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FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

ANNUAL REPORT 2013 2014

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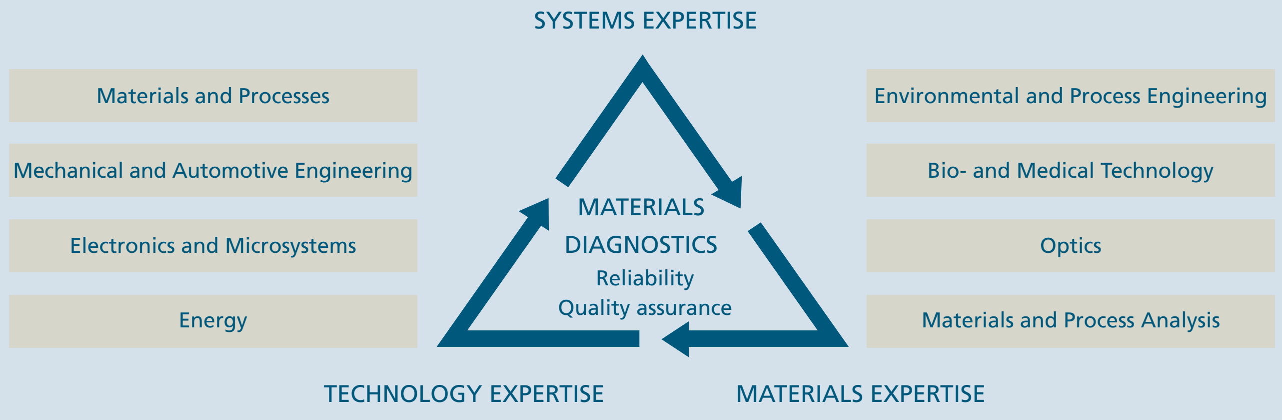
FOREWORD

Dear friends of IKTS,

It is with pleasure that I announce the expansion of the IKTS family: since January 1st, 2014 the former Dresden branch of the Fraunhofer IZFP (Institute for Non-Destructive Testing) with its 125 employees belongs to the IKTS. This union ideally complements our core competencies. So far, our activities have already covered the entire value chain ranging from the **ceramic material** to the **system** and end product, particularly including all **ceramic technologies and manufacturing processes**. This competence triangle is now completed by the competence of **material and process diagnostics**. Accordingly, we named our new branch IKTS-MD (Materials Diagnostics). IKTS-MD has outstanding expertise in the fields of nanoanalysis, test and diagnosis methods and is now ideally supplemented by our materials and technology knowledge. In the future, we will increasingly address the development of methods for in-line quality assurance, condition monitoring, and evaluation of products, processes, structures and biological objects. It is these fields, in particular, in which we identified an increasing need of our industry partners, and we are looking forward to new project approaches. However, aside from the synergies there are also significant economic challenges which we will have to overcome within the three year integration process.

Another highlight of the year is shown on the cover of this annual report. On May 7, 2014 our spectacular new building in Hermsdorf was inaugurated. Already in the beginning of 2014, we have moved into the new building and started work. Numerous well-equipped laboratories and pilot-scale facilities on more than 5000 square meters are now available for research activities in the field of membrane technology for liquid filtration and gas separation, as well as oxide ceramics. With this building we have also significantly contributed to the establishment of the Greentech Campus Hermsdorf where new companies working in the field of environmental technology are to settle in the future. Our research activities in the field of medical technology, as well as storage and tape casting technologies also benefited from these developments. Thus, we established a Competence Center of Tape Casting Technology, as well as new laboratories and pilot plants to strengthen our activities in the research field of high-temperature sodium batteries.

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



Of course, developments in Dresden are certainly no less exciting. In the reporting period we moved into our third building complex where approx. 2500 square meters of laboratories, pilot plants and office areas are available. In this building we bundled our activities in the field of injection molding, Li-ion batteries as well as molten carbonate fuel cells (MCFC), and we will establish a Competence Center of Printing and Thick-Film Technology. Together with the Competence Center of Tape Casting Technology mentioned above and our multilayer MEMS production lines we have already taken important measures to expand the topic of additive manufacturing in which we have already been active for many years. Additive manufacturing is a strategic focal point at Fraunhofer IKTS.

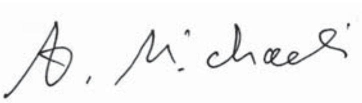
We also strengthened our international business activities by establishing the Fraunhofer Center for Energy Innovations CEI in Connecticut, USA. With the provision of our competencies in the field of energy and environmental technologies, we intend to gain access to the US market. The Fraunhofer CEI was established in close cooperation with the prestigious University of Connecticut in Storrs and is headed by Professor Prabhakar Singh. Thus, we mutually benefit from each other's know-how. The center is financed in two thirds by US and in one third by German funds.

In summary, we expanded the infrastructure in our competency fields of advanced ceramics and materials diagnostics. This was only possible due to the great support from the German Federal Ministries BMBF and BMWI. My special thanks go to the Saxon and Thuringian ministries SMWK, SMWA, TMBK and TMWAT for their excellent support from which – as stated in our mission – our industry partners will benefit. Once again, I invite you to make use of our competencies. We see ourselves as a provider of research services for industry partners and are available for future collaboration.

Last but not least, I would, once again, like to thank our IKTS staff for its great and very successful commitment. As one team, we have reached top results in 2013: we could significantly increase our industry revenues to 14.4 million euros (corresponds to an increase of 1.8 million euros, industrial revenues amount to 40 percent). The current business year has also started well, and we aim for an overall operating budget of more than 52 million euros.

I hope you enjoy reading the new annual report. In order to give you a better orientation we restructured the report in line with our eight business divisions. Our business units and the aforementioned competence triangle are shown in Figure 1. I hope that the report helps to initiate new projects. The entire IKTS team is looking forward to cooperating with you.

Yours,



Alexander Michaelis

May 2014

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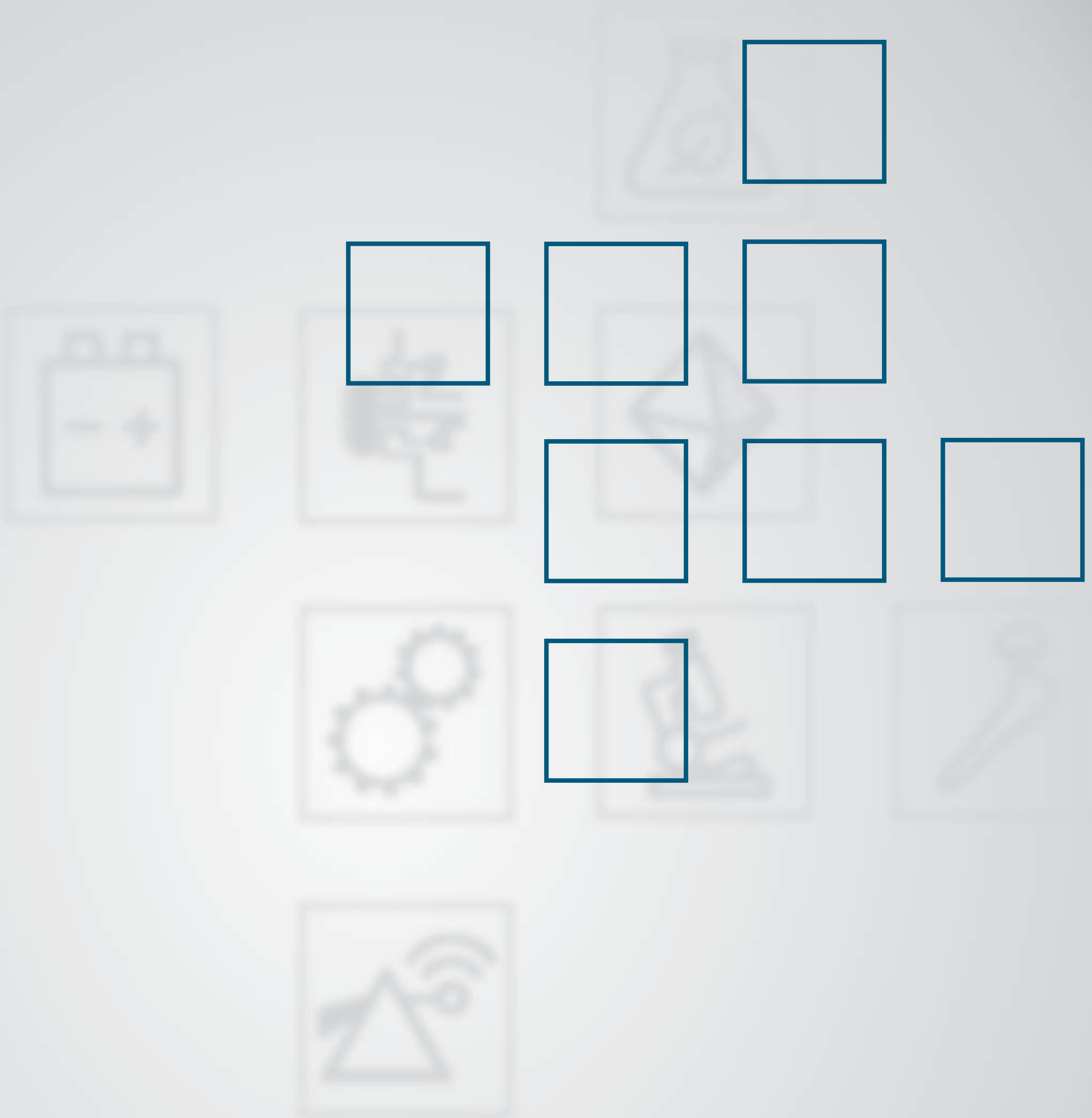
FRAUNHOFER IKTS PROFILE



PORTRAIT

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS covers the field of advanced ceramics from basic preliminary research through to the entire range of applications. Superbly equipped laboratories and technical facilities covering 30,000 m^2 of useable space have been set up for this purpose at the sites in Dresden-Gruna, Dresden-Klotzsche, and Hermsdorf.

Based on comprehensive materials expertise in advanced ceramic materials, the development covers the entire value creation chain, all the way to prototype production. Fraunhofer IKTS is distinguished by its multiple areas of expertise: The triad of materials know-how, production technology know-how and systems integration know-how is enhanced by the highest level of materials and process analytics. Chemists, physicists, materials scientists and engineers work together on an interdisciplinary basis at IKTS, with the support of highly skilled technicians.

Besides the ceramic manufacturers, the focus is specifically placed on existing and future users of ceramics as project partners and customers. Fraunhofer IKTS operates in eight market-oriented divisions in order to demonstrate and qualify ceramic technologies and components for new industries, new product ideas, new markets outside the traditional areas. These include the conventional Materials and Processes, Mechanical and Automotive Engineering, Electronics and Microsystems, Energy, Environmental and Process Engineering, Bio- and Medical Technology, Optics as well as Materials and Process Analysis. The Institute is therefore available as a competent consulting partner and starting point for all ceramics-related issues: a real "one-stop shop" for ceramics.

Among our unique areas of expertise, we offer:

End-to-end production lines: from starting materials to prototypes

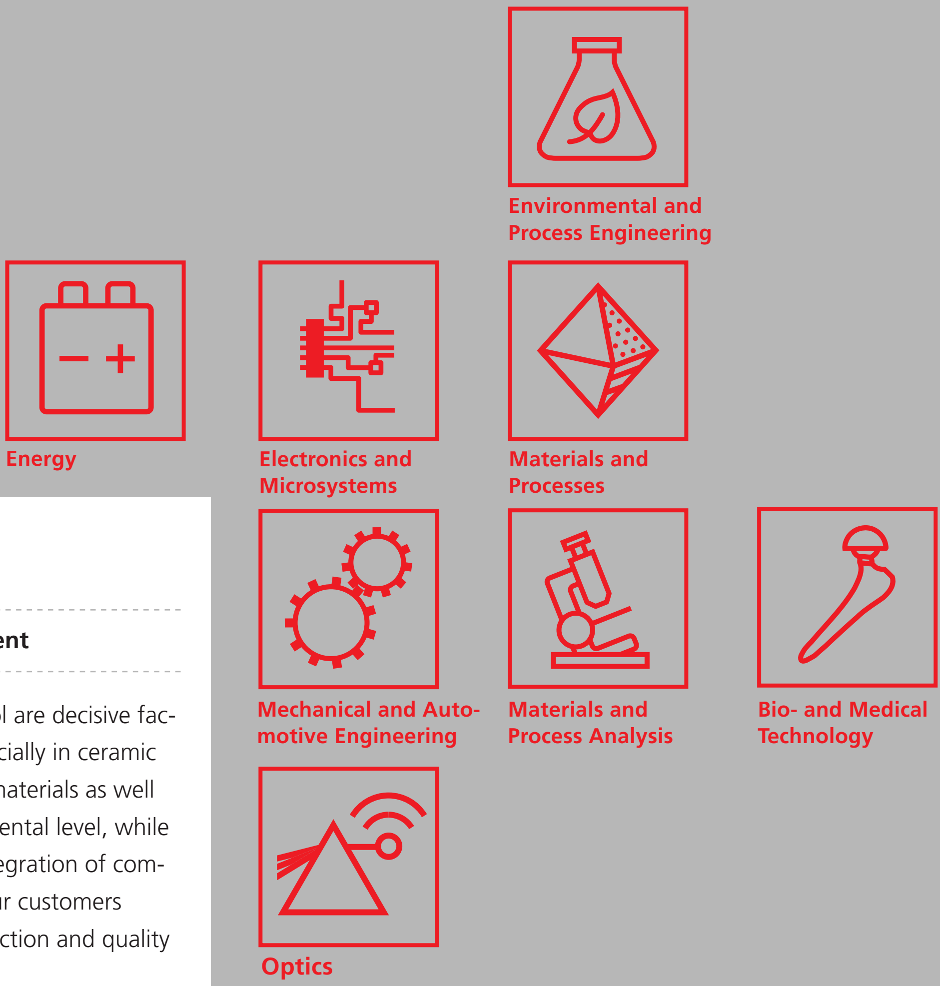
For any class of ceramic materials, we have access to all the standard processes of raw materials preparation, forming, heat treatment and finish processing. Where it makes sense, the Institute can even conduct phase synthesis. In functional ceramics, we hold a particular core competency in paste and film technology. Multiple clean rooms and low-contamination production areas are kept at the ready, among other things, for multilayer ceramics and highly purified oxide ceramics lines of technology.

Multi-scale development

Fraunhofer IKTS can convert developments from the lab scale into the technical scale. There is industrially suited equipment and machinery of the latest designs available for all relevant lines of technology, in order for partners and customers to realize the prototypes and pilot-production series needed for market launch, to develop production processes, and to implement quality processes. Thus, residual cost risks and time to market can be minimized.

Synergies between materials and technologies

The combination of differing technology platforms, of functional and structural ceramics for example, allows for multifunctional components and systems that intelligently exploit ceramic properties. This enables the production of innovative products with significantly added value at low cost.



