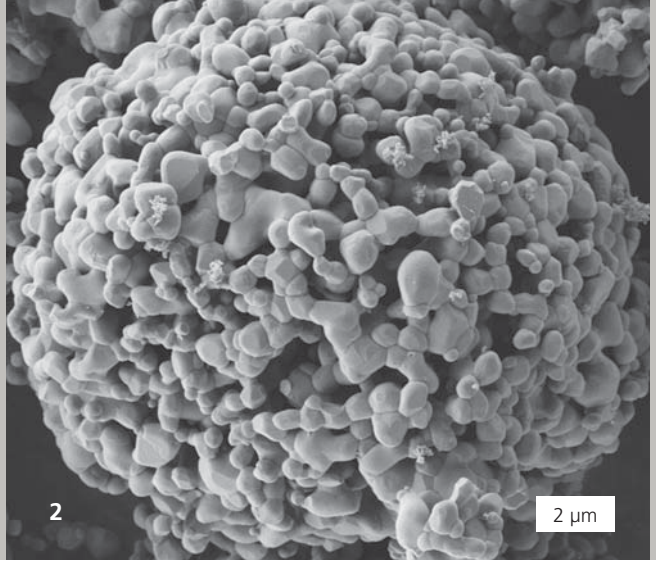
Services offered

- Process and component design
- Design, construction and test of systems
- Investigations at reactors
- Test stand development
- Catalyst development
- Lifetime analysis

Please find further information on www.eneramic.de.

1 *eneramic® system.*
2 *Cutaway model.*
3 *Stack test.*
4 *Thermal simulation.*

1



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LITHIUM ION BATTERY: MATERIAL DEVELOPMENT, CHARACTERIZATION AND TESTING

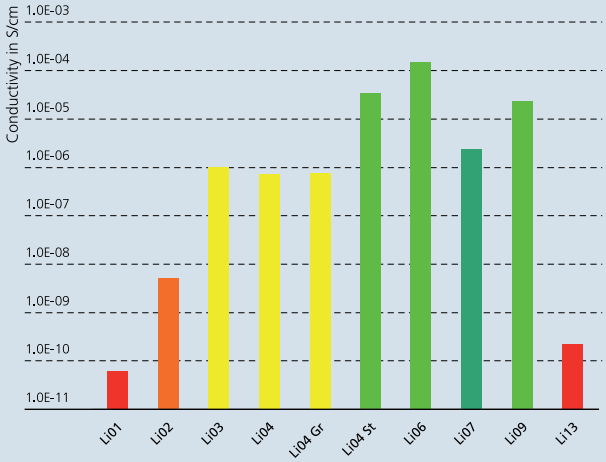
Dr. Mihails Kusnezoff, Dr. Mareike Schneider, Dr. Wieland Beckert, Dr. Michael Schneider, Dr. Manfred Fries, Dr. Michael Stelter

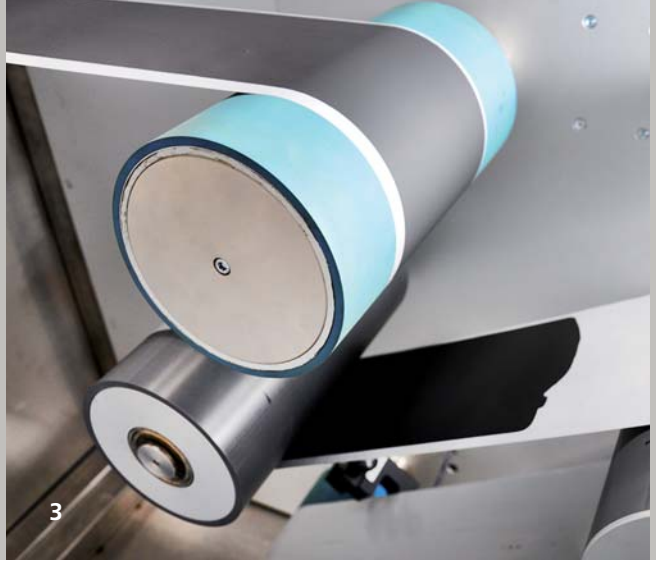
Li-ion batteries are an integral part of future, sustainable energy supply. Although they are mainly used in consumer devices at present, where a high energy density has priority, Li-ion batteries will be of great importance for e-mobility and stationary storage of electric energy in the future. Here, ceramic materials and technologies play a crucial role since the active electrode materials as well as the separators mainly consist of ceramics' determining power, reliability and costs of a battery system. For this reason, Fraunhofer IKTS follows an integral approach comprising material and technology development, suitable characterization methods as well as productions and application aspects. The relevant process chains can be reproduced in laboratory and pilot scale to support the direct technology transfer to mass production. So, active materials from 10 g to 100 kg batches are synthesized, characterized and applied. In this way, for example, granulation methods for cathode powders were developed by means of which the morphology and size of the active agglomerates can be adjusted. Particle size and packing density can be effectively controlled by the calcination temperature. To improve the safety and ion conductivity Li-ion conducting glasses were successfully developed (diagram on the right).

Ceramic technologies are also used for the preparation of powders, pastes, slurries and extrusion masses as well as for the deposition of electrodes. For this purpose, the active materials are mixed with solvent, carbon particles and binder, and the flow behavior of the suspension is adjusted to the particular deposition process. The electrodes manufactured this way are analyzed using electrochemical methods. The focus is on capacity and cyclability as well as structural changes as a result of lithium intercalation or deintercalation. In addition to electrochemical methods such as cyclic voltammetry and impedance spectroscopy, vibration spectroscopy methods (Raman and IR spectroscopy) are used. Furthermore, comprehensive experience in sample preparation for scanning electron microscopy allows to analyze the electrode structures over the whole life cycle of the battery.

Modern test stands allow to test and characterize commercial cells up to a capacity of 40 Ah. Thus, information about temperature dependence of electrical characteristics, self-heating and cell ageing can be obtained using current-voltage measurements and impedance spectroscopy. In addition, tests can be performed using application-specific load cycles. Aside

Ion conductivity of lithium-based glasses for separator manufacturing





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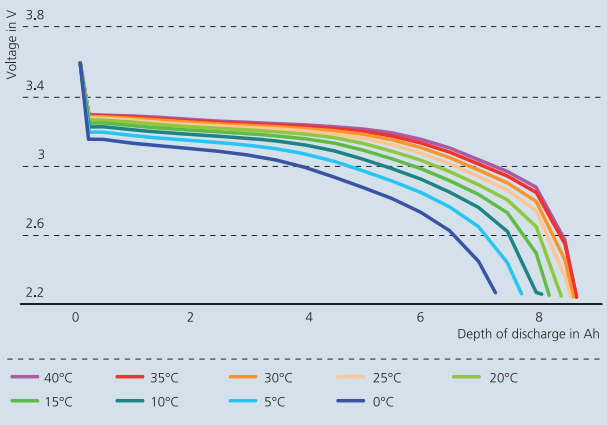
from statements on performance and stability of the cells the experimental results form the basis for further modeling activities. It is the goal to support model-based battery management or the thermal design of battery systems.

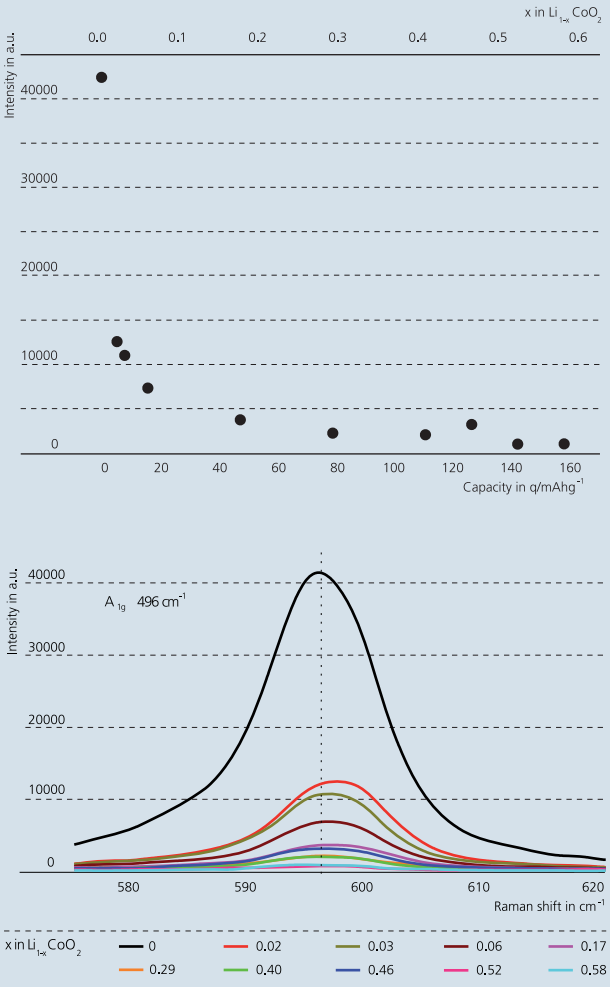
Services offered

- Development and characterization of battery powders
- Electrode manufacturing
- Electrochemical investigations
- Testing of batteries and post-mortem analysis
- Multiphysics simulation of electrical and thermal battery behavior

Variation of charging voltage and available capacity of a commercial lithium ion battery (10 Ah, $LiFePO_4$ cathode) with temperature



Raman spectroscopy on cathode material for deintercalation of lithium ions with increasing state of charge



1 *Spray dryer for powder processing.*

2 *Powder microstructure of a 10 kg batch; micrograph of cathode microstructure.*

3 *Layer deposition.*

4 *Battery test container.*

MATERIALS AND TECHNOLOGIES FOR HIGH-EFFICIENCY SOLAR CELLS: FROM LAB TO FAB

Dr. Uwe Partsch, Dr. Markus Eberstein, Dr. Lars Rebenklau

The growing market for renewable energies led also to an extraordinary expansion of the manufacturing capacities for PV modules wordwide. Being able to compete with conventionally generated electric current, a PV module prize of < 1€/W_{peak} must be achieved. According to that, it is a main requirement for PV cell and module manufacturers to redefine volume and manufacturing cost goals. This implicates that very large quantities of high-efficiency PV modules must be offered for a significantly lower price. Besides cost aspects the quality and long life cycle of the PV modules have a special relevance for customers.

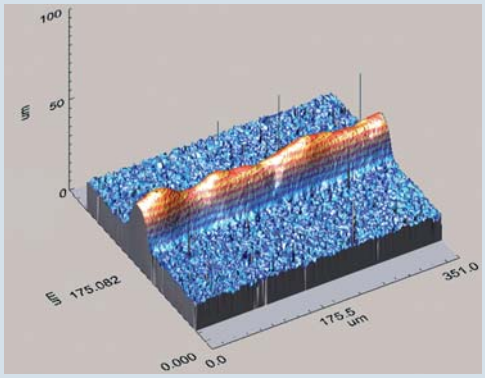
Fraunhofer IKTS research activities focus on the mentioned aims and are contributed to the optimization of mono-crystalline and multi-crystalline solar cells, in particular. In addition to efficiency optimization of standard solar cells (reduction of shading or electrical losses) or high-efficiency cell concepts (selective emitter, local back side contacts), options for a cost reduction (e.g. by noble metal substitution) are investigated.

Environmentally friendly materials and processes play an important role regarding a medium-term RoHS or REACH conformity of the solar cell manufacturing process. In this context lead-free (also heavy-metal-free) pastes for the front side metallization of crystalline solar cells as well as lead-free soldering technologies for PV module assembling (laser, infrared, induction brazing) are developed at Fraunhofer IKTS.

Paste and technology development for crystalline solar cells

Screen printing is the current standard deposition technology for front and back side metallization of crystalline solar cells. After printing, the metallization structures are fired very rapidly. For optimal cell characteristics, optimized paste rheologies as well as contact forming mechanisms are required. The emitter with a thickness of only 200 nm must be optimally contacted to prevent electrical losses. Paste rheology is strongly affected by the interactions of organic and inorganic paste constituents. Actual projects deal with tailor-made paste compositions for different printing technologies. Besides standard screen printing, ultra high definition screen and stencil printing (also double and dual printing) as well as inkjet and aerosol printing are investigated. The microstructure and functional properties of the contact fingers can be controlled by the particle size distribution of the contained metal particles as

Contact finger of a crystalline solar cell, fine-line-double print



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well as the composition of the used glasses. Current research of Fraunhofer IKTS is focused on the increase of solids contents in pastes as well as on lead-free glasses.

Fraunhofer IKTS provides numerous possibilities to benchmark the processability of the pastes as well as to characterize the full-processed cells. Thermal analyses (shrinkage, DTA, DTG/MS) characterize e.g. the burn out of organic paste components (solvents, binders), the sintering and densification of the metallic fingers as well as the mechanism of contact formation. Different analyzing methods (SEM, XRD, FIB) can be used to evaluate the microstructure of the front and back side metallization as well as the quality of the emitter contact. Completely processed metallization layers as well as solar cells can be characterized using different measurement sites (R_k, R_{sqr}, I-U characteristic curve).