Competent analysis and quality assessment

High-performance analysis and quality control are decisive factors for market acceptance of products, especially in ceramic production processes. Since we understand materials as well as ceramic production processes at a fundamental level, while at the same time master the drafting and integration of complex physical testing systems, we can offer our customers unique solutions for materials issues in production and quality monitoring.

Network creator

We are currently associated with over 450 national and international partners in our ongoing projects. In addition, Fraunhofer IKTS is active in numerous alliances and networks. Within the Fraunhofer-Gesellschaft, for example, we work with the Fraunhofer Group for Materials and Components. Furthermore, Fraunhofer IKTS serves as the spokesperson for the Fraunhofer AdvanCer Alliance, which consists of four institutes specialized in ceramics. We are in a position to support the development of networks that are needed to develop successful processes, and also to convey and to integrate expertise that goes beyond our own abilities. Our efforts on the front lines of research are based on a wealth of experience and knowledge acquired over many years, which is geared toward our partners´ interests.

Standardized management for sustainable quality assurance

Quality, traceability, transparency and sustainability: to us, these are our most important tools for setting ourselves apart from the competition. The IKTS therefore administers a standardized management system per DIN EN ISO 9001, as well as an environmental management system in accordance with DIN EN ISO 14001. Furthermore, each branch of the institute is certified according to additional guidelines, including the German Medical Devices Act, and is regularly subjected to a variety of industrial audits.

CORE COMPETENCIES

MATERIALS / SEMI-FINISHED PARTS

STRUCTURAL CERAMICS

Oxide ceramics

Non-oxide ceramics

Hard metals and cermets

Powders and suspensions

Polymer ceramics

Fiber composites

Composite materials

Ceramic foams

FUNCTIONAL CERAMICS

Non-conducting materials

Dielectrics

Semiconductors

Ion conductors

Magnets

Pastes and tapes

Solders, brazes and glass sealings

Precursor-based inks and nanoinks

Composites

ENVIRONMENTAL AND PROCESS TECHNOLOGY

Substrates
- Granulates
- Plates
- Tubes
- Capillaries
- Hollow fibers
- Honeycombs
- Foams

Membranes and filters
- Oxides, non-oxides
- Zeolites, carbon
- MOF, ZIF, composites
- Ion and mixed conductors

Catalysts
- Oxides
- Metals, CNT

RAW MATERIAL, PROCESS ANALYSIS AND MATERIALS DIAGNOSTICS

Analysis and evaluation of raw materials
- Analysis of particles, suspensions and granulates
- Chemical analysis

In-process characterization in ceramic technology
- Characterization
- Process simulation and design
- Quality management

Characterized materials
- Steel, non-ferrous metals
- Ceramics, concrete
- Materials of semiconductor industry
- Plastics, composite materials (GFRP and CFRP)
- Biomaterials and tissues

Process design, process monitoring

TECHNOLOGY

Powder technology

Shaping

Heat treatment and sintering

Final machining

Precursor technology

Fiber technology

Additive manufacturing

Pilot production and upscaling

Coating technology

Joining technology

Thick-film technology

Multilayer
- HTCC, LTCC

Aerosol and inkjet printing

Thin-film technology

Electrochemical machining

Galvanics

Material separation
- Filtration
- Pervaporation
- Vapor permeation
- Gas separation
- Membrane extraction

Catalysis

Biomass technology
- Preparation
- Conversion

Photocatalysis

Chemical process engineering

COMPONENTS / SYSTEMS

Component design

Prototype production

Wear-resistant components

Tools

Optical components

Heating systems

Medical device technology and implants

Filters

System definition and plant development

Modeling and simulation

Design and prototype production

Validation/CE marking

Test stand construction

Support in field tests

Samples and prototypes
- Membranes, filters
- Membrane modules
- Membrane plants

Filtration tests
- Laboratory, pilot, field
- Piloting

Modeling and simulation
- Material transport
- Heat transport
- Reaction

Reactor development

Plant design

Material and component characterization
- Microstructure and phases
- Mechanical and physical properties
- High-temperature properties
- Corrosion

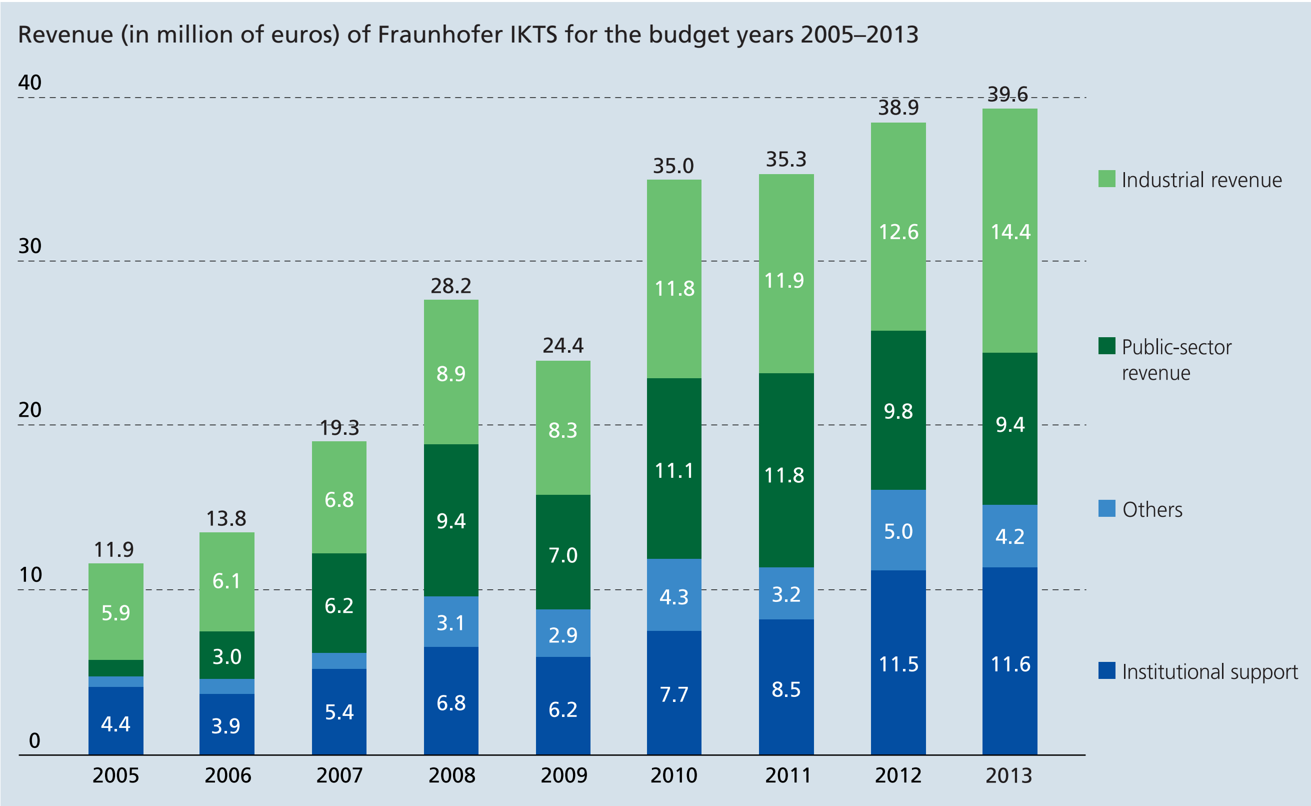
Component and system behavior
- Damage analysis
- Failure mechanisms
- Measurement and simulation of component behavior
- Testing in accordance with certified and non-certified standards

Technologies
- Micro and nanoanalytics
- Ultrasonic testing
- High-frequency eddy current
- Optical methods
- X-ray methods

Components, systems and services
- Sensors and sensor networks
- Testing heads and systems
- Structural health monitoring
- Data analysis and simulation
- Biomedical sensor systems
- Testing in accordance with certified and non-certified standards

Component behavior, reliability analysis, lifetime and quality management, calibration

FRAUNHOFER IKTS IN FIGURES



Operating budget and revenues

The operating budget of Fraunhofer IKTS has increased by approx. 0.7 million euros to a total of 36.1 million euros: 25.7 million euros fall to the Dresden branch, and 10.4 million euros to the Hermsdorf branch. We achieved further synergies by connecting both branches. Furthermore, 3.5 million euros were invested in equipment. Therefore, the total operating budget amounts to 39.6 million euros. Additionally, extensive building works have been carried out in both branches associated with further investment for initial installation.

In total, we have earned 28 million euros in external funds. We are delighted to report that we were able to increase industry revenues to 14.4 million euros. The Hermsdorf branch contributed to this success with revenues of 5.5 million euros that compared to the previous year have been increased by 0.92 million euros. In Dresden the industry revenues have increased by 0.88 million euros reaching a new record of 8.9 million euros. Both branches reached a share of 39.9 % of industry revenues showcasing once again the importance of the institute for manufacturers and users of advanced ceramics. The industry revenue increase compensates the slight decrease in revenues from EU projects which amounted to one million euros.

Staff development

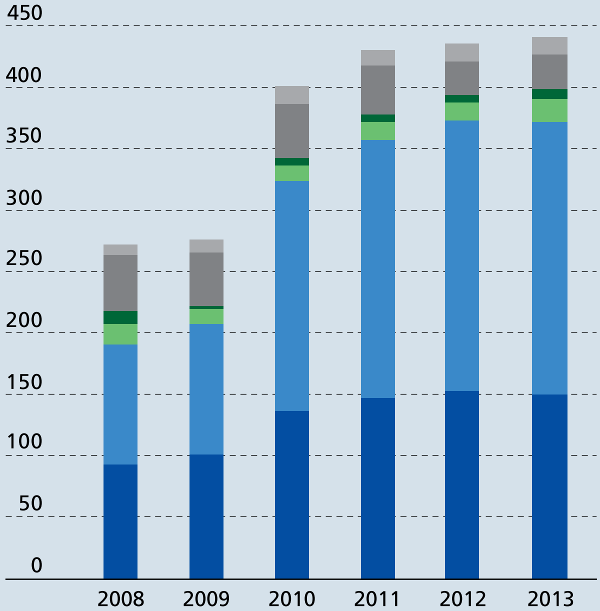
Last year was marked by a consolidation of human resource capacity creating four new full-time positions. In total, we now have 442 full-time positions. Many of these jobs are part-time jobs so that we have a significantly higher number of employees. In total, we have 517 employees: 368 in Dresden and 148 in Hermsdorf. Many of our student workers stay on at Fraunhofer IKTS to write their PhD theses. Exchange of staff between both sites is increasing. Additionally, due to the foundation of Fraunhofer CEI, IKTS employees now have the opportunity to work in the USA. This is another element in career development for PhD students and permanent staff.
The cooperation with the chair of the IfWW, Institute for Materials Science at TU Dresden, continues to be an essential part of our staff recruitment. Currently, 60 PhD theses are being supervised.

For long-term personal recruiting, Fraunhofer IKTS also offers apprenticeships within the institute's administration. An extension of this apprenticeship program is planned in IT management, as well as press and public relations in 2014/2015.

Expansion of the research basis

Moving into the new buildings in 2013 and 2014, the research options of Fraunhofer IKTS were extended. The new laboratories and offices contribute to the optimization of research at both sites. For example the Competence Center of Injection Molding including micro and two-component injection molding has been successfully established. Furthermore, additive manufacturing technologies are being introduced to complement the shaping technologies. Fraunhofer IKTS has continued its investment in equipment for raw material and powder preparation as well as coating of components, granules and fibers. Therefore, we can provide new composite materials

Personnel developments at Fraunhofer IKTS
Number of employees 2008–2013, full-time equivalents
Personnel structure on December 31 of each year



	8	9	15	13	16	14
	47	45	43	40	27	28
	10	2	6	6	5	8
	17	13	13	14	15	19
	97	106	187	211	221	223
	94	101	137	147	154	150
=	**273**	**276**	**401**	**431**	**438**	**442**

Apprentices
Student workers, trainees, undergraduate students
Part-time and contract workers
PhD candidates
Employees with university degrees and technicians
Scientists

including adjusted binder systems, optimized processing conditions, as well as perfect debinding and sintering methods.

At the Hermsdorf site, a local competence for energy storage systems has been established by a research group funded by the Thuringian Ministry of Economy, Labour and Technology (TMWAT). Here, different technologies are developed including, for example, stationary batteries based on sodium beta aluminate (cerenergy®) and metal/air batteries. TMWAT and the Fraunhofer-Gesellschaft have supported the industrialization of this technology by funding the equipment for a battery pilot production which is currently being established. In the field of sodium high-temperature batteries, in particular, Fraunhofer IKTS is considered to be a leading player in Germany resulting in many inquiries from the industry.

1 *Institute management of Fraunhofer IKTS, f.l.t.r.: Prof. Michael Stelter, Dr. Christian Wunderlich, Prof. Alexander Michaelis, Dr. Michael Zins, Dr. Ingolf Voigt.*

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Deputy Institute Director/ Head of Administration
Dr. Michael Zins

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Dr. Christian Wunderlich

Marketing and Strategy
Prof. Dr. Michael Stelter
Dr. Bärbel Voigtsberger

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Nonoxide Ceramics
Dipl.-Krist. Jörg Adler

Precursor-Derived Ceramics and Composites
Dr. Isabel Kinski

Processes and Components
Dr. Hagen Klemm

Environmental and Process Engineering

Nanoporous Membranes
Dr. Hannes Richter

High-Temperature Separation and Catalysis
Dr. Ralf Kriegel

Biomass Technologies and Membrane Process Technology
Dr. Burkhardt Faßauer

Chemical Engineering and Electrochemistry
Dr. Matthias Jahn

Sintering and Characterization
Dr. habil. Mathias Herrmann

Energy Systems

Materials and Components
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System Integration and Technology Transfer
Dr. Roland Weidl

Smart Microsystems

Smart Materials and Systems
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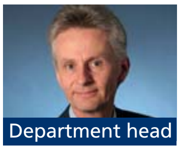

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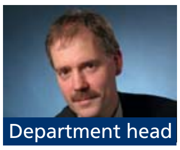

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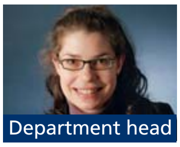

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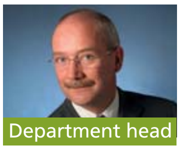

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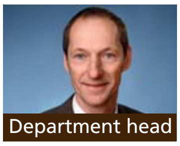

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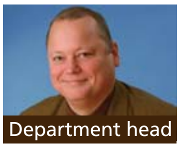

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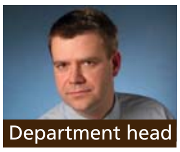

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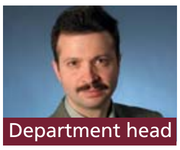

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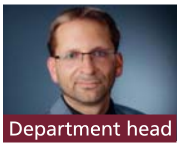

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Smart Materials and Systems
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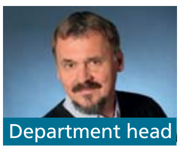

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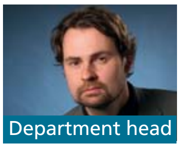

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FRAUNHOFER IKTS PROFILE

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 the board of trustees

Dr. J. Damasky
Board member of Webasto AG, Stockdorf

Dipl.-Ing. R. Fetter
Thuringian Ministry of Education, Science and Culture, Erfurt

Dr. habil. M. Gude
Thuringian Ministry of Economy, Labour and Technology
Head of department 5 – Energy Politics, Technology and Research Funding, Erfurt

A. Heller
Landrat of the Saale-Holzland region

Prof. Dr. C. Kaps
Bauhaus University Weimar, Chair of Building Chemistry

A. Krey
CEO of State Development Corporation of Thuringia, Erfurt

Dr. R. Lenk
CeramTec GmbH, Plochingen
Head of Central Development Department

Dr. C. Lesniak
ESK Ceramics GmbH & Co. KG, Kempten
Vice president Technology and Innovation

Dr. H.-H. Matthias
Managing director of Tridelta GmbH, Hermsdorf

Dr. R. Metzler
Managing director of Rauschert GmbH, Judenbach-Heinersdorf

Dipl.-Ing. P. G. Nothnagel
Managing director of Saxony Economic Development Corporation (WFS), Dresden

Dipl.-Ing. M. Philipps
Endress+Hauser GmbH & Co. KG, Maulburg
Head of business sector Sensor Technology

Dr.-Ing. W. Rossner
Siemens AG, München
Head of Central Department Technology, Ceramics

Dr. K.-H. Stegemann
X-FAB Dresden GmbH & Co. KG
Manager Business Development

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

MR C. Zimmer-Conrad
Saxon Ministry of Science and the Fine Arts, Dresden
Head of Technology Policy and Technology Funding Department

Newly appointed:

Dr. W. Köck
Executive Director of PLANSEE SE, Reutte

Dr. Peter Heilmann
Manager of arxes Information Design Berlin GmbH

Dr. Dirk Stenkamp
Board of Management of TÜV Nord AG, Hannover

THE FRAUNHOFER-GESELLSCHAFT

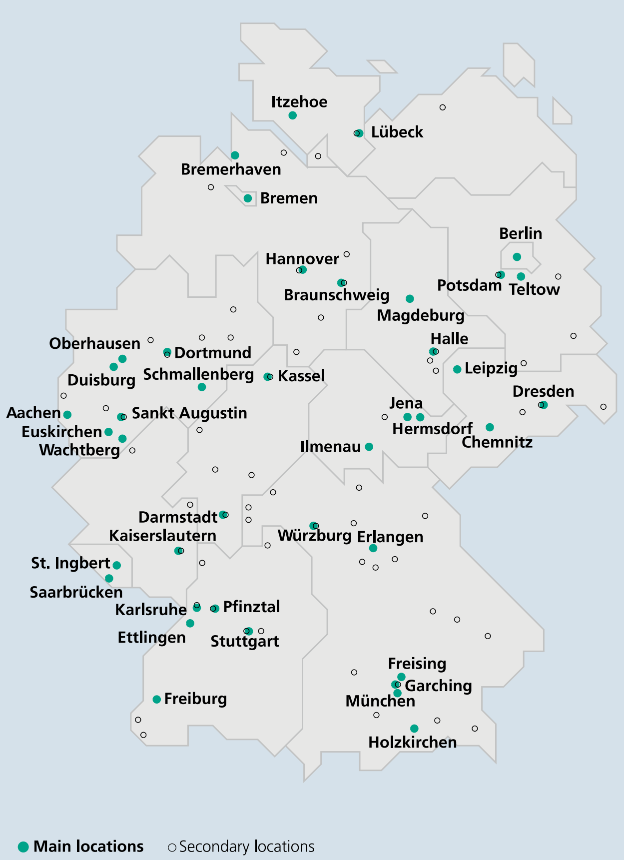
Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual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

At present, the Fraunhofer-Gesellschaft maintains 67 institutes and research units. The majority of the more than 23,000 staff are qualified scientists and engineers, who work with an annual research budget of 2 billion euros. Of this sum, more than 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and *Länder* governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the 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.

EVENTS AND HIGHLIGHTS

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April 17 and 18, 2013

Third nano4water workshop

Since its foundation in 2008, the Nano4water cluster has become a central contact point for EU research projects in the field of nanobased water treatment technologies. The third nano4water workshop themed Nano- and Membrane-Based Systems for Water Treatment was held at Fraunhofer IKTS on April 17 and 18, 2013. 90 participants from 18 countries accepted the invitation of the research cluster in order to catch up on current research results. In addition to the exchange of experiences, the meeting focused on the exploitation of synergies and the commercialization of new membrane and filter technologies.

July 15, 2013

Opening of the Center for Energy and Environmental Energy CEEC in Jena

Christoph Matschi, the Thuringian State Minister for Education, Science and Culture, and Professor Jens Goebel, chief executive of the Ernst Abbe Foundation, signed a financing agreement for the new Center for Energy and Environmental Energy CEEC in Jena on July 15, 2013. The CEEC is operated jointly by the Friedrich Schiller University Jena and the Fraunhofer IKTS. Construction work started in the spring of 2014. In the future, 20 research groups will work on an area of 1200 square meters focusing on energy storage and energy efficiency.

July 25, 2013

Fraunhofer Center for Energy Innovation CEI established in the USA

On July 25, 2013, the Fraunhofer IKTS, the State of Connecticut's Department of Energy and Environmental Protection DEEP and the University of Connecticut UConn established the Fraunhofer Center for Energy Innovation CEI, making it the seventh Fraunhofer USA research center. The mission of the Fraunhofer Center for Energy Innovation CEI at the University of Connecticut is to develop and commercialize advanced technologies related to energy storage, fuel cells and water power utilization through contract research.

1 The Dresden Kreuzchor starting its tour at the Fraunhofer Institute Center Dresden.

2 Participants of the nano4water workshop visiting the laboratories and pilot plants of Fraunhofer IKTS.

3 Governor Dannel P. Malloy proclaims July 25th to be Fraunhofer Day in the State of Connecticut (source: Peter Morenus/UConn).

August 21, 2013

MUW SCREENTEC GmbH and Fraunhofer IKTS jointly develop innovative energy storage technologies

On August 21, 2013, MUW SCREENTEC GmbH received funding in the amount of 1.2 million euros for a joint project with Fraunhofer IKTS. The research project is funded through the Thuringian technology development program for individual companies. Until the end of 2014, MUS SCREENEC will develop a catalytic membrane reactor for power-to-gas strategies. Fraunhofer IKTS contributes its know-how in the field of ceramic membranes for material separation as well as catalysts for heterogeneous catalysis. MUW SCREENTEC GmbH has long standing experience in hydrogen generation as well as tool manufacturing and mechanical engineering for solar and hydrogen technology.

September 18, 2013

Fraunhofer Smart Materials Industry Day

On September 18, 2013, 70 participants and exhibitors with both industry and research backgrounds discussed various potentials of smart materials for modern products and production processes during the Fraunhofer Smart Materials Industry Day in Dresden. It was the aim of the conference to bring together regional companies and institutions working in the field of smart materials, and to discuss application and marketing potentials of intelligent materials for different industry sectors. The event was sponsored by the Saxony Economic Development Corporation (WFS) and the Saxon State Ministry for Science and the Arts.

September 19 and 20, 2013

International Symposium on Piezocomposite Applications ISPA

On September 19 and 20, 2013, already for the fifth time, the International Symposium on Piezocomposite Applications ISPA took place at Fraunhofer IKTS Dresden. The two-day conference focused on current results and services as well as market requirements and research interests in the field of piezocomposites. More than 80 participants and 10 exhibitors from 14 countries visited the symposium and the accompanying exhibition making it an excellent platform for knowledge transfer. The symposium will be continued in September 2015 in Dresden.

October 17, 2013

The Dresdner Kreuzchor performs at the Fraunhofer Institute Center Dresden

At the invitation of Fraunhofer IKTS, 180 guests, amongst them many Fraunhofer employees, visited the final rehearsal of the Dresdner Kreuzchor before its China tour in November 2013. The program comprised of 30 German and Chinese folk songs. Like the St. Thomas Choir in Leipzig, the Dresdner Kreuzchor belongs to the most famous and oldest boys' choirs of the world.

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January 1, 2014

Integration of Fraunhofer IIZFP Dresden into Fraunhofer IKTS

In January 2014, the Dresden-based location of the Fraunhofer Institute for Non-Destructive Testing IZFP was integrated into Fraunhofer IKTS – becoming the Institute's Materials Diagnostics Branch. As part of the integration process, the Dresden-Klotzsche location is to be further expanded and developed into a center for materials diagnostics. The new branch expands the Fraunhofer IKTS' research portfolio by the fields of materials diagnostics, structural health monitoring and test electronics, nano analytics and sensor technology as well as biotechnology and environmental technology. Thus, Fraunhofer IKTS is able to improve its quality assurance of products and manufacturing technologies in the aerospace, electronics, microsystem technology, environment, energy and life sciences sectors.

January 16 and 17, 2014

Ceramics Vision

More than 210 people accepted the invitation of Professor Michaelis to visit the eighth Ceramics Vision on January 16 and 17, 2014 in Dresden. The Ceramics Vision system held by Fraunhofer IKTS every two years, focuses on current developments and future trends of advanced ceramics in terms of material, component and system development for applications in mechanical engineering, electronics, photovoltaics and fuel cell systems. Within the framework of the accompanying exhibition, 18 exhibitors from both industry and research presented their products. An exhibition of the Product Design department of the Burg Giebichenstein University of Art and Design Halle complemented the Ceramics Vision symposium. A reception celebrating Professor Alexander Michaelis' 50th birthday was also part of the symposium.

Awards

Fraunhofer New Customer Award for the first quarter of 2013

Fraunhofer IKTS won the Fraunhofer New Customer Award for the first quarter of 2013. The award is given to the institute that received the largest order from a new customer. Together with Mayur REnergy Solutions Ltd., Fraunhofer IKTS researchers develop solid oxide fuel cells (SOFC) for clean and reliable power supply in India. The project volume amounts to 1.4 million euros. The fuel cell systems currently in development can be powered by methane or liquid gas – energy carriers which are wide spread in India. Mayur REnergy Solutions will use these devices for decentral power supply in order to ease the tense situation in power supply in India and other developing countries.

1 *MUW SCREENTEC GmbH receives funding for the development of energy storage devices with Fraunhofer IKTS.*
2 *Participants of the ISPA visiting IKTS laboratories.*
3 *Opening of the eighth Ceramics Vision with more than 210 guests.*
4 *Fraunhofer New Customer Award for IKTS researchers Dr. Christian Wunderlich and Thomas Pfeifer.*

Hans Riegel Award for research work at Fraunhofer IKTS

Friederike Kuhl from Sankt Afra secondary school in Meißen won the first price of the Hans Riegel Award in the field of biology with her work The Influence of Different Zirconia Contents on the Mechanical, Structural and Biological Properties of a Hydroxyapatite Implant. The work was written in the context of the PhD thesis of Matthias Ahlhelm providing internal resources for one year. Fraunhofer IKTS contributed its expertise in materials, processes, characterization and research.

Fraunhofer Medal for Professor Alexander Michaelis

During the symposium Ceramics Vision on January 16, 2013, Professor Alexander Michaelis was honored with the Fraunhofer Medal for his contribution to the Fraunhofer-Gesellschaft. Michaelis received the medal from Professor Reimund Neugebauer, President of the Fraunhofer-Gesellschaft. Professor Michaelis has been leading Fraunhofer IKTS for ten years. Under his leadership, Fraunhofer IKTS developed into the largest Fraunhofer Institute in Saxony and the most important research institution in the field of advanced ceramics. Michaelis took important strategic decisions by focusing on ceramic systems solutions which has also been reflected by the institute's name which it took on in 2006. Furthermore, the institute has been strongly focusing its research in the fields of energy and environmental technology. Today, more than 50 % of revenue is being earned by these two business units. In 2004, the institute had a staff of 120 employees and an operating budget of 10 million euros. Today, Fraunhofer IKTS employs 630 employees and has an operating budget of 45 million euros. This is due to the continuous growth of the research volume and the integration of the Hermsdorf Institute for Technical Ceramics HITK in 2010 and the Dresden branch of the Fraunhofer Institute for Non-Destructive Testing in January 2014.

Integrated Management ensuring Sustainable Quality Assurance and Compliance with Environmental Requirements in both institute branches

In February 2013, the Fraunhofer IKTS in Dresden obtained the DIN EN ISO 14001 certification after having started the certification process with the support of the Hermsdorf branch in 2012.

Fraunhofer IKTS is certified in accordance with DIN EN ISO 9001, DIN EN ISO 14001 and DIN EN ISO/IEC 17025. The institute branch Hermsdorf is also certified in accordance with EN ISO 13485 for the design and development, manufacture and distribution of crown and bridge frameworks made of oxide ceramics. Thus, we can guarantee that our processes comply with industrial safety and environmental standards as well as legal conditions and regulations while maintaining

1 *Professor Alexander Michaelis receives the Fraunhofer medal from Fraunhofer President Professor Reimund Neugebauer.*
2 *Presentation of the DIN EN ISO 14001 certification.*

SCIENCE MEETS MARKET – TRADE FAIR REVIEW 2013


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Three continents, 244 square meters: Fraunhofer IKTS presented its various products and services at 24 international trade fairs and exhibitions. In business to business communication, trade fairs are one of the most important instruments (AUMA e.V.) for personal dialogue with representatives from the industry and political sector.

Highlights

At the beginning of the year, the scientists of the Energy division unit presented the latest generation of eneramic® at the World Future Energy Summit in Abu Dhabi and at the ninth Fuel Cell Expo in Tokyo. The portable, LPG powered fuel cell system will be tested in the field this year.

Within the framework of nanotech in Tokyo, Fraunhofer IKTS held a workshop focusing on thick-film pastes for aluminum nitride for applications in power electronics. The workshop was sponsored by the Fraunhofer office in Tokyo, which established contacts with Japanese companies. At the SMT in Nuremberg, IMAPS in Orlando and EU PVSec in Paris the Electronics and Microsystems division made quite an impression. The scientists presented inks and pastes made of nano-scale noble metals as well as smart components such as ceramic MEMS for modern applications in aerospace, safety and measurement technology and the automotive industry.

The Environmental and Process Engineering division participated at the TerraTec in Leipzig, BiogasWorld and GreenTec Awards in Berlin. Fraunhofer IKTS presented its extensive expertise in the field of materials, technology and system development for efficient, safe and economic production, transformation, storage and use of energy. Furthermore, the scientists introduced technologies and processes for the optimization of mixing processes in materials management and water treatment plants. Utilizing a laboratory test stand, filtration processes and the application of ceramic membranes were illustrated.