Technology evaluation at pilot line scale

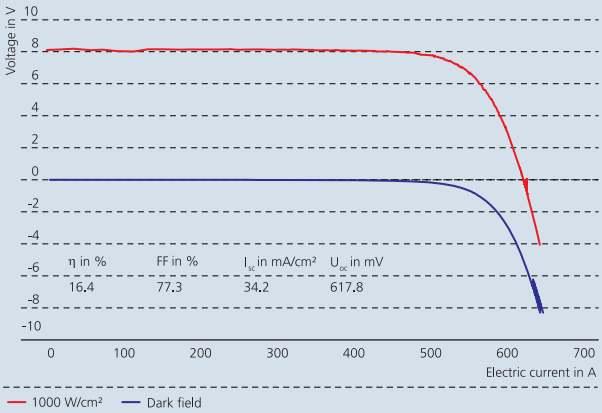
In spring 2010 a pilot line for the manufacturing of monocrystalline and multi-crystalline solar cells, co-operated by Roth & Rau AG and Fraunhofer IKTS, started running in Hohenstein-Ernstthal. The pilot line allows the complete industry-oriented processing of solar cells starting with the removal of saw damages and texture etching. Further processing steps include doping, anti-reflex coating, metallization and firing, etch isolation and test/sorting. The concept of the pilot line is modular. So, it is possible to interrupt the process flow for necessary characterizations before and after every processing step. Furthermore, different technology steps e.g. for the processing of high-efficiency cells (selective emitter, MWT, EWT, local back side contacts, hetero junction) can be implemented in the standard solar cell process flow.

In comparison with state-of-the-art PV production lines, the pilot line is equipped with an extensive instrumentation. Using a MES (Machine Executing System) with virtual wafer tracking for every single wafer process data can be collected for all process steps.

Services offered

- Development of optimized pastes for front and back side metallization of crystalline cells
- Process optimization in laboratory scale as closed loop with paste development
- Characterization of pastes and solar cells
- Process scale-up into pilot plant scale

I-U characteristic curve (standard wafer)

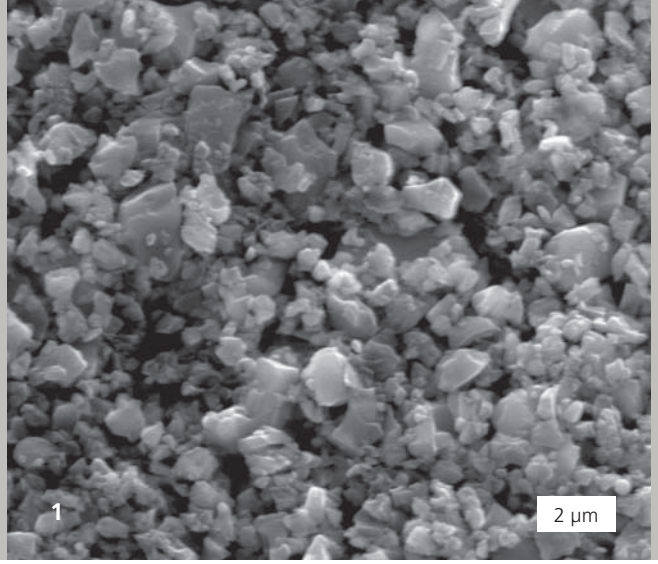


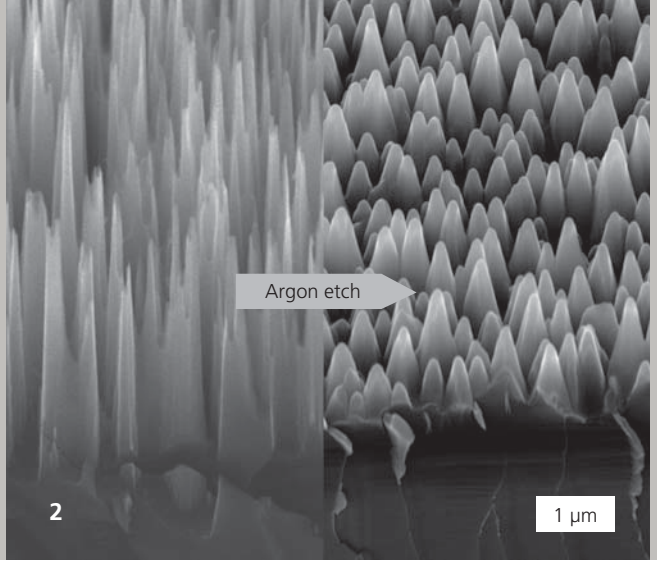
1 *Paste development at a three-roll mill.*

2 *Screen printing of front side metallization.*

3 *Opening of the new photovoltaics pilot production line in Hohenstein-Ernstthal in presence of the Saxon state minister Prof. von Schorlemer.*

4 *Screen printing production line for front and back side metallization.*





DEVELOPMENT OF A LAMINATED SILICON-CERAMIC SUBSTRATE

Dipl.-Chem. Beate Pawlowski

Introduction

In close cooperation with the Institute for Micro and Nanotechnologies of the Ilmenau University of Technology a new integration concept was developed to join a LTCC substrate (Low Temperature Cofired Ceramics) and a nanostructured wafer (black silicon). This new technique benefits from the advantages of silicon and ceramic technologies. Present concepts require joining materials such as glass frits, solders or other adhesives. The anodic bonding technique is an alternative method to combine a silicon wafer and a special LTCC substrate (BGK tape) with matched thermal expansion behavior. However, this process requires an expensive polishing step of the ceramic surface which is not necessary when using the described joining technique.

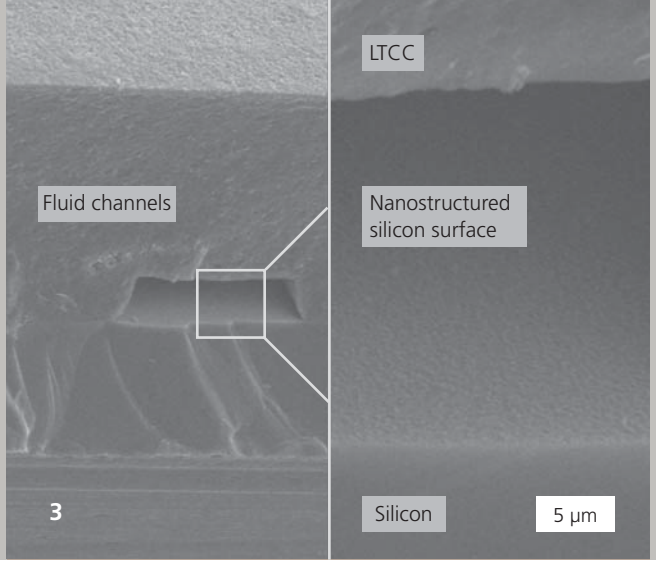
The new concept is based on a standard lamination process in which the prestructured silicon wafer or wafer components are joined with a green ceramic substrate without additional intermediate layers before sintering. The wafer is joined with a ceramic green tape by isostatic or uniaxial lamination, and then densified by pressure-assisted sintering. The resulting composite (SiCer) with a nanoscale interface has an extremely high bonding strength exceeding the strength of an anodically bonded composite.

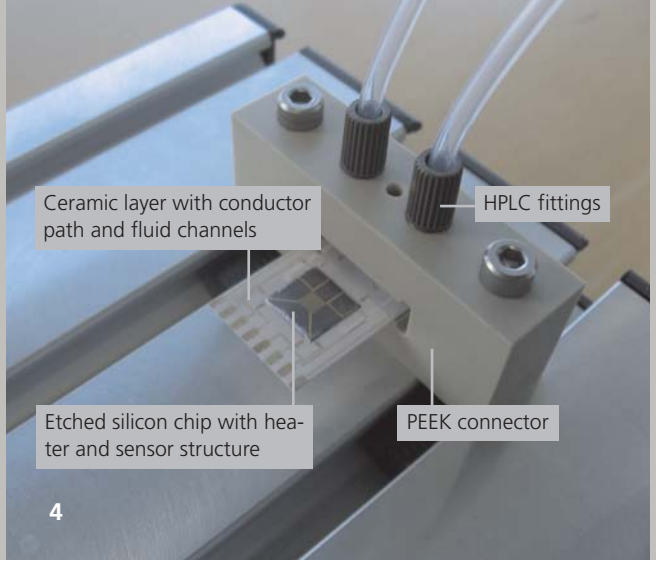
Adaption of bonding components

Before joining the bonding components to a monolithic composite, both substrates have to be adjusted to each other in terms of morphology and needle geometry. Using a standard etching process, black silicon needles with a length of 2.5 µm can be realized. The needle density providing space for the powder particles cannot be changed, whereas the length of the needles can be modified. The nanostructured silicon surface is generated by a modified reactive ion etching process using SF_6/O_2 plasma. The needle geometries have to be adjusted to the powder morphology of the BGK (particle size and distribution) and optimized for the lamination process (length stability). Therefore, an additional plasma treatment with argon is performed to cut and thin out the needles. The resulting optimized needle geometry is about 1.5 µm in length, the diameter varies between 100 nm to 400 nm from top to bottom. The main constituents of the bondable LTCC tape are borosilicate glass, two ceramic components and a polymer binder. The ceramic components as well as the glass are fine-milled to a grain size of about d_{50} = 400 nm.

Tape casting

In preparation of the tape casting process, the rheological properties of the slurry were analyzed. To optimize the casting behavior, a dispersant based on phosphoric ester was used. The powder components and the phosphoric ester were dispersed in organic solvents for 24 hours. Afterwards, binder and plasticizer were added and the slurry was further homogenized for 24 hours. The resulting green tapes were analyzed with regard to cracks, separation behavior, wettability, and flatness.





Processing of the single substrates

The adapted LTCC tape is processed by standard LTCC technologies such as punching, via filling, screen printing of conductive, resistance or insulation pastes and lamination. Then, the nanotextured silicon wafer and the prelaminated LTCC multilayer are laminated by isostatic pressing. The needles penetrate into the polymer matrix of the green tape and get into contact with the solid particles. Lamination parameters such as pressure, time, temperature and pressure ramp significantly determine the joining process. By pressure-assisted firing a hermetically tight and extremely strong joint is realized.

Results

The functionality of the silicon-ceramic substrate was demonstrated with a fluidic system. The substrate was characterized by mechanical, fluidic and electrical methods. The excellent bonding strength is an outstanding property of this substrate. To determine the bonding strength, the bonded silicon-ceramic substrate was separated, and the test chips were fixed onto a test specimen. Then, a modified pull test was performed. The samples exhibited an average bonding strength of 5474 N/cm². In order to characterize the tightness of the bond interface, test structures consisting of a microfluidic vacuum chamber with different bonding frames mounted onto an adapted vacuum flange were used. Helium leak rates down to $1.1 \cdot 10^{-8}$ mbarl/s were measured for bonding frames starting from 1.5 mm. Electrical functionality is achieved by penetrating metalized black silicon needles into metal-filled LTCC vias to form interconnects between the two layers. The transfer resistance at the Au (via)/Pt (needle) metallization was determined with 3.3 Ω.

Acknowledgments

This work was funded by the Federal Ministry of Education and Research and was supported by the Thuringian Ministry of Education, Science and Culture within the framework of the "Mikro-Nano-Integration" project (15SV3566) and the "SiCeram" research project (B514-09026).

Services offered

- Preparation of anodic bondable LTCC tapes
- Design of test layouts
- Preparation of functional samples

1 *Optimized powder morphology.*
2 *Standard (left) and optimized (right) black silicon.*
3 *REM image of a fluidic channel at the silicon/LTCC interface.*
4 *Fluidic system.*

1

DEVELOPMENT OF GREEN TAPES FOR LEAD-FREE PIEZOELECTRIC MULTILAYER ACTUATORS

Dipl.-Chem. Beate Pawlowski

Motivation

The application of piezoelectric actuators for diesel and petrol fuel injection plays an important role to achieve novel exhaust emission standards. This is caused by the excellent properties of the new actuators, e.g. precise microposition, high blocking force as well as high dynamics. Other application fields of piezoelectric actuators can be found in telecommunication, precision machining and scientific instrumentation.

Growing environmental awareness has led to the restriction of lead-containing materials to be used in automotive applications. The interest in lead-free alternatives for non-automotive applications, as well, has not only sharply increased in Germany and Europe, but also in the USA.

It is an ambitious aim: It is planned to develop a high-efficient, reliable and long-term stable multilayer actuator based on lead-free piezoelectric ceramics with a piezoelectric strain higher than 300 pm/V at 2 kV/mm and an operation temperature ranging from 20 to 150°C. It is to be produced as multilayer component in combination with thin metallic inner electrodes by co-firing. Thus, simple systems could be realized.

The breakthrough in the development of an efficient, high-precise actuator on the basis of environment-friendly, lead-free materials would significantly contribute to expand the excellence platform of German research institutes and to promote Germany as a business location.

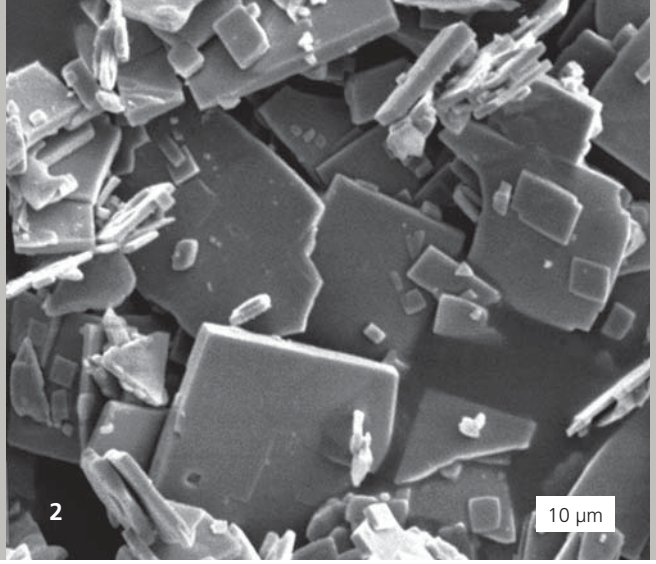
Objectives

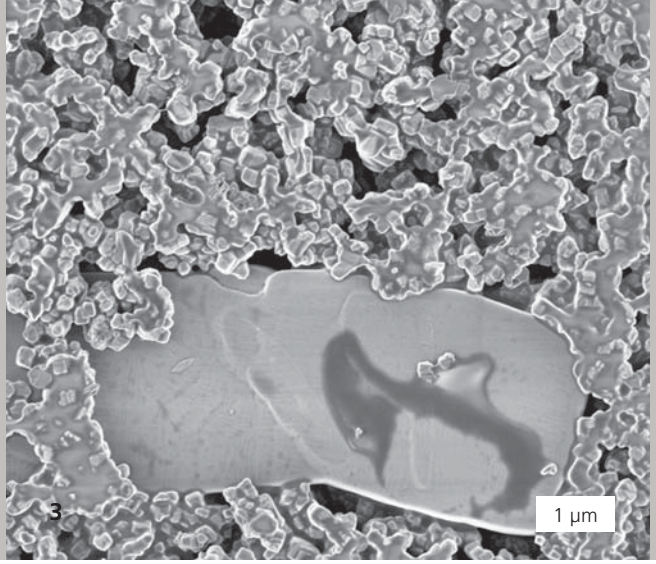
It is the aim of the "RealMak" research project to develop a reliable, high-efficient and long-term stable multilayer actuator based on lead-free piezoelectric ceramics. Multilayer components of lead-free piezoelectric ceramics in combination with thin metallic inner electrodes are to be manufactured by co-firing. The subproject of Fraunhofer IKTS aims at developing an optimized tape casting technology to produce lead-free, cofireable piezoelectric green tapes. The lead-free piezoelectric tapes are optimized with respect to homogeneity, binder burnout and sintering behavior, lamination behavior, shrinkage, thermal expansion coefficient, compatibility to inner electrode pastes, co-firing process as well as ageing behavior and long-term degradation.

Results

First, different green tape compositions based on two model substances, potassium-sodium niobate (KNN) and bismuth-sodium titanate (BNT), were developed. Different dispersing agents were characterized in terms of their efficiency by streaming potential measurements. After an algorithm for the measurement and the interpretation of the streaming potential in organic solvents has been developed, information about type, concentration and efficiency of the dispersing agents for the systems BNT and KNN were extracted.

In a second step, different binders and plasticizers were tested and evaluated. The slurry composition was finally optimized





with the aim to get green tapes which show no drying effects (segregation, cracks), can easily be removed from the carrier tape, have a good lamination behavior as well as a homogenous microstructure after sintering. To achieve the targeted functional parameters, it is necessary to prepare textured green tapes. Different seed crystals were tested. To prepare the seeds-containing slurry, a new gentle processing technology was developed. The textured green tapes were characterized by scanning electron microscopy, thermogravimetric methods, dilatometric measurements and sintering experiments.

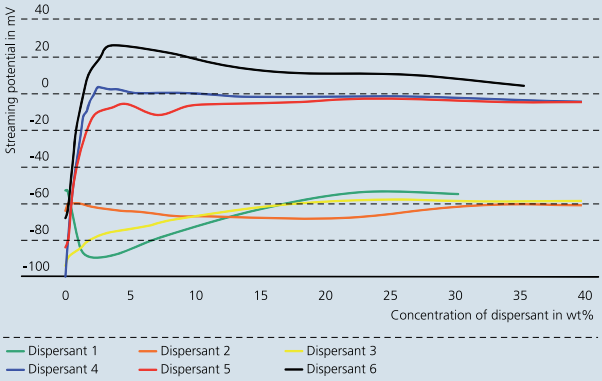
Acknowledgments

This work was funded by the German Federal Ministry of Education and Research (BMBF) within the "RealMak" project (03X4007E).

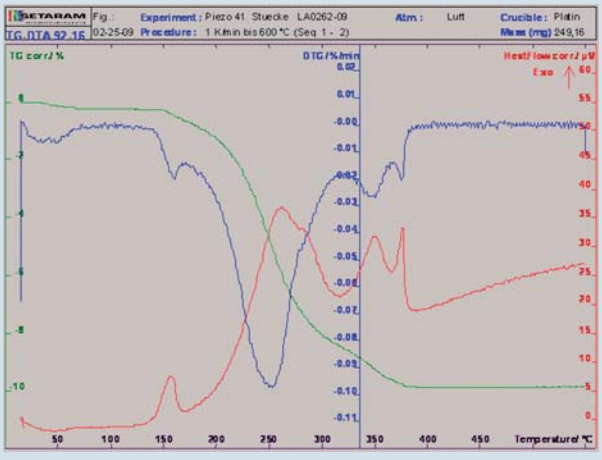
Services offered

- Preparation of lead-free piezoelectric materials in laboratory scale
- Development of slurry composition for tape casting of lead-free piezoelectric materials

Measurement of the streaming potential of BNT with different dispersants



TG/DTA measurement of a textured green tape



1 *Tape casting equipment at Fraunhofer IKTS Hermsdorf.*
2 *REM image of seed crystals.*
3 *REM image of a textured green tape.*

RESEARCH ACTIVITIES AT FRAUNHOFER IKTS

RESEARCH FIELD

SMART MATERIALS AND SYSTEMS

Department head:
Dr. Andreas Schönecker

Profile

Engineering and scientific processes are applied to develop and integrate dielectric functional ceramics into devices, microsystems and active structures.

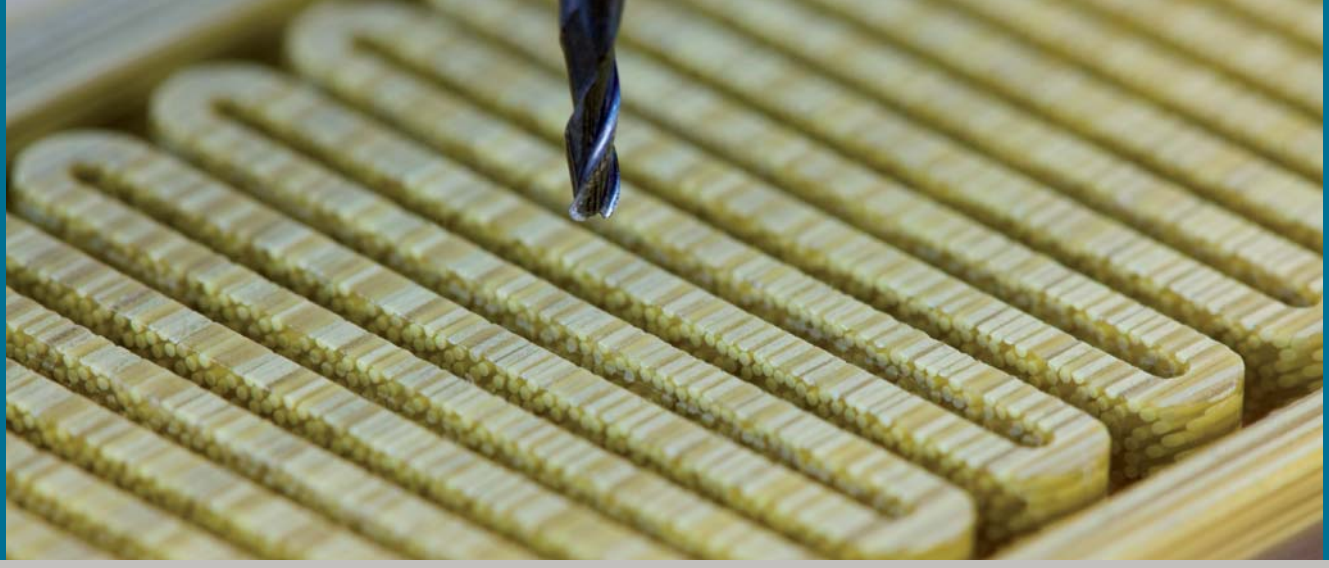
Complex, interdisciplinary problems are solved in optimization cycles covering all aspects of the value chain from materials synthesis to functional verification in prototype systems. Functional optimization is accordingly performed on several scales, through functional consolidation in materials, utilization of property combinations of composites, and adaptation of components to the system environment. Special materials expertise exists in the field of complex perovskites, which, as high-performance piezoceramic or dielectric ceramics, provide sensing, actuating, and electronic functions in monolithic components and composites with polymers, metals, glasses, and other ceramics.

Thick film, multilayer, and piezocomposite technologies are available as closed technology chains. Combination with unique design and characterization tools enables innovative developments in piezotechnology, adaptronics, and mechatronics as well as microsystems technology and microenergy technology. This also includes in-house systems developments (especially in piezotechnology).

Preparation of thin film structures is done by CVD, PVD, and sol-gel processes in combination with reactive ion etching for structuring. With this technology portfolio, we offer new materials solutions for semiconductor technology and wear protection.

Services offered

- Studies and concept developments for high-performance dielectric ceramics in the form of powders, components, and integrated functional elements
- Development of materials and technologies
- Development and integration of components
- Manufacture of prototypes
- Supply of key materials and components
- Characterization of dielectric, piezoelectric, and ferroelectric functional properties
- Vibration and sound field measurements
- Modeling and simulation for systems design for sensors, actuators, and ultrasonic transducers
- Scientific instrument design, electronics, and software development



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Piezo Systems
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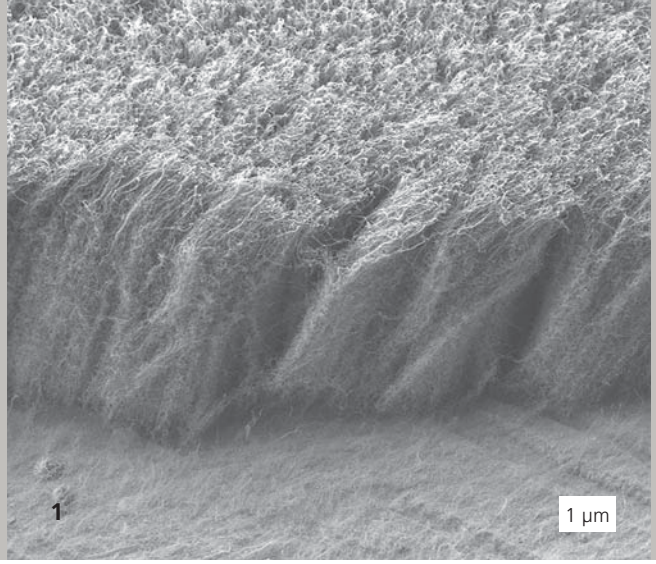
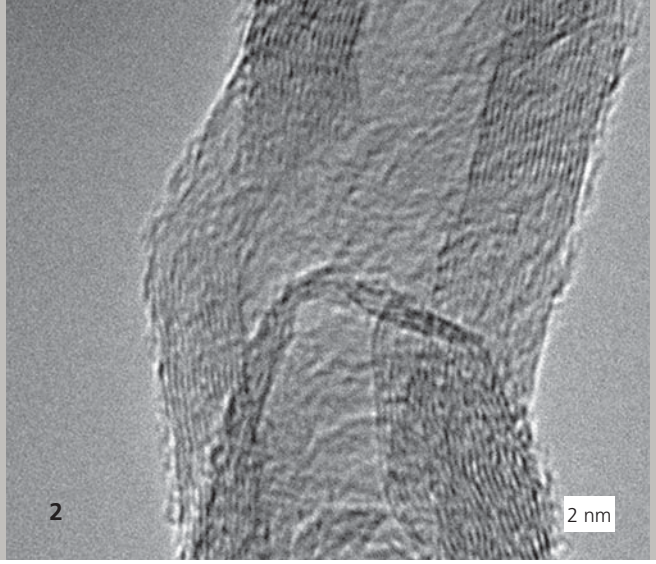




CARBON NANOTUBES AS ELECTRODE MATERIAL FOR ENERGY STORAGE

Dipl.-Ing. (FH) Frank Meißner, Dr. Ingolf Endler

Motivation

The increasing importance of e-mobility requires more efficient, modern energy storage systems. Today, new lithium ion batteries typically contain mixed oxide compounds in the cathode and graphite in the anode. To increase power density and reliability, new cathode and anode materials can make an important contribution. Due to their combination of high electrical conductivity and high aspect ratio, aligned carbon nanotubes (CNT) are well suited to be used as anode materials in lithium ion batteries or as electrode materials in supercaps.