1 *Many visitors showed great interest in the IKTS fuel cell competencies at FuelCell Expo in Tokyo.*

2 *The then Thuringian State Minister for Economics Matthias Machnig visited the IKTS booth at the Hannover Messe.*

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Hannover Messe, the world´s biggest industrial fair, was the ideal platform to present the whole institute. With more than 6650 exhibitors from 62 countries and 225,000 visitors the Hannover trade fair maintained its position as the top leading technology event. At four joint booths (Fraunhofer Energy Alliance, MNT Mikro-Nanotechnologie Thüringen e.V., State Development Corporation of Thuringia, Energy Saxony e.V.) IKTS presented current product developments in the fields of Research & Technology, Industrial Supply and Energy. The Power from Straw exhibit visualized the utilization of straw for the generation of biogas using ceramic membranes. The biogas was cleaned and concentrated to be used as biofuel for cars as well as to be further converted into electricity by fuel cells. Additionally, the waste heat can be used for heating.
Fraunhofer IKTS also showed green and sintered transparent optoceramics made from synthesized phosphors. Due to their outstanding optical and mechanical properties, these new materials are particularly interesting for applications in the medical, laser and lighting technology.

The Bio- and Medical Technology division of Fraunhofer IKTS participated at the 35th International Dental Show (IDS) in Cologne. With 125,000 visitors from 149 countries the trade fair set a new record. The Hermsdorf institute branch showed ceramic crown and bridge frameworks as well as CAD/CAM applications. At Compamed in Düsseldorf bioresorbable 3D printed bone replacement and honeycomb structures were shown in collaboration with the Fraunhofer IFAM Bremen.
Current technologies and developments of the Materials and Process Analysis division unit were presented at the POWTECH in Nuremberg. The focus was on powder technology as well as suspension characterization methods.

Current developments of the Mechanical and Automotive Engineering division were presented at the world machine tool exhibition EMO in Hannover and at EuroPM in Göteborg. For the first time, completely dense sintered tungsten carbide tools for the manufacture of extremely thin disc knives as well as high-performance hard metal tools for the machining of super and titanium alloys were presented.

Overview

World Future Energy Summit
Abu Dhabi, January 15–17, 2013
German pavilion

TerraTec
Leipzig, January 29–31, 2013

nano tech
Tokio, January 30–February 1st, 2013
Joint Fraunhofer booth

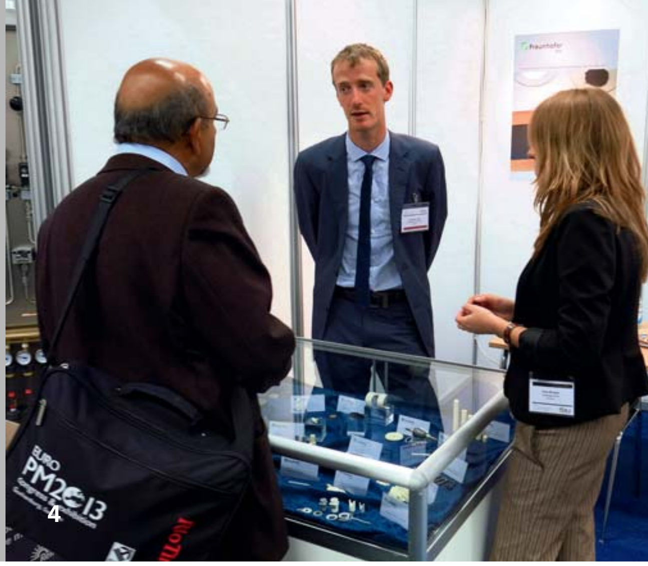
Fuel Cell Expo
Tokyo, February 27–March 1st, 2013
German pavilion

intec 2013
Leipzig, February 26–March 1st, 2013
Joint Fraunhofer booth

International Dental Show IDS
Cologne, March 12–16, 2013

Hannover Messe
Hannover, April 8–12, 2013
Joint booths: MNT Thuringia, Energy Saxony, Fraunhofer Energy Alliance, LEG Thuringia

SMT Hybrid Packaging
Nuremberg, April 16–18, 2013
Joint booth "Future Packaging 2013"



Powtech
Nuremberg, April 23–25, 2013

BiogasWorld
Berlin, April 23–25, 2013

Sensor & Test
Nuremberg, May 14–16, 2013
Joint booth "Forschung für die Zukunft"

GreenTec Awards
Berlin, August 30, 2013

EuroPM
Göteborg, September 15–18, 2013

EMO
Hannover, September 16–21, 2013
Joint Fraunhofer booth

IMAPS
Orlando, September 29–October 3rd, 2013

EU PVSec
Paris, October 1–3, 2013
Joint WFS booth

Materialica
Munich, October 15–17, 2013

Productronica
Munich, November 12–15, 2013
Joint Fraunhofer booth

CompaMed
Düsseldorf, November 20–22, 2013
Joint IVAM Service GmbH booth

Hagener Symposium
Hagen, November 28–29, 2013

EuroMold
Frankfurt am Main, December 3–6, 2013
Joint booth Fraunhofer Additive Manufacturing Alliance

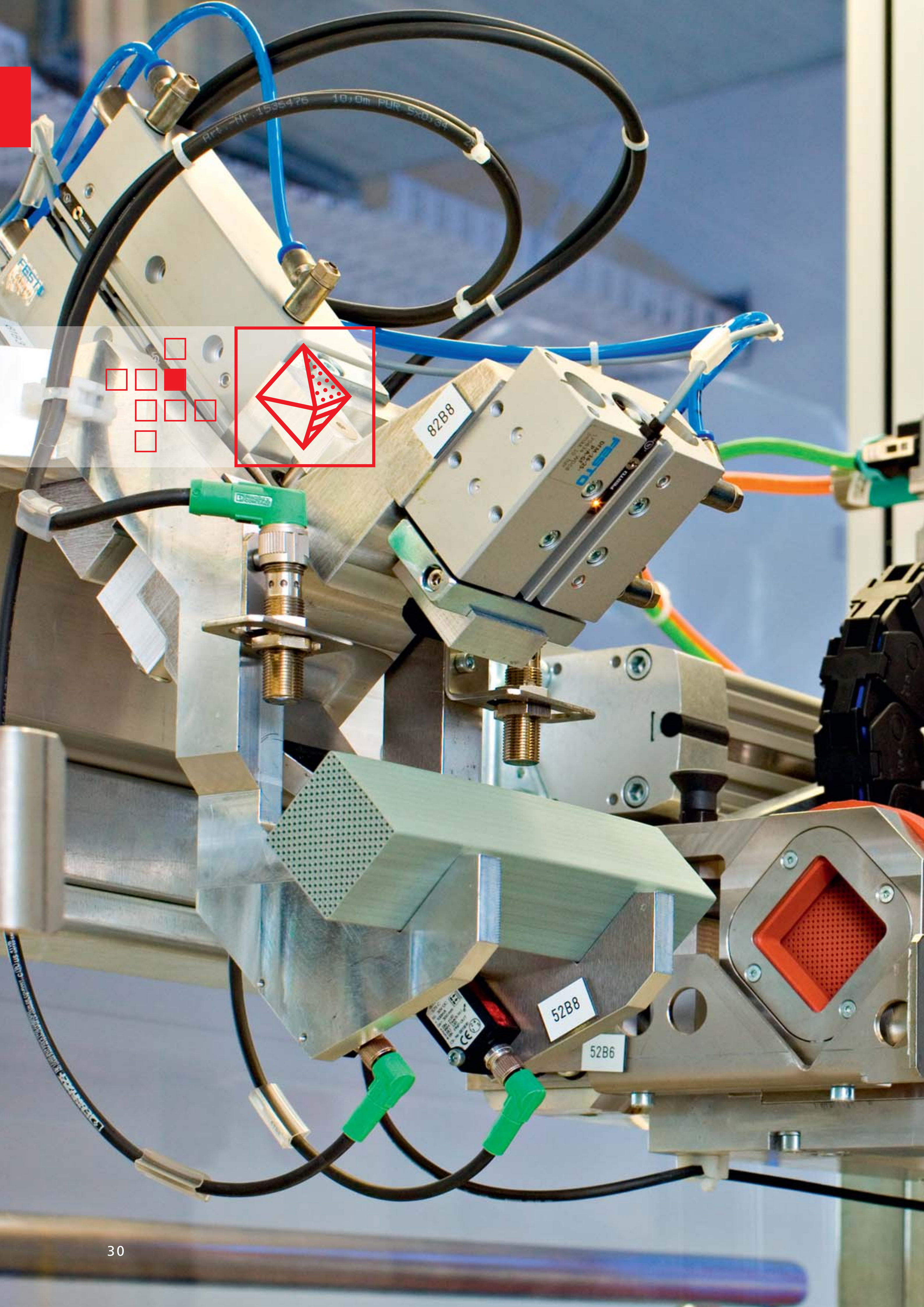
Dresdner Sensor-Symposium
Dresden, December 9–11, 2013

1 *Press conference at Hannover Messe: Together with Chip Bottone and Andreas Frömmel (FuelCell Energy, Inc., FCES GmbH) institute director Alexander Michaelis answered various questions concerning Energy Turnaround without Grid Expansion: decentral, clean power generation with Fuel Cell power plants.*

2 *Components made from structural ceramics withstand extreme conditions – many visitors at the joint booth in the Industrial Supply sector.*

3 *System integration in microelectronics – tailored solutions presented at SMT Hybrid Packaging in Nuremberg.*

4 *EuroPM in Göteborg: Adjusted material and shaping technologies at the leading event regarding powder metallurgy.*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DIVISION

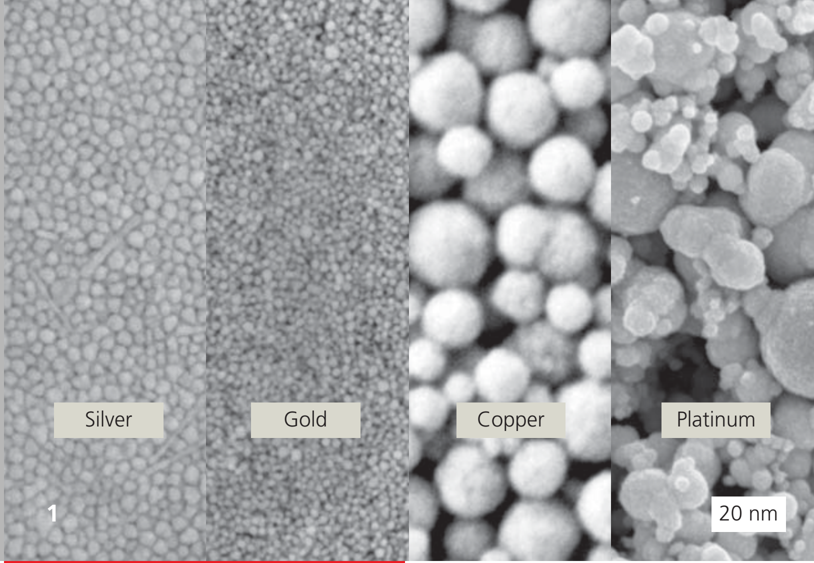
MATERIALS AND PROCESSES

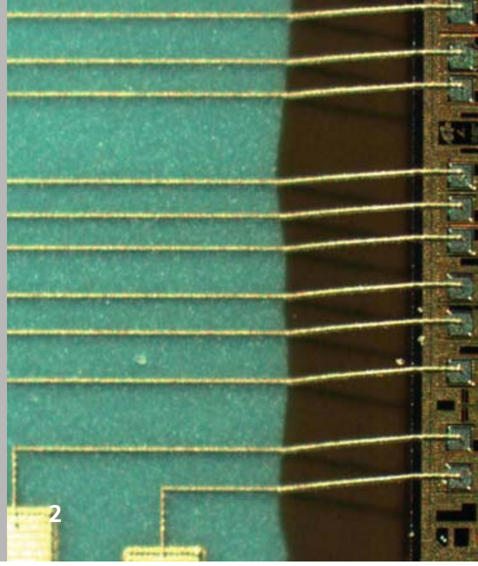
Project reports

In the "Materials and Processes" division, we engineer and modify oxide, non-oxide and silicate ceramic substances as well as composite materials, glasses, hard metals and cermets. The range of services extends from the targeted synthesis of materials from the pre-ceramic stages, as well as commercially available raw materials, through to application-oriented materials development. Depending on the defined targets, the materials are processed to powders, suspensions, granulates, feed stocks, pastes, inks, films, or fibers, as well as high-density, cellular or porous sintered parts. We have successfully tapped into new fields of application by combining, in a targeted manner, the structural and functional characteristics of ceramic materials or ceramic/metal composites. This achievement is reflected in many things, including the development of high-temperature materials, electrically conductive ceramics, luminescent materials, super-hard, wear-resistant materials, polycrystalline abrasives and functional ceramic layers.

Another focal point is the development of new powder technology production processes, and the optimization of existing ones, with an eye to defect elimination and cost savings. Nano-scale powder qualities and defect-free crystal structures make entirely new characteristics possible, such as transparent ceramic components, materials with especially advantageous combinations of hardness and strength, as well as components with high impact resistance or, in terms of optics, highly reflective surfaces.

The broad scope of services that we offer in forming methods extends from pressing, casting, and plastic forming and additive manufacturing through to multilayer technology and direct printing. A great number of heat treatment processes as well as high-capacity green and final machining top off the comprehensive portfolio of expertise of Fraunhofer IKTS. Using coating processes such as chemical vapor deposition or thermal spraying, surface characteristics can be modified and components adapted to specifications. Our customers benefit from closed technological chains that make a technological development, right up to the pilot model scale possible.





MATERIALS AND PROCESSES

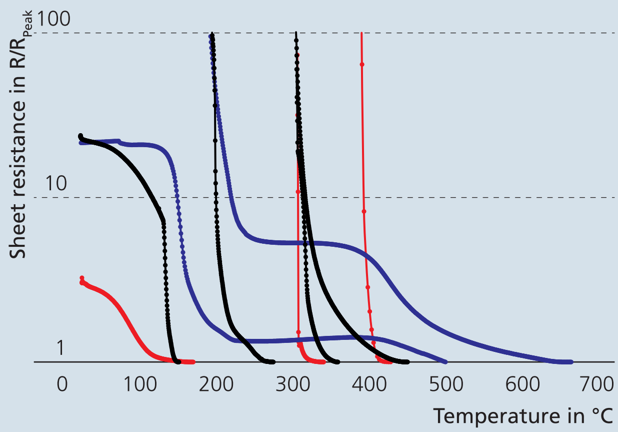
NANOINKS AND CONTROL OF THEIR SINTERING TEMPERATURE

Dr. Marco Fritsch, Dr. Sindy Mosch, Robert Jurk, Dr. Nikolai Trofimenko

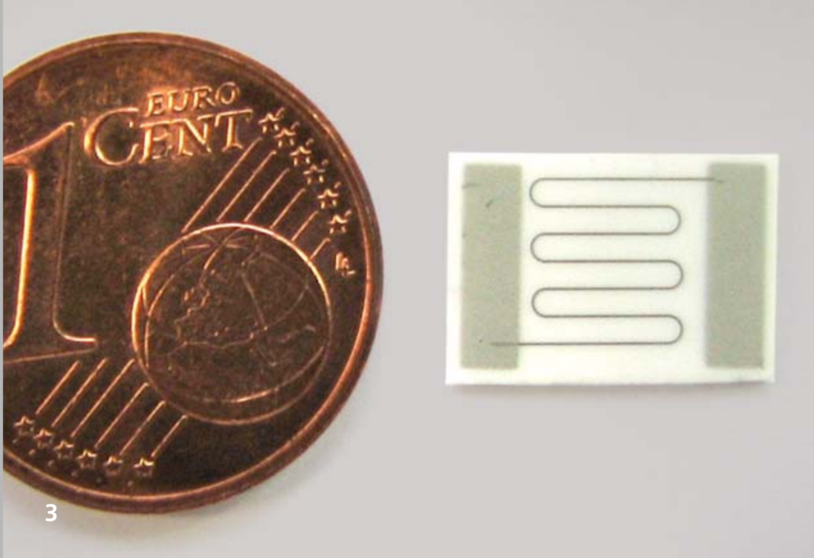
Digital printing of functional materials leads to innovations in the production of electronic and sensor devices. Methods like inkjet printing are characterized by a high flexibility, speed as well as scalability of the printing process. In contrast to the classic semiconductor technology material inks are used to print the circuit component directly on the substrate. This development has already led to numerous innovative applications: Flexible electronic circuits, miniaturized and cost-saving sensor systems, wafer/chip rewiring and connecting, light generation with OLEDs or photovoltaic power generation. To tap the full potential of such and other applications the development of suitable material inks is necessary. Within the framework of a SME-oriented research project, Fraunhofer IKTS developed material synthesis methods for metals for direct printing applications. The metals demonstrated so far comprise gold, silver, platinum, palladium, rhodium and copper. Furthermore, material inks based on carbon and glass are under development.