Synthesis of aligned CNT at Fraunhofer IKTS

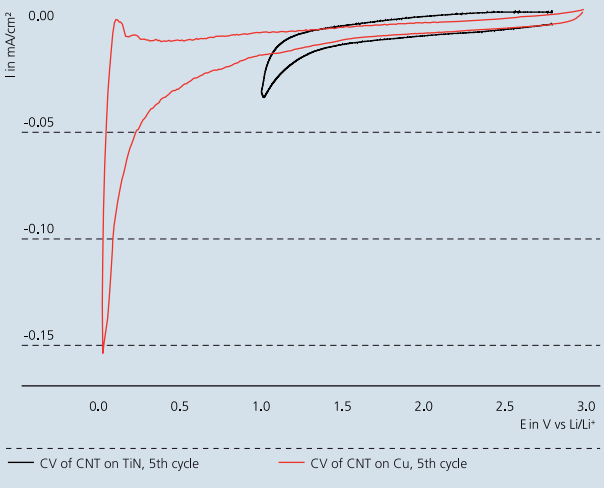
At Fraunhofer IKTS the synthesis of aligned carbon nanotubes on different carrier materials has been established since 2005. Two deposition systems based on chemical vapor deposition (CVD) are available. They allow for the synthesis of CNT on samples up to 100 mm in diameter. Carbon nanotube growth is possible either using thermal CVD or high-frequency (HF) plasma.

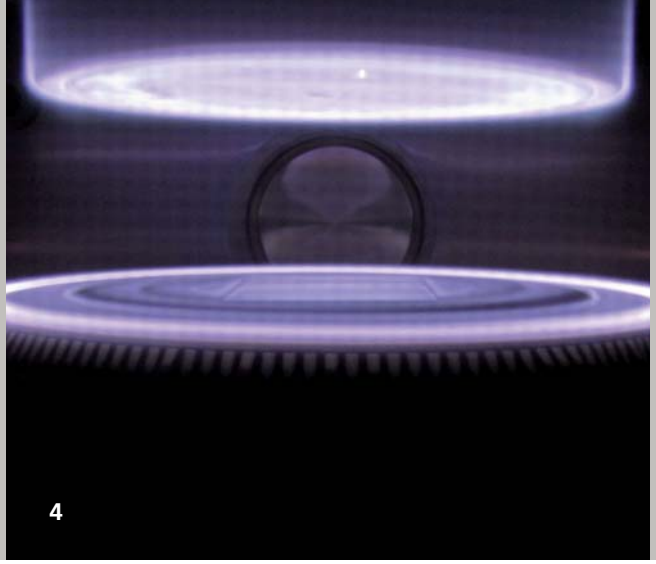
Properties of CNT electrodes

For the growth of aligned CNT nickel foil, copper foil and titanium nitride layers on silicon, wafers were used as carrier materials. Multi-walled carbon nanotubes (MWCNT) with a length of approx. 10 µm and an outer diameter of 20 nm were deposited on TiN layers. The TiN layer serves as base electrode as well as diffusion barrier. This prevents silicide formation and allows the use of silicon wafer substrates.

Figure 1 shows vertically aligned CNT on nickel foil having a length of 12 µm after a deposition time of 20 minutes. Using a special copper quality, insulating interlayers were not necessary to grow CNT on copper substrates. The outer diameter of the as-grown CNT on copper is 35 nm. The cyclovoltammetric measurements (CV) show the typical behavior of a double-layer capacitor. The stability window is between 1.4 and 3.0 V for the TiN based substrate and between 0.6 V and 3.0 V for the copper substrate. Neglecting the negative shift for low voltages due to the low active mass, a double layer with a remarkable charge capacity of about 130 F/g has been realized.

CV measurements of carbon nanotubes on TiN layers and copper substrates (measurements by Fraunhofer ISC Würzburg)





Further applications

Besides the here mentioned opportunities of CNT use for energy storage, CNT are an interesting material for further applications due to their high Young's modulus, high thermal conductivity and their good chemical resistance. In electronic packaging laterally structured CNT can be used for fast current and heat transport in components. For this reason, they may be interesting for concepts of future electronic devices. The high aspect ratio of CNT resulting from length of some micrometers compared to diameters of some nanometers makes them also interesting for filter applications in the nanometer scale.

Acknowledgments

The presented works are results of the cooperative project KoLi-WIn (03SF0343B) and of Fraunhofer systems research electromobility FSEM (13N10599). The German Federal Ministry of Education and Research as well as the project management organizations VDI and PT Jülich are gratefully acknowledged for their financial support. Furthermore, we are indebted to Fraunhofer ISC for electrochemical characterization of the samples.

Services offered

- Manufacturing of aligned carbon nanotube layers on metallic and other electrically conductive carrier materials
- Structural CNT deposition on substrates up to 100 mm in diameter
- Characterization of carbon nanotube structures by SEM and spectroscopic analysis
- Electrochemical characterization of CNT on substrates
- Production of electrodes based on CNT for lithium ion batteries and supercaps

1 *SEM image of aligned CNT on nickel foil.*
2 *HRTEM image of a carbon nanotube made on a conductive TiN layer.*
3 *PECVD system in a cleanroom of Fraunhofer IKTS.*
4 *Synthesis of aligned CNT by HF plasma CVD.*

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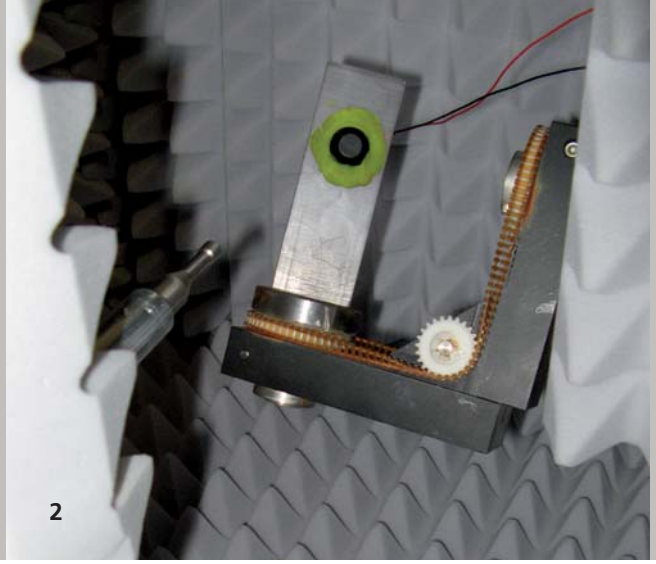

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PIEZOSYSTEMS – AN INTEGRATED APPROACH

Dipl.-Ing. Thomas Rödig

Starting situation

Fraunhofer IKTS is dealing with the development of materials and technologies for piezoceramic transducers. Best suited chemical compositions are synthesized in all possible ceramic forms like thin film, thick film and multilayer or bulk material. The market interest for piezoceramics results from their electromechanical coupling behavior. The use in sensors, actuators and ultrasound transducers in commercial applications is commonly known. Recent developments consider the application of piezoelectric transducers as generator to provide small amounts of electrical energy from structural vibrations. This so-called "energy harvesting" is one key function to increase functionality and smartness of structural components. Successful implementation requires the optimization of the system. Here, we support customized solutions for all subsystems that means materials and technologies as well as mechanical and electrical components. The "Piezosystems" research group supports customers in all aspects of systems integration. So, the group completes the services of the „Intelligent Materials und Systems" research field which comprises the value added chain from the initial idea to the manufacturing of prototypes.

Motivation

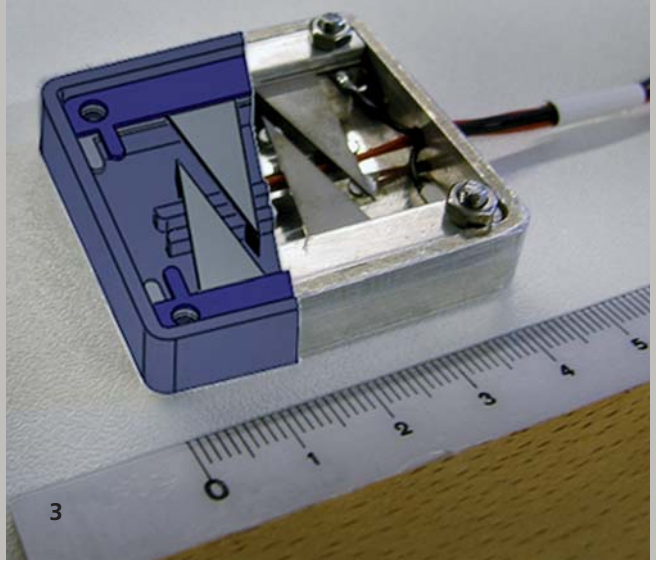
The "Piezosystems" research group deals with the design of piezoelectric transducers based on conventional and new, lead-free piezoceramic materials both as single element and as integrated elements in multiphase material systems. Customers benefit from technical solutions with highest coupling efficiency. Fields of applications are ultrasound technology, decentralized power generation, voltage conversion and coupled sensor-actuator structures. By choosing the best suited transducer material and by adapting electronics, an enormous potential for the optimization of existing and the creation of new applications is provided. Our developments include suggestions for an easy and cost-efficient production as well as high design reliability.

System aspects

Piezoelectric transducers connect mechanics with electronics. Based on our physical knowledge, specialized measurement set-ups, modeling methods and simulation tools, we are able to develop new systems very effectively. A strong interaction between other research groups at Fraunhofer IKTS allows for access to the latest developments in materials and technologies as well as components.

Modeling and simulation

Special methods of modeling to describe coupled piezoelectric systems are needed. Our approach is based on the theory of electromechanical systems. In this case, the considered system is divided in electrical (sub-)networks and simulated with commercial software packages. This approach has been proven by a variety of applications. Alternatively, piezoelectrically coupled systems are simulated using FEM. This includes also the calculation of sound fields of ultrasound transducers.



Development and design

The mechanical and especially the electro-mechanical properties of piezoceramic materials require an appropriate (piezo-) design. This means controlled loading and the utilization of strain levels in the micrometer range. Furthermore, tensile and shear stresses as well as moments must be avoided. We systematically apply and develop construction and design methods for precision fine mechanics.

Developments of electronics

For the best utilization of the features of piezoelectric materials, adapted electronics are essential. In general, standard electronic solutions are not sufficient because of the strong non-linear, capacitive behavior of the piezoceramic transducers. Over the years, we have developed specialized electronics which are suited for these characteristics. We are able to bring this experience into new developments.

Measurement technique

Specialized measurement equipment is needed for characterizing systems with integrated piezoelectric transducers. New measurement methods providing meaningful data have been developed and investigated. One example is a fully automated measurement set-up for ultrasound transducers for use in air/gases.

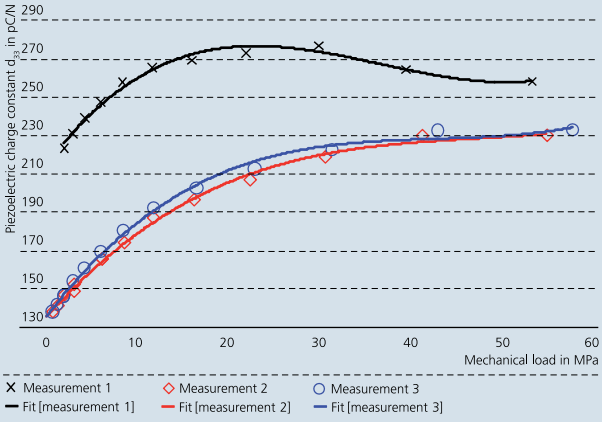
Main topics of current research

- Piezoelectric energy converter for wireless connected sensor systems with focus on aircraft and production technology, figure 3 ("Cool Silicon")
- Novel piezoelectric force sensor, figure 1 ("PiWA")
- Ultrasound transducer for the use in air/gases in automotive applications, figure 2

Services offered

Our services include the development of systems using piezoelectric transducers for sensor, actuator, generator and ultrasound applications. This comprises material selection, modeling and simulation, development and design, development of electronics as well as characterization and measurements.

Degradation of piezoceramic materials under high dynamic loading



1 *Force sensor with piezoelectric transducer in thick film technology.*

2 *Measurement set-up for ultrasound transducers for the use in air/gases.*

3 *Prototype of a piezoelectric generator.*

4 *Low-temperature measurement set-up.*

RETROSPECTIVE

EVENTS, EXHIBITIONS

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January 22, 2010
Ceramics Vision

On January 22, the colloquium series "Ceramics Vision", already taking place for the seventh time, was not held in Dresden as usual, but in Hermsdorf celebrating the integration of the Hermsdorfer Institut für Technische Keramik into the Fraunhofer IKTS. Under the motto "Integrated ceramic research from the idea to the product" the potentials of innovative ceramic technologies for new solutions were presented in interesting papers from industry and science. Aside from current developments the prospects of ceramic applications and technologies were shown. The presentations covered a wide spectrum of materials, components and systems in markets such as electronics, mechanical engineering, photovoltaics, and fuel cell systems. The prime minister of the Free State of Thuringia, Christine Lieberknecht, as well as representatives of the Saxon ministries opened the colloquium. Afterwards, Prof. Hans-Jörg Bullinger, president of the Fraunhofer-Gesellschaft, presented the successful model of the Fraunhofer-Gesellschaft as innovation driver for industry. The colloquium was supplemented by tours through the HITK with approx. 220 participants.

March 20, 2010
Visit of Volkswagen's "Production" management board accompanied by Saxony's prime minister

On March 20, 2010 Volkswagen's "Production" management board and Saxony's prime minister Stanislaw Tillich visited Fraunhofer IKTS to inform about the newest developments in the field of automotive and energy engineering. Prof. Alexander Michaelis presented the latest results of fuel cell, battery and photovoltaics research, and introduced active structural components for traffic engineering. During the institute tour specific research projects of Fraunhofer IKTS as well as current development trends were shown.

April 14, 2010
Commissioning of a photovoltaics pilot production line in the presence of Saxony's state minister Prof. Sabine von Schorlemer

The Roth & Rau AG and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS opened a new pilot line for the development and production of efficient and cost-effective crystalline solar cells in Hohenstein-Ernstthal on April 14, 2010. The results generated on the pilot line will help to produce and test new cell concepts as well as to develop new production equipment and plants for crystalline solar cells in the future. So, it is now possible to study newly developed materials and technologies in terms of their realizability on industry-oriented production lines.

The pilot line built up only within one year includes all process steps for the production of crystalline solar cells, beginning with wet-chemical treatment of wafers through application of anti-reflex coatings to frontside and backside metallization as well as functional tests. It is the aim of the extensive research and development activities in the field of traditional as well as

1 *Volkswagen's "Production" management board and Saxony's prime minister Stanislaw Tillich visiting Fraunhofer IKTS.*
2 *Festivities on occasion of "Ceramics Vision" at the new Fraunhofer IKTS branch in Hermsdorf in presence of the Thuringian prime minister Christine Lieberknecht.*
3 *Institute tour in presence of the Saxon prime minister Stanislaw Tillich.*

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new, advanced cell concepts to increase the efficiency and reduce the production costs.

September 23, 2010
Industrial seminar "Ceramics for exhaust gas treatment"

On September 23, 2010 Fraunhofer IKTS invited for the industrial seminar "Ceramics for exhaust gas treatment" taking place in Dresden for the first time. 70 participants informed and discussed about the current state as well as trends of ceramic development and manufacturing aspects. The official start-up of the new hot gas test stand with soot injector was one highlight of the interesting program. This test stand helps scientists at Fraunhofer IKTS to analyze components in hot gas environment and under thermal stress. The relevant and current topics presented in the seminar program met with a very positive response and are planned to be extended in future seminars and symposia.

November 5 to 7, 2010
Fraunhofer Talent School Dresden

In early November, 30 talented young persons interested in technology visited the Fraunhofer Talent School in Dresden. There, they got to know what current research deals with and which methods are used to research and develop new technologies. The three-day seminar focused on project work in workshops on various scientific topics. Scientists at the Fraunhofer Institutes FEP, IKTS and IPMS imparted the necessary theoretical basics and were available for discussion. At Fraunhofer IKTS the students learned in exciting experiments, how different kinds of fuel cells work, where they can be used and then built their own fuel cell. Fraunhofer IKTS will also host the Fraunhofer Talent School in 2011.

November 25 and 26, 2010
Galvanic Symposium

In 2010, electrolytic layers were in the focus of this symposia series that has been started in 2005 and is referring to topics on applied electrochemistry. In addition to results from basic research the 15 speakers also presented and discussed results from application-oriented research focused on electrochemical deposition. Some presentations also dealt with measurement techniques connected with formation and investigation of electrolytic layers.

The symposium was completed by a small exhibition of eight companies which was used as platform for discussion as well. On account of the very positive response of the 60 participants the symposium is planned to be continued in 2012.

Awards

Fraunhofer IKTS Hermsdorf wins Innovation Award

The Fraunhofer IKTS, branch Hermsdorf, won the Innovation Award of the Fördergesellschaft für Erneuerbare Energien e.V. (FEE), which was announced nationwide, for the development of a nanoporous membrane to dry bioethanol. With this award the FEE honors inventions for the reduction of energy consumption, efficient energy conversion and storage as well as for the use of renewable resources.

Among the 31 candidates the Fraunhofer IKTS came out on top with a ceramic filter, which is able to separate ethanol from water by a kind of "sieving". The pore size of the filter is only 0.4 nanometer, and thus is larger than the water molecule's diameter, but smaller than the ethanol molecule. In contrast to conventional methods the newly developed filter saves up to 90 % of energy. The method is already used in a production plant for biofuel.

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Stifterverband Award for Science goes to DiaCer®

Scientists from four Fraunhofer institutes, among them three institutes of the Fraunhofer Demonstration Center AdvanCer, together with partners from industry, succeeded in producing a new composite material combining the best of diamond and ceramics: diamond-coated ceramics DiaCer®. Any place where components and tools are subjected to heavy strain DiaCer® offers maximum wear resistance coupled with low values of friction. This combination guarantees an extended product lifespan, improves production processes, and reduces energy consumption. Diamond-coated axial face seals for pumps have successfully established on the market for critical environments, like the conveyors for oil, sand and gas mixtures.

In recognition of their achievement, the researcher team was bestowed the Stifterverband Award for Science at the annual conference of the Fraunhofer-Gesellschaft in Leipzig in the end of May. The award recognizes the scientific excellence of joint projects in applied research that the Fraunhofer institutes have developed in conjunction with business and/or other research organizations.

1 *Opening of the new photovoltaics pilot production line in Hohenstein-Ernstthal in presence of the Saxon state minister Prof. Sabine von Schorlemer.*
2 *Institute tour during the industrial seminar "Ceramics for exhaust gas treatment".*
3 *Winners of the FEE Innovation Award 2010 (left to right: Dr. Weyd, Dipl.-Ing. Kühnert, Dr. Voigt and Dr. Richter).*
4 *Congratulations of Federal Minister Annette Schavan (right) to the winners of the Stifterverband Award for Science (left: Dr. Herrmann, Fraunhofer IKTS).*

PARTICIPATION IN TRADE FAIRS AND EXHIBITIONS

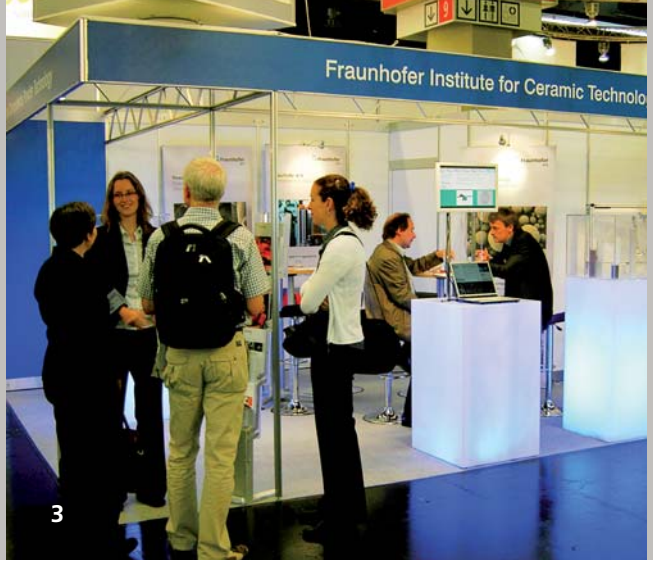
1

nano tech
Tokyo, February 17-19, 2010
Joint stand of Fraunhofer-Gesellschaft

Solar Energy
Berlin, February 16-20, 2010
Joint stand of Fraunhofer Energy Alliance

Hannover Messe
Hanover, April 19-23, 2010
- Joint stand of Fraunhofer High-Performance Ceramics Alliance/TASK GmbH
- Joint stand of Fraunhofer Fuel Cell Initiative Saxony
- Joint stand of Fraunhofer Energy Alliance
- eneramic® fuel cell system
- Joint stand of IHK Gera
- Joint stand of Micro-Nanotechnology Thuringia

2



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Conference of the German Association for Water, Wastewater and Waste
Potsdam, April 19-21, 2010

POWTECH
Nuremberg, April 27-29, 2010

18th Biomass Conference and Exhibiton
Lyon, May 3-7, 2010

World Hydrogen Energy Conference
Essen, May 16-21, 2010

Sensor + Test
Nuremberg, May 18-20, 2010
Joint stand "Research for the future – Saxony, Saxony-Anhalt, Thuringia"

Energy Harvesting and Storage
Munich, May 26-27, 2010

SMT/HYBRID/PACKAGING
Nuremberg, June 8-10, 2010
Joint stand of VDI/VDE

Fuel Cell Forum
Lucerne, June 29-July 2, 2010

25th European Photovoltaic Solar Energy Conference and Exhibition
Valencia, September 6-9, 2010
Joint stand of Saxony Economic Development Corporation (WFS)

IFAT
Munich, September 13-17, 2010
Joint stand of Fraunhofer-Gesellschaft

Clean Tech World
Berlin, September 15-19, 2010

Biotechnica
Hanover, October 5-7, 2010
Joint stand "Research for the future – Saxony, Saxony-Anhalt, Thuringia"

Highlights of Physics
Augsburg, October 9-14, 2010

EURO PM
Florence, October 10-14, 2010

Electronica
Munich, November 9-12, 2010
Joint stand of Fraunhofer-Gesellschaft

Hagen Symposium
Hagen, November 25-26, 2010

EuroMold
Frankfurt/Main, December 1-4, 2010
Joint stand of Fraunhofer Additive Manufacturing Alliance

1 *Presentation of the new eneramic® fuel cell system at Hannover Messe in presence of Prof. Bullinger, president of the Fraunhofer-Gesellschaft (right).*
2 *Visitors in Ceramics Meeting Point at Hannover Messe.*
3 *Successful participation in POWTECH 2010 in Nuremberg.*

COOPERATION IN GROUPS, ALLIANCES AND NETWORKS

Scientists at Fraunhofer IKTS are active in numerous thematically oriented groups, networks and associations. Our customers benefit from this by having a coordinated range of joint services available to them.

Membership in Fraunhofer groups, alliances, networks and demonstration centers

Fraunhofer Group for Materials and Components – MATERIALS

Ceramics Meeting Point in Dresden

Fraunhofer High-Performance Ceramics Alliance

Fraunhofer Demonstration Center AdvanCer

Fraunhofer Adaptronics Alliance

Fraunhofer Energy Alliance

Fraunhofer Nanotechnology Alliance

Fraunhofer Numerical Simulation of Products, Processes Alliance

Fraunhofer Additive Manufacturing Alliance

Fraunhofer Water Systems Alliance (SysWasser)

Fraunhofer Sensor Network

Association for Manufacturing Technology and Development e.V. (GFE)

Association of Ceramic Industry e.V. (VKI)

Association of Electrochemical Research Institutes e.V. (AGEF)

Association of German Engineers

Association of the Thuringian Economy e.V., committee of research and innovation

Association of Thermal Spraying e.V. (GTS)

BioMeT Dresden Network

DECHEMA - Society for Chemical Engineering and Biotechnology e.V.

DKG/DGM Community Committee

European Powder Metallurgy Association (EPMA)

European Research Association for Sheet Metal Working e.V. (EFB)

Expert Group on Ceramic Injection Molding (Working Group in the German Ceramic Society)

Fuel Cell Initiative Saxony e.V. (BZS)

German Ceramic Society e.V. (DKG)

German Society for Materials Research e.V. (DGM)

International Zeolite Association

Materials Research Network Dresden e.V. (MFD)

Meeting of Refractory Experts Freiberg e.V. (MORE)

Micro-Nanotechnology Thuringia e.V. (MNT)

NanoMat - Supraregional Network for Materials Used in Nano-technology

Nanotechnology Center of Excellence for "Ultrathin Functional Layers"

ProcessNet – an Initiative of DECHEMA and VDI-GVC

Research Association for Diesel Emission Control Technologies e.V. (FAD)

Research Association on Welding and Allied Processes of the German Welding Society (DVS)

Silicon Saxony e.V.