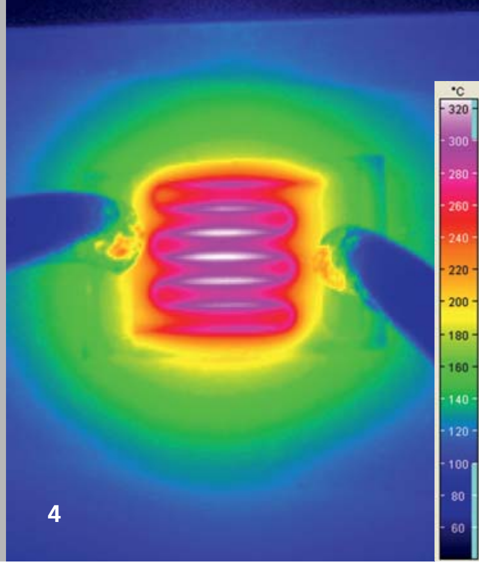
Such inks must meet several technical requirements. First, the inks have to be compatible to the printing technology. Secondly, the target parameters like geometry or conductivity on the substrate have to be reached. Due to the fact that the printing method is based on the generation and deposition of small ink droplets through printing nozzles, the particle size in the inks should be considerably below one micrometer. Because the production of such particles using conventional powder technologies like grinding, classification and grading is insufficient and complex, Fraunhofer IKTS developed a nanoparticle synthesis method for metals. In a first step, the metal nanoparticles are generated within a controlled precipitation reaction. In a second step, these particles are transferred to the final printing ink. The targeted particle sizes and size distribution can be adjusted in the range from 10 nm to 500 nm by varying the synthesis parameters.

Sintering behavior and relative sheet resistance of nanoinks



The required ink properties like a low viscosity and a proper surface tension for the droplet generation are adjusted by selecting and applying solvents and organic additives. To reach a sufficiently high electrical conductivity or the formation and densification of the microstructure, the printed structures are exposed to heat in a sintering cycle. The difficulty in this is the limited temperature compatibility of the substrate materials. Particularly, substrates based on polymers have to be fired considerably below 180 °C, whereas ceramic substrates can be treated up to several hundred degrees Celcius. Results of





Fraunhofer IKTS show that it is possible to influence the necessary sintering temperature of the printed ink microstructure by selecting and applying organic dispersants in the ink preparation process. Here, the thermal debindering behavior of the dispersant on the particle surface defines the necessary temperature for the sintering of the microstructure. Based on that approach it is possible to adjust the ink recipe in such a manner that various applications can be realized by using variable substrate materials. For example, the electrical contacts of a silicon chip on a polymeric substrate was realized by printing and sintering a gold ink at 200 °C. The electrical sheet conductivity achieved is lower by a factor of 3 in comparison to that of bulk gold metal and comparable to gold thick-film pastes. Another example is a miniaturized platinum heater on a ceramic substrate sintered at considerably higher temperatures of 500 °C. Using such a heater, a sensor device can be operated at constant temperatures up to 350 °C. Because of the thermal coefficient of resistance, which is close to that of pure metals, it is furthermore possible to use the metal inks for miniaturized temperature sensors. For many applications such sensors can be integrated in a space-saving manner in already existing electronic devices.

Services offered

- Synthesis of metal nanoparticles
- Formulation and manufacture of material inks
- Optimization of ink characteristics with regard to various substrates ranging from polymeric to ceramic materials
- Application of inks in digital printing like inkjet and aerosol jet
- Development of devices for printed electronics and sensors
- Development of miniaturized devices for energy converters and energy storage systems

Examples of IKTS metal inks for DoD-inkjet and aerosol jet printing

Properties	Gold	Silver	Platinum
Mean particle size d_{50} nm	40–150	40–300	40–100
Solid content wt.-%	15–60	5–70	20–60
Liquid carrier	Organic solvents or water		
Ink density g/cm³	1.1–2.5	1.1–3.0	1.1–2.8
Film thickness printed µm	Adjustable from 0.3 to 15.0		
Sintering peak temp. °C	25–440	25–500	180–700
Substrate materials	Variable e.g. polymer, metal, ceramic		
ρ Ωmm²/m	0.046–0.07	0.03–0.05	0.22–0.33

1 *Nanoparticles.*
2 *Chip-contacting gold ink.*
3 *Heater with platinum meander.*
4 *Thermal image of platinum heater demonstrator.*

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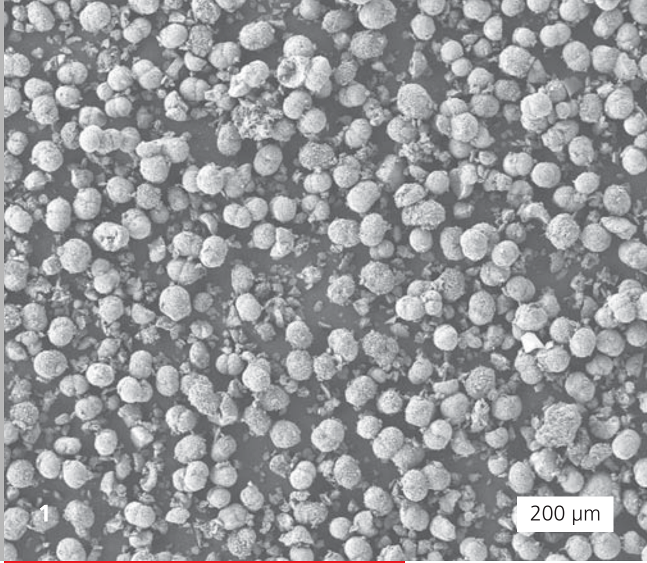
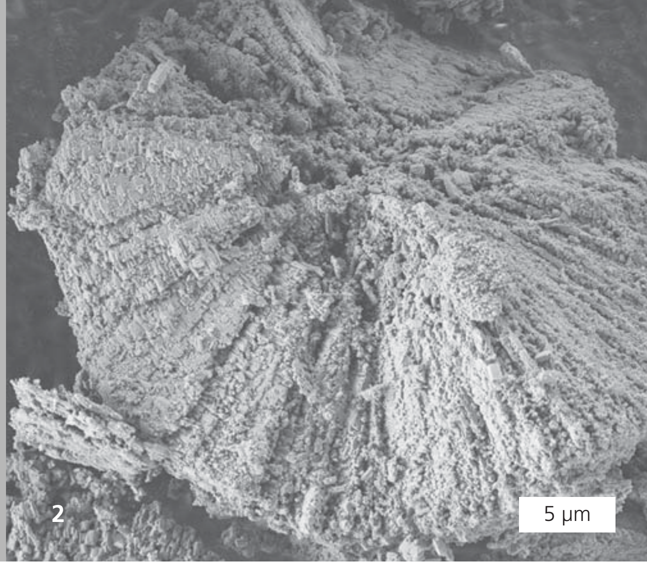




DIRECT SYNTHESIS OF LITHIUM-ION ELECTRODE MATERIALS

Dr. Isabel Kinski, Dr. Mareike Wolter, Dr. Kristian Nikolowski

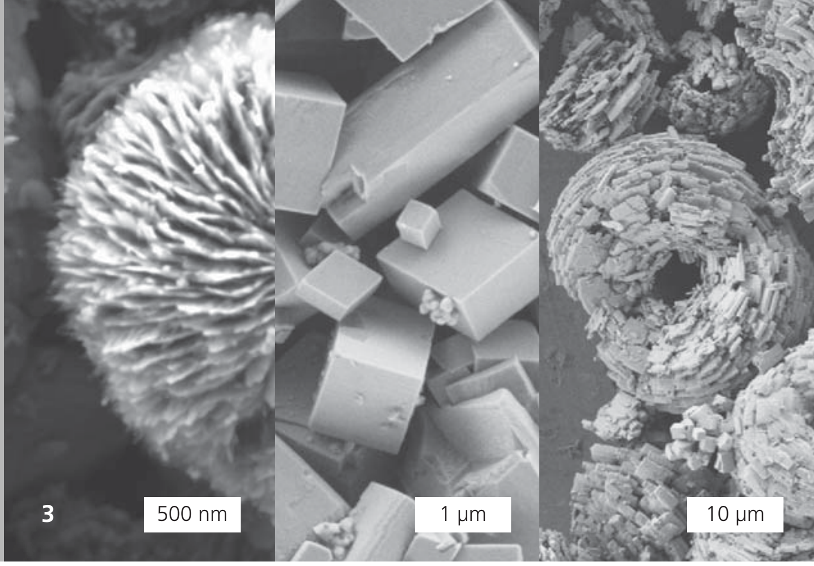
The widespread use of Li-ion batteries in the future for E-Mobility applications and the storage of renewable energy puts high demands on the used electrode materials: They should allow for batteries with a prolonged cycle life as well as high energy and/or power density. Additionally, they should be cost-effective, reliable and environmental friendly.

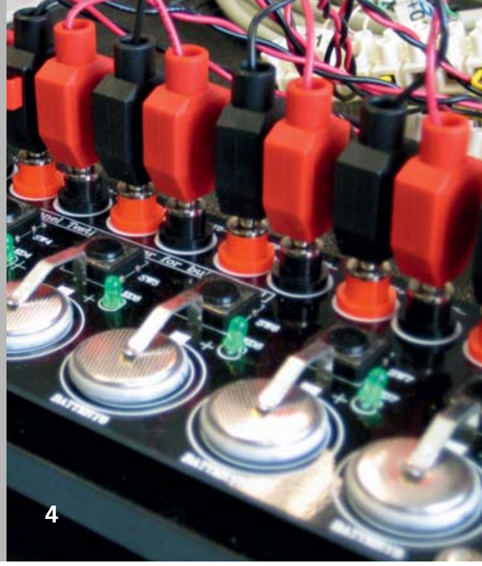
In order to meet these requirements, the properties of the well-known materials have to be further developed and optimized at different levels. For a high energy density, a higher specific capacity as well as a high cell voltage are necessary in comparison to systems currently used. In order to achieve high power densities and a long life-time, it is necessary to exactly tune the particle size and morphology already during the synthesis process. This is the only way to create optimal conditions for ion and electrode transport in the solid and at the interfaces (e.g. to the electrolyte).

For this purpose, new active materials have been developed and specifically optimized using different methods. For the cathode side, materials with olivine structure, such as $LiFePO_4$ (LFP) and $LiMnPO_4$ (LMP), have been synthesized. Furthermore, the manufacturing of high-voltage materials such as $LiNi_{0.5}Mn_{1.5}O_4$ crystallizing in a spinel structure are studied. For the anode side, alternative materials are investigated showing significantly higher specific capacities compared to graphite, which is widely used today. The research focus is on processes which can be scaled up to industrial scale. At Fraunhofer IKTS, these processes are well established from laboratory to pilot scale.

There are different methods to specifically adjust the particle morphology. Following a top-down approach, for example, commercially available powders are brought to the desired size by milling processes. In contrast, using a bottom-up approach particle morphology, size and distribution can already be adjusted during the synthesis of the primary particles. Besides the classic solid-state reactions and sol-gel processes under normal pressure, hydrothermal or solvothermal syntheses are performed under elevated pressure in autoclaves or in microwave-assisted reactors.

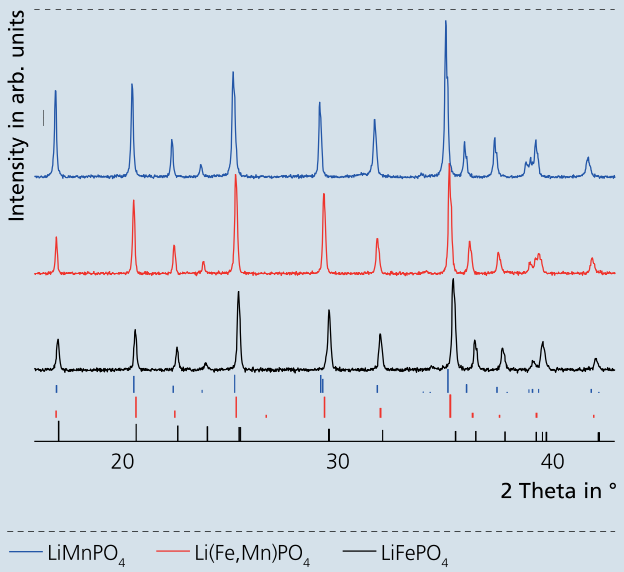
As an example for the bottom-up approach the syntheses of LFP and LMP are described in the following. Phase-free LFP and LMP as well as the mixed phase $Li(Mn,Fe)PO_4$ were synthesized in a microwave and an autoclave (see diagram). The formation of single-phase phosphates is significantly influenced by the pH value and the ratio of Li, P and Mn or Fe content of the used starting materials. Furthermore, reaction time and temperature in an autoclave or a microwave reactor have an effect on the degree of crystallinity and the crystallite size. In addition, the reaction time can be significantly reduced from 24 hours to 21 minutes using a microwave reactor. Electron microscope images of selected powders are shown in Figure 1 to 3. For those syntheses, mainly phosphates, hydroxides and acetates are used.





Electrodes are manufactured from the developed electrode powders and characterized in terms of their electrical properties. For this, different cell designs (coin cells, pouch cells) can be manufactured (Figure 4). At Fraunhofer IKTS, a huge number of measuring channels (> 100) for a wide temperature range is available, where performance and life-time tests as well as impedance spectroscopic analyses can be carried out. After these electrochemical tests, the powders are characterized using postmortem analyses and a broad spectrum of analytical methods in order to develop strategies for further systematic material optimization.