Society for Knowledge and Technology Transfer of TU Dresden mbH

TransNanoPowder Information and Consulting Center

University of Applied Sciences Jena, university council

THE FRAUNHOFER GROUP FOR MATERIALS AND COMPONENTS – MATERIALS

Fraunhofer research in the field of materials science and technology covers the entire value chain from the development of new materials and the improvement of existing ones to manufacturing technology on a semi-industrial scale, the characterization of materials' properties and the assessment of their performance. This work extends to the components produced from the materials and their performance in systems.
In addition to experimental tests in laboratories and pilot plants, numerical simulation and modeling techniques are applied in all these areas. The Fraunhofer Group for Materials and Components – MATERIALS encompasses the entire field of metallic, inorganic-nonmetallic, polymer and sustainable materials, as well as semiconductor materials.
The Group concentrates its expertise in the Energy & Environment, Mobility, Health, Machinery & Plant Engineering, Construction & Living, Microsystems Technology, and Safety business sectors. System innovations are achieved by means of tailor-made material and component developments and customer-specific performance assessment.

Key aims of the group are

- To increase safety and comfort and to reduce the consumption of resources in transport, mechanical engineering and plant construction
- To raise the efficiency of systems for generating, converting and storing energy
- To improve the biocompatibility and functioning of materials used in medical engineering and biotechnology
- To increase the integration density and improve the utility properties of components in microelectronics and microsystem technology
- To improve the use of raw materials and the quality of the products made from them

The group comprises the Fraunhofer Institutes for

- Applied Polymer Research IAP
- Building Physics IBP
- Structural Durability and System Reliability LBF
- Chemical Technology ICT
- Manufacturing Technology and Advanced Materials IFAM
- Wood Research, Wilhelm-Klauditz-Institut, WKI
- Ceramic Technologies and Systems IKTS
- High-Speed Dynamics, Ernst-Mach-Institut, EMI
- Silicate Research ISC
- Solar Energy Systems ISE
- Systems and Innovation Research ISI
- Mechanics of Materials IWM
- Non-Destructive Testing IZFP

Permanent guests of the group are the Institutes for:
- Industrial Mathematics ITWM
- Interfacial Engineering and Biotechnology IGB.

Chairman of the group

Prof. Dr.-Ing. Holger Hanselka
Fraunhofer Institute for Structural Durability and System Reliability, LBF

www.materials.fraunhofer.de

CERAMICS MEETING POINT DRESDEN

Due to the cooperation of Fraunhofer IKTS, TASK GmbH and its various members, the Ceramics Meeting Point could be further established as an inherent part of the technology transfer landscape in Dresden. Many partners use the fast access to the research infrastructure of the Fraunhofer-Gesellschaft.

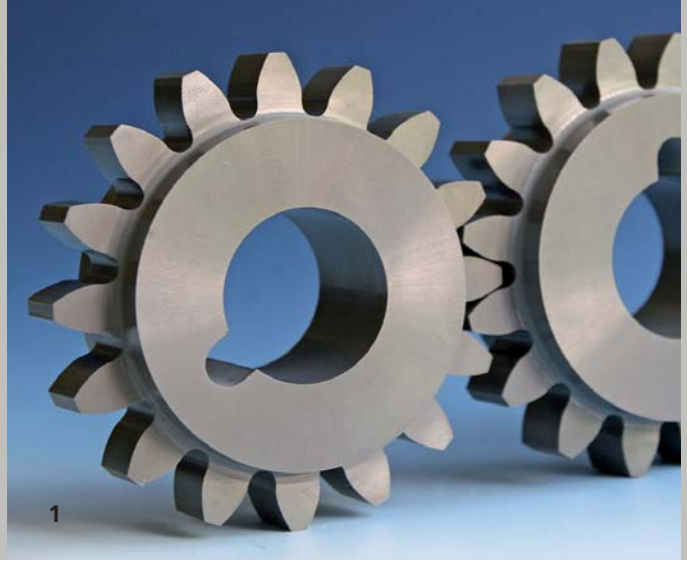
The spectrum ranges from the analysis and characterization of materials to the exclusive development project for large-scale production. The institute and the ceramic manufacturers draw a bow from raw materials to systems and from prototypes to series components. TASK GmbH supports the Fraunhofer Demonstration Center AdvanCer in conducting its workshops and training courses by providing the required practice-relevant and market information. Close collaboration between the researchers of the Fraunhofer Demonstration Center AdvanCer and the ceramic manufacturers has enabled users to quickly realize their ideas. Thus, a project forum for small and medium-sized companies has developed facilitating contacts to project initiators and research institutes.

By visiting Ceramics Meeting Point within the framework of numerous events taking place at Fraunhofer IKTS once again more than 2000 visitors could inform about ceramic product innovations and manufacturers in 2010. Main focus of the external industrial exhibitions under the motto "Meet Ceramic Experts" was on the Hannover Messe with a booth size of 300 m² and on the "Technical Ceramics Day" at Hannover Messe.

Members of Ceramics Meeting Point

TASK
Technologie-Agentur
Struktur-Keramik

1 *Visitors tour through Ceramics Meeting Point.*



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FRAUNHOFER HIGH-PERFORMANCE CERAMICS ALLIANCE

Systems development with high-performance ceramics

The application of high-performance ceramics allows for new applications in energy technology, mechanical and plant engineering, and medical technology. Well-known examples are combustion-chamber linings, roller bearings and implants. This innovative area has become an established field of expertise of the Fraunhofer-Gesellschaft.

Seven Fraunhofer institutes have joined together to form the Fraunhofer High-Performance Ceramics Alliance. The research activities of the alliance extend along the entire value added chain – from modeling and simulation through application-oriented materials development, production and machining of ceramic parts to component characterization, evaluation and non-destructive testing under application conditions. Current R&D activities focus on joining and integration methods.

In the Fraunhofer Demonstration Center AdvanCer the alliance's institutes expanded their presentation, training and consulting offerings in the field of high-performance ceramics. Using demonstration systems the added-value chain from powder to component as well as the implementation of knowledge, research and development in the form of products and improved quality of life are shown. The Fraunhofer Demonstration Center AdvanCer supports small and medium-sized companies in solving complex tasks ranging from prototype development to technology transfer.

Since 2005, the Fraunhofer Demonstration Center AdvanCer has been offering training courses for technicians and engineers. The three parts being offered follow one after another, but can also be taken as single courses.

The topics are:
- Materials, technology
- Machining
- Construction, testing

Through the AdvanCer newsletter, the Fraunhofer Demonstration Center regularly informs about new developments related to the topic of high performance ceramics.

Fields of cooperation

- Materials development for structural ceramics, functional ceramics, fiber-reinforced ceramics, cermets, ceramic composites and adaptive composite materials
- Component design and development of functional prototypes
- Systems integration and verification of batch-production capabilities
- Development of powder, fiber and coating technologies
- Materials, component and process simulation
- Materials and component testing, proof-testing and non-destructive testing
- Defect analysis, failure analysis, quality management

Service offerings

- Consulting and execution of feasibility studies
- Method and technology development
- Prototype development, technology transfer
- Completion of contract research, conceptualization and execution of alliance projects
- Workshops, seminars, training programs

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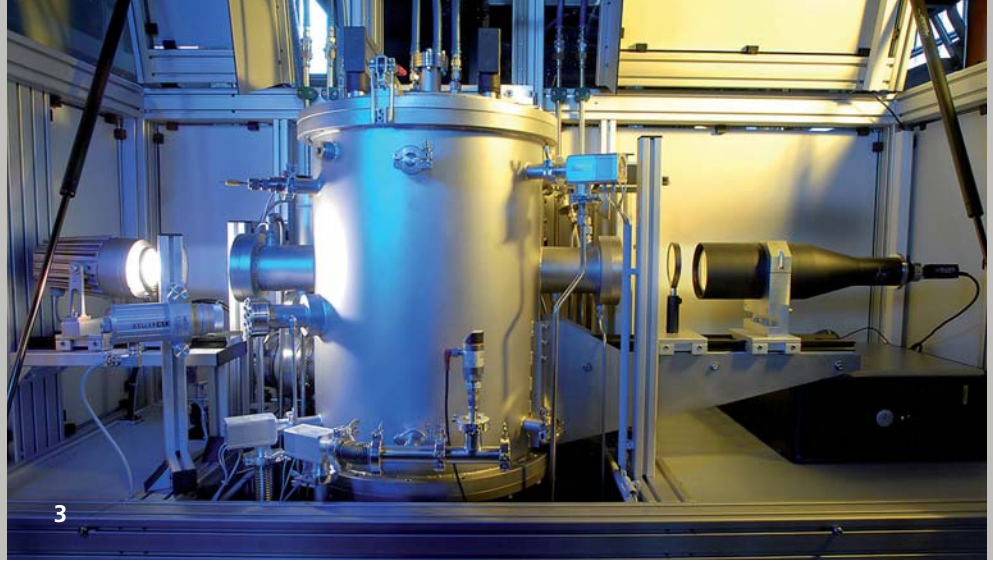
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Institutes

Fraunhofer Institute for Ceramic Technologies and Systems IKTS
www.ikts.fraunhofer.de

Fraunhofer Institute for Production Systems and Design Technology IPK
www.ipk.fraunhofer.de

Fraunhofer Institute for Production Technology IPT
www.ipt.fraunhofer.de

Fraunhofer Institute for Silicate Research ISC
www.isc.fraunhofer.de

Fraunhofer Institute for Mechanics of Materials IWM
www.iwm.fraunhofer.de

Fraunhofer Institute for Non-Destructive Testing IZFP
www.izfp.fraunhofer.de

Fraunhofer Institute for Structural Durability and System Reliability LBF
www.lbf.fraunhofer.de

Steering committee

Prof. Dr. Alexander Michaelis (spokesperson of the alliance)
Fraunhofer IKTS

Prof. Dr. Peter Gumbsch
Fraunhofer IWM

Prof. Dr. Fritz Klocke
Fraunhofer IPT

Office leader

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1 *Shot-peened ceramic gears.*
2 *CerCut is one of seven projects within the Fraunhofer Demonstration Center AdvanCer that have already been completed. The prototype tool will now be further qualified with industrial partners.*
3 *Thermooptical measuring device for the characterization of ceramics in controlled atmosphere up to 2000°C.*

NAMES, DATES, EVENTS

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3. Veranstaltung der Energie-City Leipzig Innovationen, Leipzig (21.10.2010), present.

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6th World Congress on Particle Technology – WCPT6 2010, Nürnberg (26.-29.4.2010), CD, presentation

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Lankau, V.; Martin, H.-P.; Michaelis, A.
Modification of the thermoelectric properties of sintered silicon carbide
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13. Internationale Metallographie-Tagung 2010, Leoben (29.9.-1.10.2010), present.

Stahn, M.; Endter, A.
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Stahn, M.
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Arbeitskreis »Keramische Membranen«, Frankfurt/M. (06.5.2010), presentation

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Aufbereitung von Nanoteilchen im industriellen Maßstab durch Automatisierung des Nassmahlprozesses
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DKG-Jahrestagung 2010, Hermsdorf/Thüringen (22.-24.3.2010), presentation

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Stelter, M.; Schneider, M.; Reuber, S.
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Fuel Cell Seminar & Exposition, San Antonio, TX, USA (18.-21.10.2010), present.

Stockmann, J.
Verbindungstechnik
Keramische Hochleistungswerkstoffe Schulungsprogramm des Fraunhofer-Demonstrationszentrums AdvanCer, Block III: Konstruktion, Werkstoffprüfung, Qualitätssicherung, Einsatzverhalten, Freiburg (11./12.11.2010), presentation

Svoboda, H.; Sobek, D.; Michaelis, A.
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stoffs auf das Pressergebnis bei der uniaxialen Verdichtung von keramischen Granulaten
DKG-Jahrestagung 2010, Hermsdorf/Thüringen (22.-24.3.2010), presentation

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Thiele, S.; Sempf, K.; Jaenicke-Roeßler, K.; Berger, L.-M.; Spatzier, J.
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Tigges, B.; Lämmel, C.; Schneider, M.; Fürbeth, W.
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Toma, F.-L.; Scheitz, S.; Berger, L.-M.; Sauchuk, V.; Kusnezoff, M.
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Töpfer, J.; Kircheisen, R.
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Töpfer, J.; Kircheisen, R.
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3rd International Congress on Ceramics, Osaka (14.-18.11. 2010), presentation

Töpfer, J.; Mürbe, J.; Kracunovska, S.; Barth, S.; Pawlowski, B.; Rabe, T.
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Triebert, A.; Martin, H.-P.
Elektrische Kontaktierung von Keramiken für Hochtemperaturanwendungen
9. Internationales Kolloquium Hart- und Hochtemperaturlöten und Diffusionsschweißen – LÖT 2010, Aachen (15.-17.6.2010), presentation

Tröber, O.; Kahle, I.; Trentsch, S.; Richter, H.
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22nd German Zeolite Conference, München, (3.-5.3.2010), poster

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DKG-Jahrestagung 2010, Hermsdorf/Thüringen (22.-24.3.2010), poster

Voigt, I.
Ceramic membranes for gas upgrading processes
Workshop »Upgrading of biologically produced gases«, Herzogenrath (24.9.2010), presentation

Voigt, I.
Tailoring of membrane pore size and wettability of ceramic NF-membranes

for application in organic solvents
3rd International Organic Solvent Nanofiltration Conference, London (13.-15.9.2010), presentation

Voigt, I.; Kriegel, R.; Adler, W.; Sommer, E.
Vacuum driven oxygen separation with BSCF membranes
11th International Congress on Inorganic Membranes, Washington D.C. (17.-22.7.2010), poster

Voigtsberger, B.
Keramische Werkstoffe – Einführung und Eigenschaften und Anwendung ausgewählter technischer Keramikwerkstoffe
IHK-Schulung für technische Mitarbeiter PI Ceramic, Hermsdorf (29.9.-1.10.2010), presentation

Voigtsberger, B.; Reichel, U.
Advanced ceramic materials – History – Present – Prospects
4th International Seminar »Nanotechnolgy, Energy, Plasma, Lasers« – NEPL-2010, Tomsk (25.-31.10.2010), presentation

Voigtsberger, B.; Michaelis, A.
Keramische Technologien und Systeme als Innovationstreiber für High-Tech Produkte des 21ten Jahrhunderts
Vision Keramik 2010 – Integrierte Keramikforschung von der Idee bis zum Produkt, Hermsdorf (22.1.2010), presentation

Wätzig, K.
Transparente Mg-Al-Keramik: Durchsichtig wie Glas, hart wie Keramik
Barkhausen-Posterwettbewerb, Dresden (16.12.2010), poster

Weidmann, S. K.; Kremmer, K.; Schneider, M.; Fürbeth, W.
Imprägnierung poröser Anodisierschichten auf Aluminiumlegierungen durch Einbau oxidischer Nanopartikel
ZVO Oberflächentage, Berlin (22.-24.9.2010), presentation

Weyd, M.
Process integrated water and waste water treatment by ceramic membranes
IFAT Entsorga 2010, München (13.-17.9.2010), presentation

Weyd, M.; Hermann, K.; Kühnert, J.-T.; Tusel, E.; Brüschke, H.; Richter, H.; Voigt, I.
Ceramic membranes for the separation of glucose and the dewatering of ethanol
18th European Biomass Conference & Exhibition, Lyon (3.-7.5.2010), poster

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Dewatering of ethanol by hydrophilic zeolite membranes in vapour permeation at high temperatures
International Scientific Conference on Pervaporation and Vapor Permeation, Torun (18.-21.4.2010), presentation

Wufka, A.
Trattamento della biomassa all`ingresso del fermentatore: Il sistema IKTS
6. Info Biogas, Montichiari (21.10.2010), presentation

Zins, M.
Anwendungen und Lieferanten keramischer Hochleistungskomponenten
Keramische Hochleistungswerkstoffe Schulungsprogramm des Fraunhofer-Demonstrationszentrums AdvanCer, Block I: Werkstoffe und Verfahren, Dresden (10./11.3.2010), presentation

Zins, M.
Keramische Hochleistungswerkstoffe: Einsatzbereiche, Entwicklungstrends
DKG-Fortbildungsseminar – Entbinderung keramischer Formteile, Dresden (28./29.10.2010), presentation

Zins, M.
Keramische Werkstoffe und Anwendungen – Entwicklungstrends und -angebote
DKG-Fortbildungsseminar – Thermoplastische Formgebung von Technischer Keramik, Dresden (6./7.10.2010), presentation

Zschippang, E.; Klemm, H.; Sempf, K.; Guth, U.; Michaelis, A.
Elektrisch leitfähige Keramiken auf Basis von Si_3N_4
DKG-Jahrestagung 2010, Hermsdorf/Thüringen (22.-24.3.2010), presentation

TEACHING ACTIVITIES OF IKTS EMPLOYEES, PARTICIPATION IN BODIES AND TECHNICAL COMMITTEES

Teaching activities of IKTS employees

Dr. Barth, S.
Lecture
»Keramische Technologie«
Fachhochschule Jena, Fachbereich Scitec (WS10/11)

Dr. habil. Herrmann, M.
Lecture
»Principles of ceramic processing«
University of Witwatersrand, Johannesburg, Südafrika (10/2010)

Dipl.-Ing. Höhn, S.
Lecture
»Keramografie«
Im Rahmen der Lehrveranstaltung »Metallografie«
TU Dresden, Institut für Werkstoffwissenschaft (11.01.2010)

Dr. Jahn, M.
Lecture
»Chemische Verfahrenstechnik/Reaktionstechnik«
HTW Dresden, Chemieingenieurwesen (SS10)

Dr. Kriegel, R.
Lecture
»Keramische Verfahrenstechnik«
Fachhochschule Jena, Fachbereich Scitec (WS10/11)

Dr. Kusnezoff, M.
Lecture
»Funktionskeramik II«, Studiengang »Elektronik- und Sensormaterialien« (9. Semester)
TU Bergakademie Freiberg (WS10/11)

Prof. Dr. Michaelis, A.
Lecture and internship
»Keramische Werkstoffe«
TU Dresden, Institut für Werkstoffwissenschaft (WS09/10; WS10/11)

Prof. Dr. Michaelis, A.; Dr. Schönecker, A.; Dr. Kusnezoff, M.; Dr. Stelter, M.; Dr. Partsch, U.; Dr. Jahn, M.; Heddrich, M.
Lecture
»Keramische Funktionswerkstoffe«
TU Dresden, Institut für Werkstoffwissenschaft (SS10)

Dr. Rebenklau, L.
Kapitel: »Technologien der Dickschichttechnik« in der Vorlesungsreihe »Hybridtechnik«
TU Dresden, Fakultät Elektrotechnik und Informationstechnik (WS10/11)

Dr. Rebenklau, L.
Lecture »Dickschichttechnik« and »Multilayerkeramik« in der Vorlesung von Prof. Michaelis »Funktionskeramik«
TU Dresden, Institut für Werkstoffwissenschaft (SS10)

Dipl.-Ing. Svoboda, H.
Lecture
»Pulveraufbereitung und –konfektionierung« im Rahmen der Lehrveranstaltung »Keramische Werkstoffe« (12.11.2010)

Dr. Voigt, I.
Lecture
»Membranen - Theorie und Anwendung«
Friedrich-Schiller-Universität Jena, Chemisch-geowissenschaftliche Fakultät (WS10/11)

Dr. Voigt, I.
Lecture
»Keramische Verfahrenstechnik«
Fachhochschule Jena, Fachbereich Scitec (WS10/11)

Dr. Voigtsberger, B.
Lecture
»Keramische Verfahrenstechnik«
Fachhochschule Jena, Fachbereich Scitec (WS10/11)

Dr. Zins, M.
Lecture
»NE-Metalle /Keramik/Kunststoffe – Technische Keramik als Leichtbaustoff«
TU Dresden, Institut für Werkstoffwissenschaft (WS10/11)

Participation in bodies and technical committees

Bodies

Prof. Dr. Michaelis, A.
- »World Academy of Ceramics« WAC
- WAC Forum Komitee, Mitarbeit
- DKG-Vorstandsmitglied
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Koordinierung«
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Funktionskeramik«, Leitung
- DECHEMA-Arbeitsausschuss »Angewandte Anorganische Chemie«
- Fraunhofer-Allianz »Hochleistungskeramik«, Sprecher
- AGEF-Arbeitsgemeinschaft Elektrochemischer Forschungsinstitutionen e.V.
- DPG-Deutsche Physikalische Gesellschaft

- Institutsrat des IfWW, TU Dresden
- FZ Rossendorf, Vereinsmitglied
- Fa. Roth & Rau, Aufsichtsratsmitglied
- AiF Wissenschaftlicher Rat
- Solarvalley Mitteldeutschland e.V., Vorstand
- Beirat Arbeitskreis »Photovoltaik Silicon Saxony«
- Hochschulrat der Westsächsischen Hochschule Zwickau
- Dresdner Gesprächskreis
- NanoChem, BMBF, Gutachter
- Gutachterausschuss »Interne Programme« der Fraunhofer-Gesellschaft
- Lenkungsgremium Innovationszentrum Energieeffizienz TUD
- Beirat eZelleron GmbH

Dr. Richter, H.
- International Zeolite Association

Dr. Voigtsberger, B.
- DKG-Vorstandsmitglied
- DGM/DKG-Gemeinschaftsausschuss »Strategiekreis«
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Koordinierung«
- Verband der Wirtschaft Thüringens e.V., Ausschuss »Forschung und Innovation«
- Hochschulrat Fachhochschule Jena
- Wissenschaftlicher Beirat Jenoptik AG

Technical committees

Dr. Beckert, W.
- Fraunhofer-Allianz »Numerische Simulation von Produkten und Prozessen« NUSIM

Dipl.-Chem. Fischer, G.
- DKG-Fachausschuss 10 »Umwelttechnik«

Dr. Friedrich, H.
- DKG-Fachausschuss 10 »Umwelttechnik«, Vorsitz
- VDI/GVC-Fachausschuss »Partikelmesstechnik«
- VDI/GVC-Fachausschuss »Abfallwirtschaft und Wertstoffrückgewinnung«
- VDI/GET-Fachausschuss »Regenerative Energien«
- VDI-Bezirksverein Dresden, Arbeitskreis »Granulometrie«
- DWA-Fachkreis »Schlammbehandlung«
- Energieprojekt »Biogas« (NL)
- Fachverband »Biogas«

Dr. Fries, M.
- DGM/DKG-Arbeitskreis »Verarbeitungseigenschaften synthetischer keramischer Rohstoffe«, Leiter
- DKG-Fachausschuss »Verfahrenstechnik«

Dr. Gestrich, T.
- Gemeinschaftsausschuss »Pulvermetallurgie«, Expertenkreis »Sintern«
- GEFTA-Arbeitskreis »Thermophysik«

Dipl.-Ing. Gronde, B.
- Gemeinschaft »Thermisches Spritzen e.V.«
- DVS-Arbeitsgruppe »Thermisches Spritzen«

Dipl.-Ing. Jaenicke-Rößler, K.
- GEFTA-Arbeitskreis »Thermophysik«
- GEFTA-Arbeitskreis »Messunsicherheit von Thermodilatometern«

Dr. Kaltenborn, N.
- DKG-Arbeitskreis »Kohlenstoff«

Dr. Klemm, H.
- DKG-Arbeitskreis »Verstärkung keramischer Stoffe«
- DIN Normenausschuss »Materialprüfung NMP 291«

Dr. Krell, A.
- Associate Editor des »Journal of the American Ceramic Society«

Kunath, R.
- Arbeitskreis »Dresdner Informationsvermittler e.V.« I
- Arbeitskreis »Spezialbibliotheken«

Dr. Kusnezoff, M.
- DIN/VDE, Referat K 141, DKE Deutsche Komission, »Elektrotechnik Elektronik Informationstechnik«

Dr. Lenk, R.
- DKG-Expertenkreis »Keramikspritzguss«, Vorstandsvorsitzender
- Fraunhofer-Allianz »Hochleistungskeramik«, Geschäftsstelle

Dipl.-Ing. Ludwig, H.
- DGM-Fachausschuss »Biomaterialien«

Dr. Moritz, T.
- ENMAT »European Network of Materials Research Centres«, Sprecher
- Management Committee of COST action MP0701 »Nanocomposite Materials«
- DECHEMA-Fachausschuss »Nanotechnologie«

- DKG-Expertenkreis »Keramikspritzguss«

Dipl.-Phys. Mürbe, J.
- VDI-Bezirksverein Dresden, Arbeitskreis »Granulometrie«

Nake, K.
- DGM-Arbeitskreis »Härteprüfung und AWT«, Fachausschuss »FA-12«

Dr. Nebelung, M.
- VDI/GVC-Fachausschuss »Agglomerations- und Schüttguttechnik«
- VDI/GVC-Fachausschuss »Trocknungstechnik«

Dipl.-Ing. Pönicke, A.
- DVS-Ausschuss für Technik, Arbeitsgruppe W3 »Fügen von Metall, Keramik und Glas«

Dr. Potthoff, A.
- DGM/DKG-Arbeitskreis »Prozessbegleitende Prüfverfahren«
- DECHEMA/VCI-Arbeitskreis »Responsible Production and Use of Nanomaterials«
- Fraunhofer-Allianz »Nanotechnologie«

Dr. Rebenklau, L.
- VDI/VDE-GMM Fachausschuss 5.5 »Aufbau- und Verbindungstechnik«
- Ges. für Mikroelektronik, Mikro- und Feinwerktechnik

Dr. Reichel, U.
- DKG-Fachausschuss 6 »Werkstoffanwendungen«
- DKG-Arbeitskreis »Verarbeitungseigenschaften synthetischer keramischer Rohstoffe«

Dr. Richter, H.-J.
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Keramische Membranen«
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Biokeramik«

Dr. Richter, V.
- DECHEMA/VCI-Arbeitskreis »Responsible Production and Use of Nanomaterials«
- Fraunhofer-Allianz »Nanotechnologie«
- EPMA-Arbeitskreis »European Hard Materials Group«
- VDI-Fachausschuss »Schneidstoffanwendung
- DIN-Normenausschuss »Werkstofftechnologie«, AA »Hartmetalle«

Dr. Schilm, J.
- DGG-Fachausschuss 1 »Physik und Chemie des Glases«
- DKG/DGG-Arbeitskreis »Glasig-kristalline Multifunktionswerkstoffe«
- DVS-Arbeitskreis W3 »Löten von Metall, Keramik und Glas«

Dr. Schönecker, A.
- Beirat der Smart Material GmbH Dresden

Dipl.-Chem. Schubert, R.
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Polymerkeramik«

Dipl.-Phys. Sikora, R.
- DVS-Arbeitsgruppe »Keramik-Metall-Verbindungen«
- DVS-Arbeitsgruppe »Kleben von Glas und Keramik«

Dipl.-Ing. Stahn, M.
- VDI-Entwicklung, Konstruktion, Vertrieb

Dr. Stelter, M.
- Brennstoffzellen Initiative Sachsen e.V., Vorstand
- VDMA-Arbeitsgruppe »Brennstoffzellen«, Arbeitskreis »Industrienetzwerk«

Dipl.-Ing. Thiele, S.
- GTS-Gemeinschaft Thermisches Spritzen e.V.