XRD diagram of a single-phase synthesized LFP and LMP powder as well as a modification where the cations were substituted



Services offered

- Synthesis of inorganic cathode and anode materials through solid-state reactions, sol-gel processes (e.g. Pechini), inert gas, hydrothermal and microwave-assisted synthesis
- Characterization of active materials in lithium-ion test cells
- Postmortem analysis of active materials and cells
- Technology and process development for lithium battery manufacturing
- Scale up of all production steps from laboratory to pilot scale

1 *10-20 µm spherical LFP particles by direct synthesis.*
2 *Broken polycrystalline particle.*
3 *Different LFP particle sizes and morphologies.*
4 *Characterization of active materials in coin cells.*

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GELCASTING – A SHAPING METHOD FOR PARTICULARLY DEFECT-FREE CERAMIC PARTS

Dr. Jens Klimke, Dr. Andreas Krell

The way to the "perfect ceramic solid body" by minimizing the defect concentration in the microstructure of the ceramics is through a multi-stage optimization process, beginning with the selection and preparation of suitable starting materials and their preparation, compaction and sintering. Development progress on this path is particularly clearly evident at dense sintered transparent ceramics because major defects are immediately visible and even smallest pores reduce the measurable transmission through their contribution to light scattering. Transparent ceramics with very good inline transparency of e.g. 95 % of the maximum value at 4 mm thickness are described by a loss coefficient of k = 0.056/cm (Methods to increase the maximum theoretical value by a reflection-reducing coating of metal fluoride are described by U.Reichel on page 98–99 in this issue of IKTS annual report). However, even higher demands apply for real "opto-ceramics" or "laser-ceramics" with k = 0.01/cm, generally even k < 0.001/cm. In addition, the following condition, based on the thickness, is to be matched for local variations of the refractive index: $\Delta n < 0.01–1$ ppm ($10^{-8}–10^{-6}$).

For the high demands of such ceramics, standard ceramic processes reach their limits because of remaining defects after pressing. On the other hand, liquid molding processes offer specific advantages in the preparation of the suspensions and the achievable homogeneity of the green body. In recent years, gelcasting as a modern shaping process received more and more attention in addition to the classic slipcasting processes.

During the gelcasting process, 3–5 wt% monomers are added to the ready-to-pour slurry of a stabilized and deagglomerated ceramic powder. After molding, the monomers bind the water by a polymerization reaction and fix the optimum state of powder dispersion of the slurry. The ceramic particles remain embedded in the hydrogel matrix forming green bodies with low defect density after drying. The flowchart gives a schematic overview of the process. Gelcasting is ideal for starting materials in the particle size range of about 0.1–2 microns. Depending on the density, sedimentation may occur for coarser powders whereas for finer powders increasing repulsive forces of the individual particles reduce the solids content. Cost advantages can be realized especially in small series through the simple casting technique in non-porous molds and through the good mechanical machinability of the green bodies. The challenges during gelcasting are associated with the optimization of the ceramic suspensions in terms of milling with suitable dispersants and solids concentrations, and with the selection of gel-forming monomers. Many years of experience have shown that almost any ceramic powder performs differently since the polymerization is influenced by the purity of the starting materials and by chemical reactions on the powder surface. High hardness, high melting point, chemical inertness and thermal shock resistance make spinel an attractive material for instance for ballistic armor, scratch resistant windows and IR domes. Whereas gelcasting for transparent corundum is now well established, no transparent spinel ceramics ($MgAl_2O_4$) prepared by gelcasting have been described previously in the literature outside Fraunhofer IKTS Dresden although a higher transmission can be achieved with spinel than with alumina ceramics due to the cubic crystal system. Causes

3

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are the difficult dispersibility of the spinel, which is impeded by hydro-lysis in aqueous medium resulting in disturbing high viscosities and low solids contents. Also, strong shrinkage during drying and sintering increases the risk for the formation of cracks and visible defects especially in thick-walled and large-sized parts. As a result of comprehensive optimization work at Fraunhofer IKTS Dresden these problems are overcome so that an aqueous and a non-aqueous route for gelcasting with unpreviously unknown qualities are available. By adjusting the gelcasting process, more complex, larger parts of spinel with a hemispherical shape could be realized for the first time. Figure 1 shows the domes after drying (left), sintering in air (middle) and hot isostatic pressing (right). Figure 2 presents a selection of large parts of transparent spinel and figure 3 a look through a virtually defect-free spinel ceramic with a thickness of 17.7 mm. With an in-line loss factor k = 0.012/cm and Δn = 0.25–36 ppm (measurement of ZEISS, Oberkochen) the transparent spinel achieves the required optical quality.
In terms of low-defect processing and a resulting optimum transparency, progress was also achieved by gelcasting of potentially suitable starting materials for ceramic laser Y_2O_3 and $Y_3Al_5O_{12}$ (YAG). Figure 4 shows samples (diameter about 2 cm) made of transparent spinel, yttria and yttrium aluminum garnet ceramics by gelcasting produced at Fraunhofer IKTS Dresden.

Flowchart: Gel casting process

1 Preparation of the slurry
↓
2 Addition of monomers
↓
3 Casting
↓
4 Deairing under vacuum
↓
5 Polymerization
↓
6 Demolding and drying
↓
7 Burning out of organics
↓
8 Sintering

Services offered

- Development of particularly low-defect oxide ceramics for high-performance tools and optical applications
- Optimization of suspensions
- Optical characterization and simulation calculations
- Manufacture of small series

1 *Spinel bodies made by gel-casting: dried (left), sintered (middle) and after HiP (right).*
2 *Transparent spinel ceramics prepared by gelcasting.*
3 *Particularly low-defect spinel with low loss coefficient.*
4 *Samples of spinel (left), yttrium oxide (middle) and YAG (right).*

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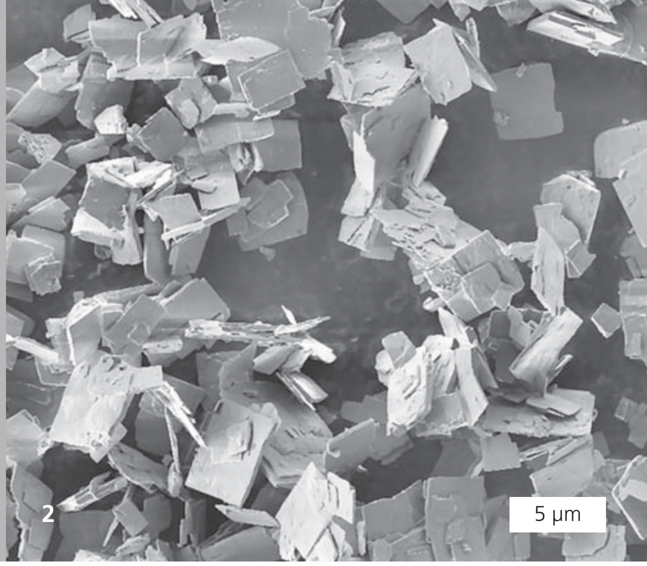

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SMART MATERIALS AT FRAUNHOFER IKTS

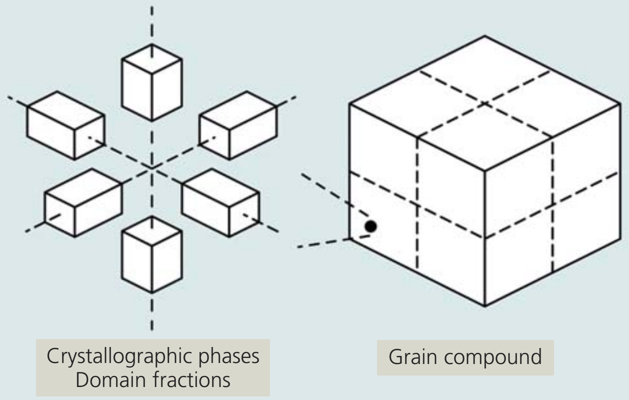
Dr. Peter Neumeister, Dr. Andreas Schönecker, Prof. Michael Stelter

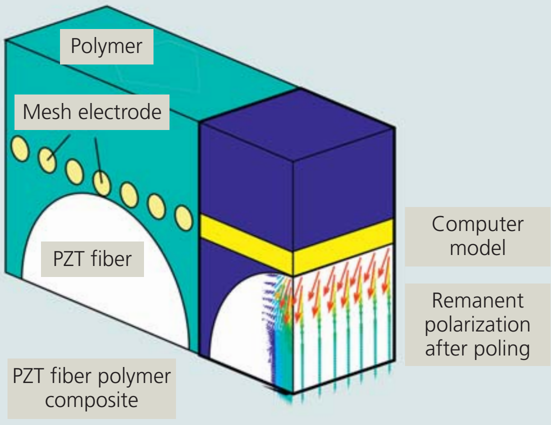
Smart materials denote materials which combine different physical properties and thus are functionally coupled. Exploiting these couplings systematically offers the possibility to concentrate such functions on the material level, drastically reducing the effort and cost of constructive design and electrical layout necessary for the implementation of the complex tasks. Smart materials, thus, depict an elegant alternative to more and more integrated micro-electro-mechanical systems.

The core expertise of the research groups "Multifunctional Materials and Components" and "Applied Material Mechanics" lies in ferroelectric perovskites, which possess various functional couplings besides their outstanding dielectric properties. Most common is piezoelectricity which represents a linear coupling between the mechanical and electrical field quantities. It forms the basis for actuators, sensors and sound transducers. As a result of the piezoelectric effect, the electric boundary conditions affect the elastic stiffness of the piezoelectric ceramics. Thus, it is possible to design structures with electrically switchable stiffness. The piezoelectric properties of ferroelectric ceramics depend strongly on temperature and electromechanical load. With regard to the thermo-mechanical interaction between functional ceramics and surrounding structure, a systematic combination of these dependencies allows for, for instance, the compensation of temperature dependency within the functional compound. Furthermore, ferroelectric ceramics possess electrocaloric properties. Inducing a high electric field results in a significant change in temperature which is restored by electrical unloading. By an adequate arrangement and electrical driving of electrocaloric elements, solid-state cooling elements become feasible. Miniaturized, they can be used for efficient cooling of highly localized heat sources in microelectronic compounds. Perovskites experience thermal and load induced phase transitions. The significant change in the thermo-electro-mechanical material properties caused by these transitions imply potentials for further applications such as highly precise thermal switches.

One current research focus lies on the development of cost-effective lead-free piezoceramics. Potassium sodium niobate compositions (KNN, Figure 1) show adequate piezoelectric coupling properties, and thus possess the potential to replace the outstanding but lead-containing PZT ceramics for specific applications. The objective of the work is the development of a robust and economic process route as well as the optimization of the coupling properties. One approach lies in texturing the polycrystal, which means imprinting a directed alignment of the lattice of the single grains. For this, chemically compatible grain nuclei have to be developed (Figure 2). By means of materials mechanical considerations, questions on the necessary level of texturing, favorable crystallographic phases as well as the effect of mechanical interactions between the grains are considered, using microscopic material models (Figure 3). Numerical modeling the macroscopic material response under coupled electromechanical loads enables the simulation of the poling behavior and the resulting piezoelectric properties within devices of complex geometry (Figure 4).

Within the next years, Fraunhofer IKTS will systematically develop the potential of smart materials. Starting from material synthesis followed by the development of efficient processing technologies up to design, manufacturing and validation of





entire systems, the complete value chain is covered. Thereby, scale-bridging modeling is of great importance. It links material design on the structural scale with the macroscopic system behavior.

Close cooperation with further departments at Fraunhofer IKTS assures a broader impact of the research field of smart materials by gaining knowledge on structural characterization (department "Sintering and Characterization"), on integrated circuit packaging and new material compounds (departments "Hybrid Microsystems" and "Materials and Components") as well as on system design for ultrasonic applications and structural health monitoring (Fraunhofer IKTS-MD).

Targeted markets of the research activities lie in the conventional business fields: power and microelectronics, automobile manufacturing, mechanical engineering and construction, optics, and measuring and test technology but also in novel and rapidly growing markets like medicine technology and ambient assisted living.

Services offered

Ferroelectric ceramics and functional systems:
- Materials syntheses
- Technology development
- Materials characterization and modeling
- System development, prototype manufacturing, validation of ferroelectric ceramics and functional systems

1 *Specimen made of calcinated KNN.*

2 *Sodium niobate nuclei for textured KNN.*

3 *Microscopic model approach.*

4 *Distribution of remanent polarization after poling in ceramic polymer compound.*

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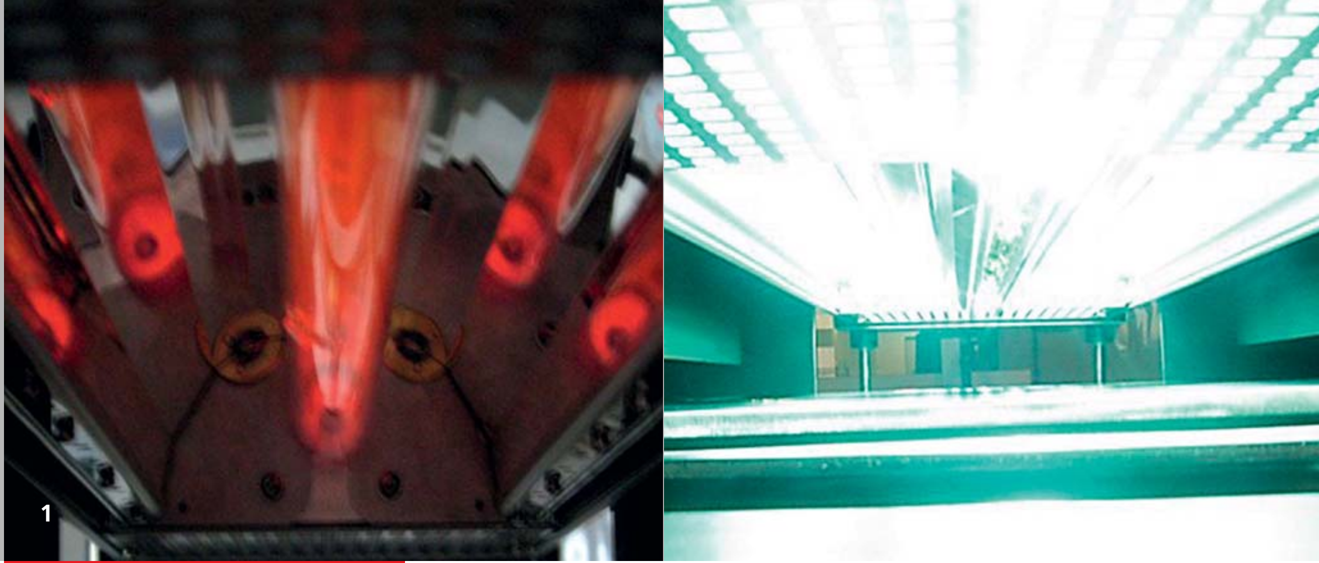


MATERIALS AND PROCESSES

CERAMIC TAPES BASED ON UV-CURABLE BINDER SYSTEMS

Dipl.-Chem. Beate Capraro

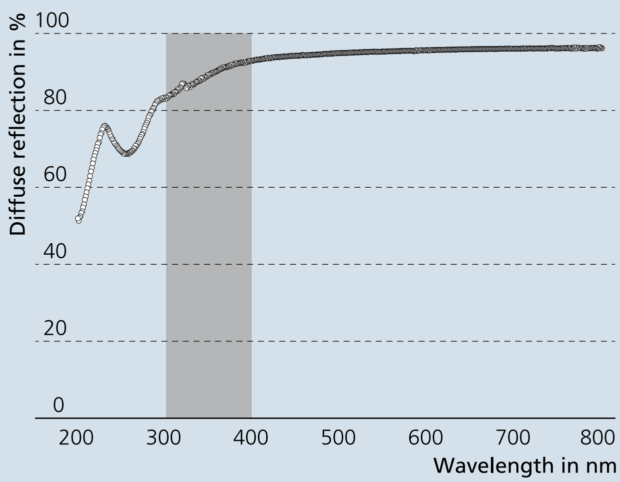
Aim of the work

In the recent years, tape casting as an efficient shaping method has increasingly gained in importance in the field of technical ceramics, especially due to developments in the field of LTCC, piezo and fuel cell technology. In the classical tape casting process, organic solvents and phthalates as plasticizers are used. As it is an established fact that they are harmful to human health and environment, and due to the stricter regulations (guideline 2002/95/EC-ROHS directive), it is the aim to replace conventional binder systems based of volatile solvents by alternative systems. There is great potential to use UV-curing systems in tape casting. Based on a ceramic model substance it was verified that UV-curable binder systems are suitable for the substitution of conventional solvent-based systems. The technological challenge was to prepare a pourable slurry with minimal organic content. This requires the investigation of alternative agents and the evaluation of adapted process conditions during slurry preparation, casting and thermal treatment.