Dr. Voigt, I.
- GVC-Fachausschuss »Produktionsintegrierte Wasser- und Abwassertechnik«
- ProcessNet-Arbeitsausschuss »Membrantechnik«
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Keramische Membranen«, Leiter
- DGM/DKG-Gemeinschaftsausschuss »Hochleistungskeramik«, Arbeitskreis »Koordinierung«

Dr. Zins, M.
- DKG-Koordinierungsgruppe »Strukturwerkstoffe Fachausschüsse«
- Fachausschuss »Pulvermetallurgie«
- DKG-Fachausschuss »Keramikanwendungen«
- Deutsche Messe AG, Fachmessebeirat »Industrial Supply«
- Messe München, Fachbeirat »Ceramitec«
- Institut für Prozess- und Anwendungstechnik Keramik, RWTH Aachen, Vorstand

Advisory boards for symposia and conferences

Prof. Dr. Michaelis, A.
- DECHEMA-Diskussionstagung »Anorganisch-Technische Chemie«, Frankfurt/Main (2010), organizing committee
- Vision Keramik 2010, Hermsdorf (22.1.2010)
- APNFM 2010 – Advanced Processing for Novel Functional Materials, Dresden
- DKG-Jahrestagung 2010 / Symposium Hochleistungskeramik DKG/DGM 2010, Hermsdorf/Thüringen (22.-24.3.2010)
- MATERIALICA Keramik Kongress München (2010)
- Symposium »Galvanik eine etablierte Technik innovativ angewendet«, IKTS Dresden (25./26.11.2010), organizer
- Materialforschungstag des MFD, Dresden (Nov/Dez 2010)
- Industrietag »Keramik in der motorischen Abgas-Nachbehandlung«, Dresden (23.9.2010), organizer
- DKG-Jahrestagung 2011, Saarbrücken (28.-30.3.2011)
- DECHEMA-Diskussionstagung »Anorganisch-Technische Chemie«, Frankfurt/Main (2011), organizing committee
- 10th CMCEE International Symposium on Ceramic Materials and Components for Energy and Environmental Applications, Dresden (20.-23.4.2012), organizing committee

Dipl.-Krist. Adler, J.
- Industrietag »Keramik in der motorischen Abgas-Nachbehandlung«, Dresden (23.9.2010), organizer

Dr. Gestrich, T.
- 29. Hagener Symposium Pulvermetallurgie »Formgebung: Chancen der Pulvermetallurgie», Hagen (25./26.11.2010), advisory board

Dr. Herrmann, M.
- DKG-Fortbildungsseminar »Entbinderung keramischer Formteile«, IKTS Dresden (28./29.10.2010), organizer

Dr. Lenk, R.
- DKG-Symposium »Plastische und Thermoplastische Formgebung«, Dresden (6./7.10.2010), organizer
- Keramische Hochleistungswerkstoffe – Schulungsprogramm des Fraunhofer-Demonstrationszentrums AdvanCer, Block I: Werkstoffe und Verfahren, IKTS Dresden (10./11.3.2010), organizer

Dr. Moritz, T.
- DKG-Symposium »Plastische und Thermoplastische Formgebung«, Dresden (6./7.10.2010), organizer
- Powder Metallurgy World Congress & Exhibition – WORLD PM2010, Florence, Italy (10.-14.10.2010), organizing committee

Dr. Nebelung, M.
- DKG-Jahrestagung 2010/ Symposium Hochleistungskeramik DKG/DGM 2010, Hermsdorf/Thüringen (22.-24.3.2010)

Dr. Fries, M.
- 15. DKG-Fortbildungsseminar »Technologische Grundlagen der Granulierung und Granulatverarbeitung«, IKTS Dresden/TU Dresden (22./23.4.2010), organizer
- DKG-Symposium »Simulation und Modellierung von Fertigungsprozessen«, Erlangen (30.11.-1.12.2010), advisory board

Dr. Reichel, U.
- 4th International Seminar »Nanotechnolgy, Energy, Plasma, Lasers – NEPL 2010, Tomsk, (25.-31.10.2010)

Dr. Richter, V.
- 10th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCEE, Dresden (20.-23.4.2012), organizing committee

Dr. Schneider, M.
- International Workshop on Impedance Spectroscopy, Chemnitz (13.-15.10.2010), advisory board
- Symposium »Galvanik eine etablierte Technik innovativ angewendet«, IKTS Dresden (25./26.11.2010), organizer

Dr. Voigt, I.
- DKG-Jahrestagung 2010/ Symposium Hochleistungskeramik DKG/DGM 2010, Hermsdorf/Thüringen (22.-24.3.2010)
- International Scientific Committee of the International Conference on Inor-

ganic Membranes – ICIM, Washington D.C. (17.-22.7.2010)
- Aachener Membran Kolloquium, Aachen (27./28.10.2010), scientific committee

Dr. Voigtsberger; B.
- DKG-Jahrestagung 2010/ Symposium Hochleistungskeramik DKG/DGM 2010, Hermsdorf/Thüringen (22.-24.3.2010)

Dr. Zins, M.
- Hannover Messe – Tag der Technischen Keramik, Werkstoff-Forum, Hannover (23.4.2010), advisory board

Dissertations

Baumann, Andreas
Pulverspritzgießen von Metall-Keramik-Verbunden
Dissertation 2010
IKTS Dresden – TU Dresden, Fakultät Maschienwesen, Institut Verfahrens- und Energietechnik

Kaltenborn, Nadine
Nanopröse Kohlenstoffmembranen auf asymmetrisch aufgebauten porösen keramischen Supporten für die Gastrennung
Dissertation 2010
IKTS Hermsdorf – TU Bergakademie Freiberg

Nawka, Stefan
Untersuchung des Wachstumsverhaltens und der Bandlücke von ALD-hafniumbasierten Oxidschichten mittels winkelauflösender XPS
Dissertation 2010
IKTS Dresden – TU Dresden, Fakultät Elektrotechnik und Informationstechnik

Paepcke, Anne
Untersuchungen des Hochtemperaturbrennstoffzellenstapels unter realen Betriebsbedingungen durch Finite Elemente Modellierung
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Kretzschmann, Lisett
Untersuchung des Herstellungsprozesses von piezokeramischen Vollfasern mit Porositäten kleiner fünf Prozent nach dem Polysulfonverfahren
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Pilz, Sirko
Untersuchung instationärer Prozesse in anodisch erzeugten dünnen Ventilmetalloxidschichten mit hoher lateraler und zeitlicher Auflösung
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Einfluss des Energieeintrages auf die Stabilisierung hochkonzentrierter Böhmit-Suspensionen
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Weder, Aniko
Aufbau und Betrieb eines Reformerteststandes zur Untersuchung der Synthesegaserzeugung mittels partieller Oxidation von Ethanol
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Zschornack, Daniel
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EVENTS AND TRADE FAIRS 2011

Conferences

Dutch-German Seminar on Energy Innovations
April 13-14, 2011

ISPA 2011 – International Symposium on Piezocomposite Applications
September 22-23, 2011, Volkswagen's Transparent Factory

Events

Long Night of Sciences
July 1, 2012

Fraunhofer Talent School
November 4-6, 2010

Seminars/workshops

DKG seminars

Technological fundamentals of granulation and granule processing
April 14-15, 2011

Thermoplastic shape-forming of advanced ceramics – technology and training
October 5-6, 2011

Debinding of ceramic bodies
October 6-7, 2011

Spray drying of ceramic suspensions
November 2011

Please find further information at www.dkg.de.

Seminars of the Fraunhofer Demonstration Center AdvanCer

Introduction into Advanced Ceramics

Part I: Materials, technology
Dresden, March 9-10, 2011

Part II: Machining
Berlin, May 4-5, 2011

Part III: Construction, testing
Freiburg, November 10-11, 2011

Please find further information at www.advancer.fraunhofer.de

Participation in trade fairs

Enertec/Terratec
Leipzig, January 25-27, 2011

nano tech
Tokyo, February 16-18, 2011

Innovation Materials and Technologies (Technical Ceramics Exhibition, Specialized Salon)
Moscow, March 1-3, 2011

Z Zuliefermesse
Leipzig, March 1-4, 2011

IDS Internationale Dental-Schau
Cologne, March 22-26, 2011

Hannover-Messe
Hanover, April 4-8, 2011

Energy Harvesting and Storage
Orlando, April 25-29, 2011

SMT/HYBRID/PACKAGING
Nuremberg, May 3-5, 2011

Internationale Biomassekonferenz Leipzig
Leipzig, May 24-25, 2011

Sensor + Test
Nuremberg, June 7-9, 2011

EURO PM
Barcelona, October 9-12, 2011

Biotechnica
Hanover, October 11-13, 2011

POWTECH
Nuremberg, October 11-13, 2011

Materialica
Munich, October 25-27, 2011

Agritechnica
Hanover, November 13-19, 2011

Productronica
Munich, November 15-18, 2011

Hagener Symposium
Hagen, November 24-25, 2011

EuroMold
Frankfurt a. M., November 29-December 2, 2011

INFORMATION SERVICE

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Information material

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Fraunhofer IKTS in Profile
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Research field
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Smart Materials and Systems
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HOW TO REACH US

How to reach us in Dresden

by car

- At the three-way highway intersection "Dresden West" exit Autobahn A4 onto Autobahn A17 in direction "Prag" (Prague)
- Exit at "Dresden Prohlis" (Exit 4)
- Continue 2 km along the secondary road in direction "Zentrum" (City Center)
- At the end of the secondary road (Kaufmarkt store will be on the right side), go through light and continue straight ahead along Langer Weg in direction "Prohlis" (IHK)
- After 1 km, turn left onto Mügelner Strasse
- Turn right at the next traffic light onto Moränenende
- Continue under the train tracks and turn left at next traffic light onto Breitscheidstrasse
- Continue 3 km (the road name will change to An der Rennbahn and then to Winterbergstrasse)
- Fraunhofer IKTS is on the left side of the road (Winterbergstrasse 28) across from the NETTO grocery store

by train

- From Dresden main railway station take train S1 (direction Bad Schandau) or train S2 (direction Pirna) to stop "Haltepunkt Strehlen"
- Change to bus line 61 (direction Weißig/Fernsehturm) or 85 (direction Striesen) and exit at "Grunaer Weg"

by plane

- From Airport Dresden-Klotzsche take a taxi to Winterbergstrasse 28 (distance is approximately 7 miles or 10 km)
- Or use suburban train S2 (underground train station) to stop "Haltepunkt Strehlen"
- Change to bus line 61 (direction Weißig/Fernsehturm) or 85 (direction Striesen) and exit at "Grunaer Weg"

How to reach us in Hermsdorf

by car

- From exit Bad Klosterlausnitz/Hermsdorf (A9, exit 23) follow the road to Hermsdorf, go straight ahead up to the roundabout
- Turn right to Robert-Friese-Strasse
- The 4th turning to the right after the roundabout is Michael-Faraday-Strasse
- Fraunhofer IKTS is on the left side

- From exit Hermsdorf-Ost (A4, exit 56a) follow the road to Hermsdorf
- At Regensburger Strasse turn left and go straight ahead up to the roundabout
- Turn off to right at the roundabout and follow Am Globus
- After about 1km turn off left to Michael-Faraday-Strasse
- Fraunhofer IKTS is on the left side

by train

- From Hermsdorf-Klosterlausnitz main station turn right and walk in the direction of the railway bridge
- Walk straight into Keramikerstrasse (do not cross the bridge)
- Pass the porcelain factory and the Hermsdorf town house
- Turn right, pass the roundabout and walk straight into Robert-Friese-Strasse
- After 600 m turn right into Michael-Faraday-Strasse
- Find Fraunhofer IKTS after 20 m

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