Results

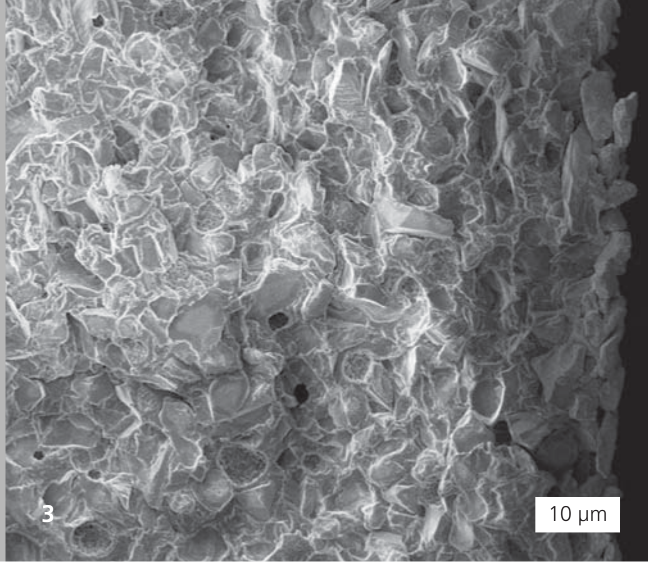
Al_2O_3 which is used as starting material for the production of porous membranes for liquid filtration and gas separation was selected as model substance for the tests. During the investigations, UV-curable slurries were developed which were casted using the doctor-blade process. At first, the used Al_2O_3 was tested in terms of its UV activity. The range of 300–400 nm is of special interest. Afterwards, suitable UV-curable binders were evaluated and the effectiveness of different photo initiators was examined.

Spectrum of the diffuse reflection of Al_2O_3 in the wavelength range of 200–800 nm

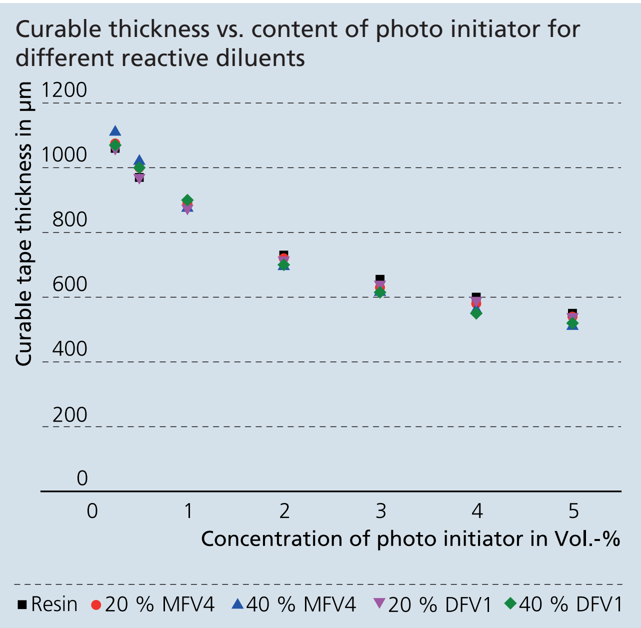


To reach a viscosity range which allows a tape casting process, investigations were carried out to determine the influence of different reactive diluents on the slurry viscosity. The influence of the content of alumina, reactive diluent and initiator on the viscosity of the slurry, the maximum curable tape thickness and the mechanical properties of the tapes were evaluated.

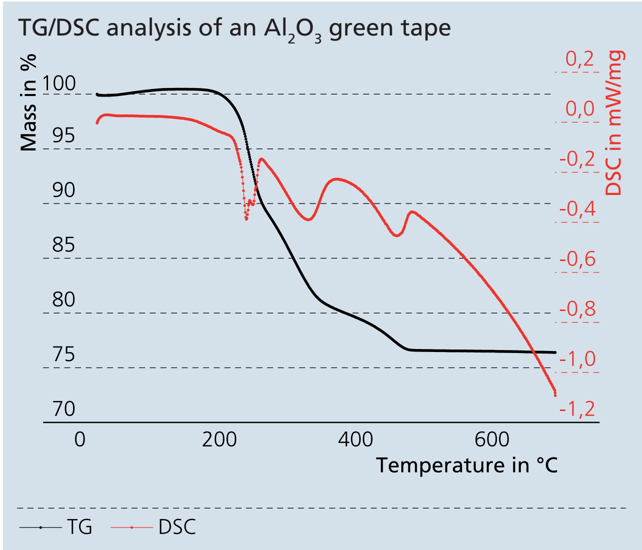
To investigate the debinding and sintering behavior thermal analyzes were carried out. Binder removal is completed at 450 °C. Technological aspects of the development of a tape casting process based on UV-curable binders were in the focus of subsequent studies. First, a processing technology for the



tape casting slurries was developed by testing different treatment units. In order to evaluate the processing technology, the rheological properties were determined and criteria such slurries in terms of surface and in-depth curing of the tape as homogeneity, exclusion of air and processing time were considered. Another focus was on the integration of the UV sources in the existing casting machines. Mercury UV lamps and ultraviolet semiconductor light sources were tested and evaluated according to their suitability for UV-curing of ceramic slurries in terms of surface and in-depth curing of the tape.



The influence of tape thickness, tape quality and the curing efficiency on the process parameters (speed, blade gap, UV sources) was examined. In the case of curing alumina, the Hg UV sources achieved best results.



Acknowledgments

The Federal Ministry of Economics and Technology and the AIF are greatly acknowledged for supporting the research project 16972N: "Basic studies on UV-curing-slurries for casting of ceramic tapes".

1 *Integrated Hg-UV source.*
2 *Preparation of UV-cured Al_2O_3 slurry.*
3 *SEM image of a UV-cured Al_2O_3 green tape.*

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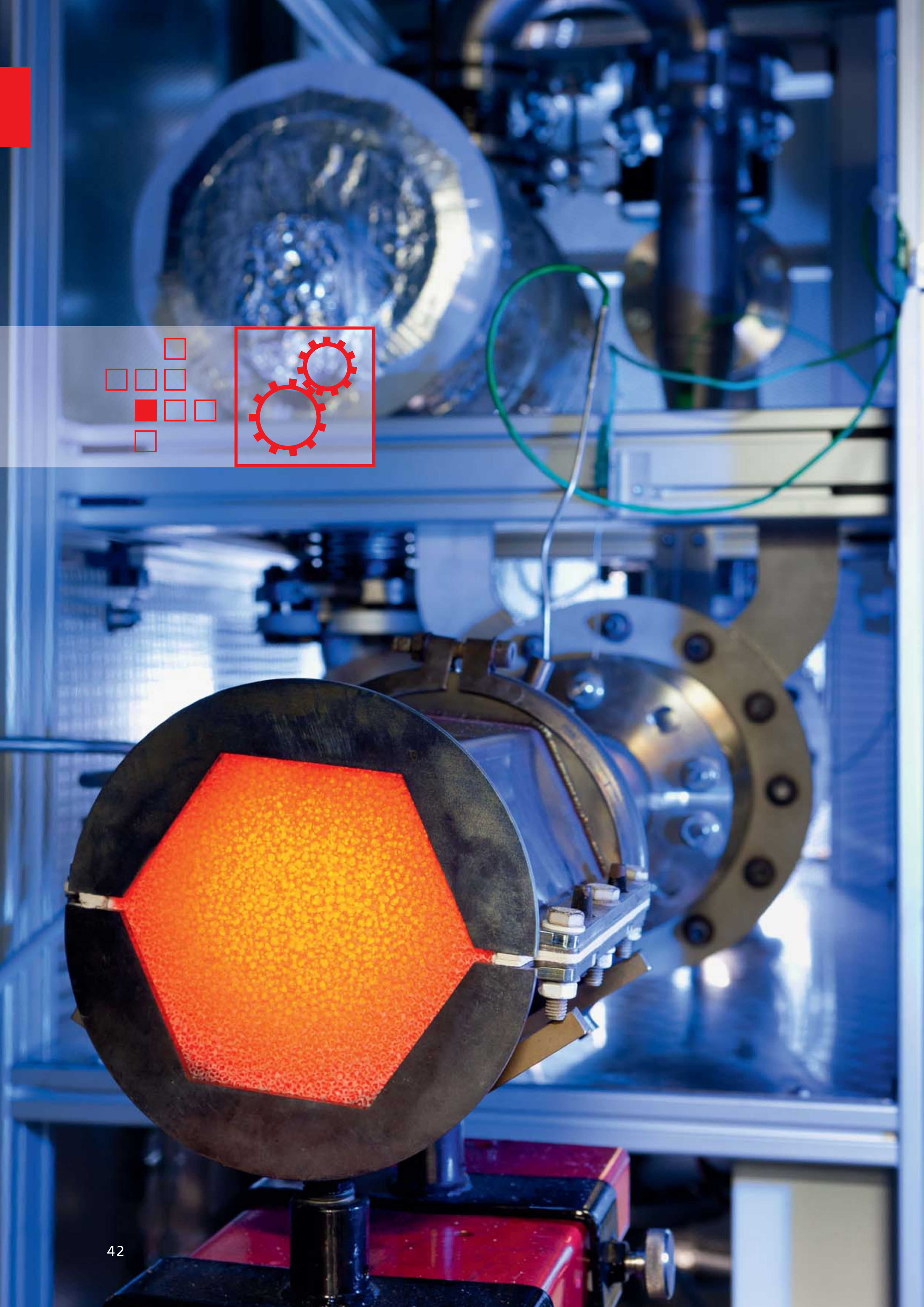

DIVISION

MECHANICAL AND AUTOMOTIVE ENGINEERING

Project reports

In the "Mechanical and Automotive Engineering" division, wear parts and tools are engineered and manufactured, as well as specifically stressed components made from high-performance ceramics, hard metals, and cermets for machine, plant, and automotive engineering.

The escalating costs of energy and raw materials, the intensified international competition and intensified demands for sustainability represent major challenges today for machine and plant engineering. In automotive engineering, the increasingly stringent exhaust standards play an additional role. Through the use of high-performance ceramic components, we can achieve decisive improvements to characteristics in existing and new systems and plants, and thus respond to the latest challenges. New tool materials, such as nanocrystalline hard metals and impact-resistant ceramics, as well as abrading media and ceramic bonding systems ensure the effective processing of new kinds of high-strength workpieces. In terms of vehicle protection, opaque ceramics and hard metals are gaining increasing significance. Transparent ceramics protect windows, viewing equipment and optical devices. Moreover, in automotive engineering, DeNOx catalytic converters for Selective Catalytic Reduction (SCR) technology play an important role as storage catalysts. Combined systems of ceramic diesel particle filters with embedded NOx storage catalysts are also currently in development for future methods of exhaust gas after-treatment.

Fraunhofer IKTS supports its customers in application-based materials selection, whereby both established materials systems as well as reengineered materials combinations are used. The scientists additionally possess decades of experience in ceramics and hard metal-suited configuration of components and comprehensive know-how with respect to the economic manufacturing process and successful integration into the user system. New ideas for applications are thus implemented quickly, reliably, and cost-effectively in prototypes and small batch-production. When selecting the optimal production process, we can fall back on a spectrum of ceramic production processes that is outstanding on an international scale. The existing equipment allows for the upscaling of selected individual technological processes, from the pilot-plant scale through to transition to industrial manufacturing at the customer's site.


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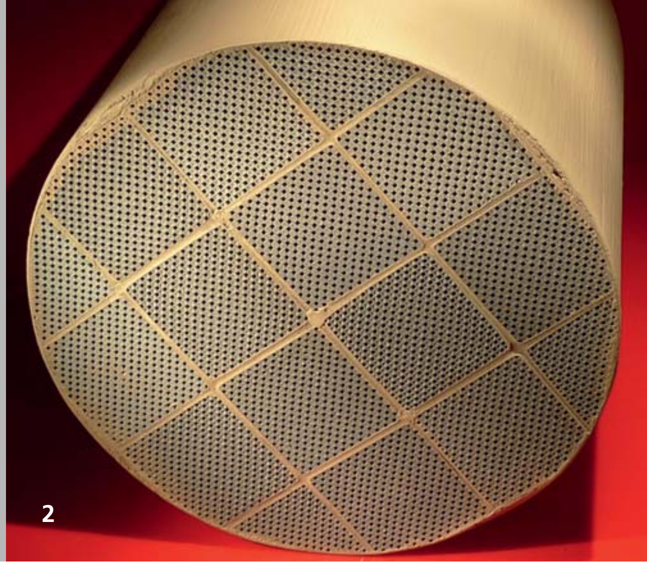
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DIESEL PARTICULATE FILTERS WITH OPTIMIZED PRESSURE DROP AND FILTRATION EFFICIENCY

Dr. Uwe Petasch, Dipl.-Krist. Jörg Adler

Diesel particulate matters are known to be harmful to human health and environment. Nowadays, diesel particulate filters are widely applied as the state-of-the-art technology for the safe and effective reduction of diesel engine exhaust gases. The filters have to satisfy the following basic functional requirements:

- Separation of soot particles from exhaust gases with adequate filtration efficiency
- Low initial pressure drop and back pressure during soot filtration
- Very good resistance against thermal shock and high temperatures during filter regeneration

In the past few years, ceramic wall-flow filters for soot particulate filtration have already enjoyed a high level of development. However, due to the tighter emission standards and the demand for more energy efficient vehicles, it is essential to have future developments of particle filters that focus on lowering the pressure drop and increasing the soot filtration efficiency.

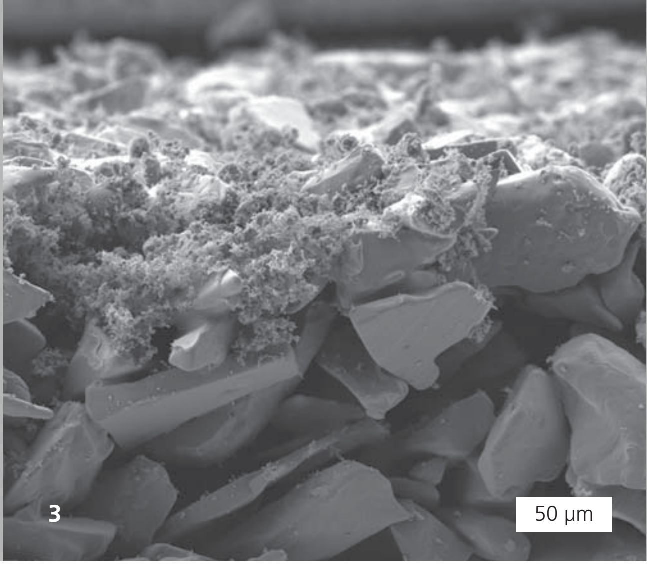
Liquid-phase sintered silicon carbide (LPS-SiC) was developed at Fraunhofer IKTS as a porous material for the application in soot filtration, and was transferred to industrial scale production, mostly for filters in off-road applications. The advantage of LPS-SiC lies not only in its excellent thermal properties but also in the reproducible and adjustable porosity controlled by the SiC grain sizes. In an attempt to further optimize the pressure drop and the filtration characteristics, experimental studies were carried out to identify the role of the material porosities on the properties of the particulate filters.

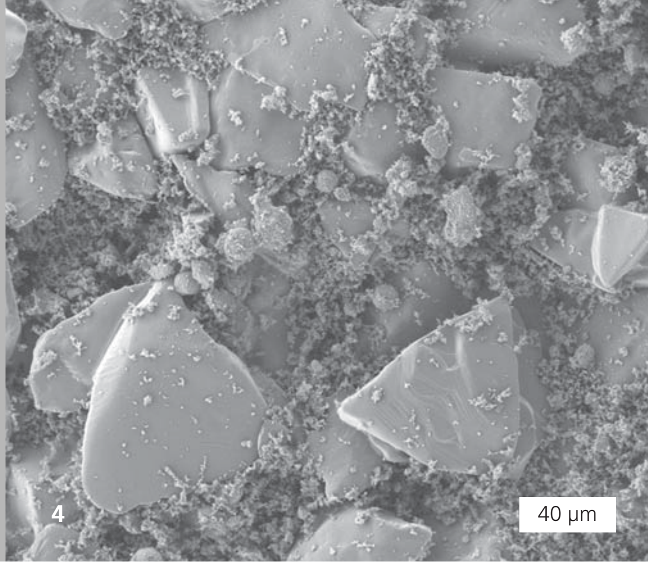
Pressure drop and filtration efficiency of disc-shaped specimens and extruded honeycombs made from porous SiC material were investigated by means of reproducible soot loading experiments on a special laboratory test bench (Figure 1). As a result, changes in filter properties of porous materials with pore sizes between 10 and 20 µm as well as their influence on the characteristics of the real filter structure were independently evaluated.

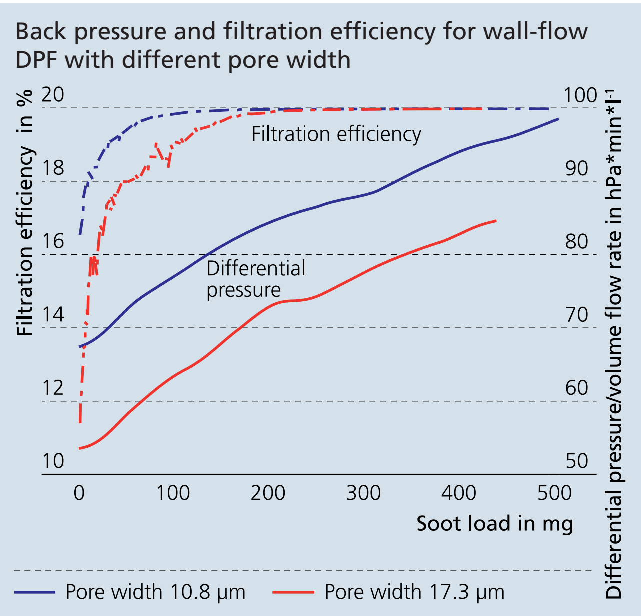
All tested materials showed a two-stage filtration behavior that is typical for wall-flow DPF: The starting depth filtration was followed by a formation of a soot layer resulting in cake filtration (Figure 3). The soot collection efficiency at the beginning of the deep-bed filtration stage ranges between 60 % and 85 % depending on the pore size of the filter material and increases to > 99.5 % due to cake filtration.

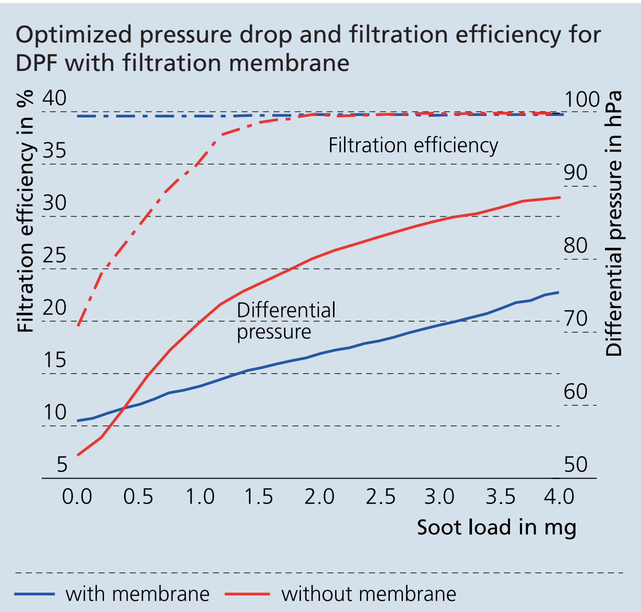
Filters with increased pore sizes of the filter wall have advantages in decreasing the initial pressure drop and the back pressure during soot loading. However, particle filters with smaller pore sizes show higher filtration efficiency since their relative inefficient deep-bed filtration phase is less pronounced.

Another approach for increasing the filtration efficiency is to use an additional fine porous filtration membrane on the filter wall. However, this method not only influences the filtration efficiency but also the back pressure of the filter. In cooperation with Fraunhofer ITWM, microstructure simulations based on experimental and analytic results of soot particulate deposition on porous LPS-SiC materials were used for a further development of optimized filters. The results of the simulation









were applied in the design and experimental development of filter membranes. An optimal balance between filtration efficiency and back pressure was obtained for filter materials whose top pore layers were filled with additional fine porous ceramic material (Figure 4). The initial pressure drop of such a filter material was only slightly affected. In contrast, the back pressure offset caused by soot deposition is lower than the value for conventional filter materials since the depth filtration step was completely avoided. The filtration efficiency stays at approximately 99 % during the overall filtration process.

Services offered

- Design, development and optimization of diesel particulate filters
- Application-oriented characterization of filter properties

1 *Soot loading and pressure drop test bench.*
2 *Wall-flow diesel particulate filter.*
3 *Cross-sectional area of a DPF wall after soot loading.*
4 *Filtration membrane on DPF for optimized pressure drop and filtration behavior.*

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PLASMA SPRAYING OF NITRIDE MATERIALS

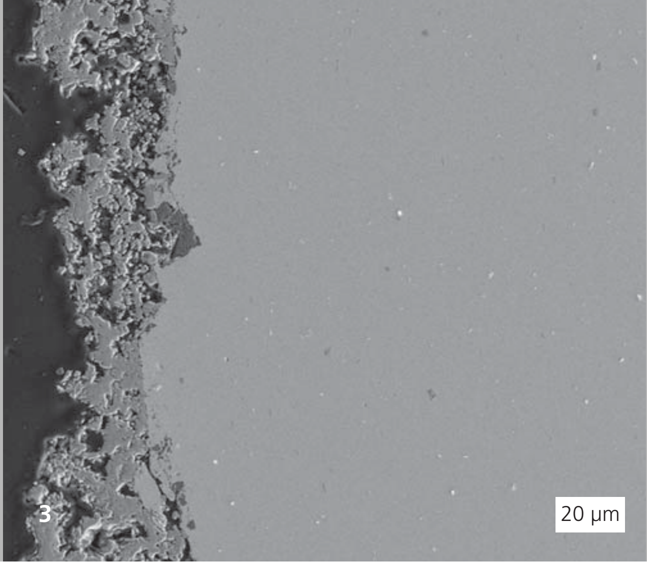
Dipl.-Ing. (FH) Bernd Gronde

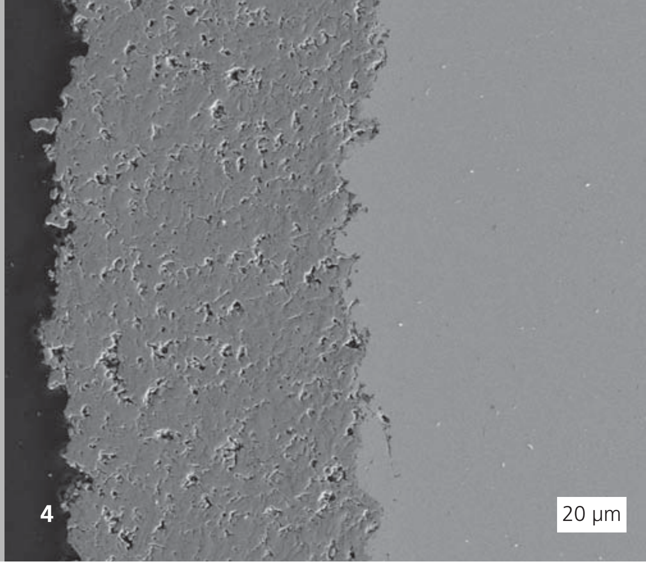
Nitride ceramics such as titanium nitride are characterized by a number of outstanding properties such as high wear resistance, excellent sliding properties, anti-adhesive properties, high biocompatibility and high-temperature stability. In addition, compact titanium nitride shows a pronounced metallic behavior, such as electrical conductivity. However, the high brittleness and the low ductility of titanium nitride are disadvantageous when used as monolithic component. In many applications the properties of conventional materials can be improved by ceramic coatings based on titanium nitride.

For this reason, Fraunhofer IKTS investigated how phase-pure nitride layers can be prepared by plasma spraying. This procedure offers the possibility to coat large components of complex geometries on an industrial scale cost-effectively as well as to improve surface resistance and quality of the substrate. Usually, nitride layers such as titanium nitride are made by vapor deposition. For the preparation of layers with higher film thickness, plasma spraying represents an economically advantageous method.

Generally, all nitride materials are subject to oxidation processes in oxidizing atmosphere and at high temperatures. In a first step, a plasma torch for a single cathode plasma spraying system in nitrogen plasma was designed. For the plasma torch a shielding gas envelope was developed and realized to prevent oxygen entry into the nitrogen plasma.

Only good free-flowing powders can be used for plasma spraying as coating materials to ensure a continuous material transport during the injection process. Research showed that none of the commercially available powders fulfills these requirements. Therefore, investigations were first limited to titanium nitride. By using spray granulation, good free-flowing titanium nitride granules were made from selected commercially available powders with a medium grain size between 1 and 10 µm. Thus, a grain size range between 40 and 80 µm was achieved. Trials for plasma spraying on stainless steel substrates were carried out with this powder. Attempts to optimize the process were carried out with and without inert gas. Furthermore, the process parameters such as plasma performance, plasma gas quantity, gas composition and spray distance were varied. The thermally sprayed layers were examined in terms of their chemical composition and their structure. X-ray diffraction investigations showed that no significant oxidation reactions occurred during the process. The coatings produced by plasma spraying showed quite the same mineralogical composition as the ceramic coating powder (diagram). In addition, the substrate adhesion and the structure (thickness, layer structure, porosity and cracking) of plasma-sprayed coatings were analyzed by FESEM investigations on a polished cross section (Figure 3). A relatively high porosity was expected due to the large grain size and the grain size distribution of the granules, which was confirmed in the FESEM graphs. The best layers had a uniform porosity, a good adhesion to the substrate and no macroscopic cracks. In addition, the mechanical and chemical properties of the layers and relating to the quality of the powder and spray parameters were investigated. Further optimization of plasma spray parameters and a revision of the shielding gas envelope are necessary for conventional use.

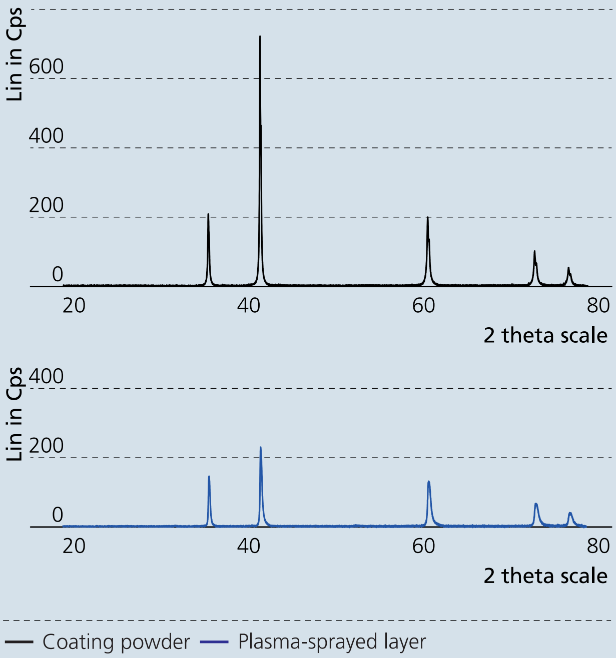




Services offered

- Development of plasma-sprayed layers and there characterization in terms of morphology, physical and chemical properties, as well as testing of there lifetime
- Coating of components of different sizes and geometries using the following facilities:
  1. Coating plant for small components with dimensions of 10–300 mm in length and 5–120 mm in diameter.
  2. Universal coating system for components with dimensions of 2400 mm in length, up to 500 mm in diameter and a maximum weight of 1 t.
  3. Universal coating system for components with dimensions of 7000 mm in length, up to 700 mm in diameter and maximum weight of 1 t. The system can also be used for surface coating of flat components with dimensions of 10–200 mm x 10–1000 mm and a maximum weight of 20 kg.

Titanium nitride X-ray diffraction diagram of the coating powder compared to the plasma-sprayed layer

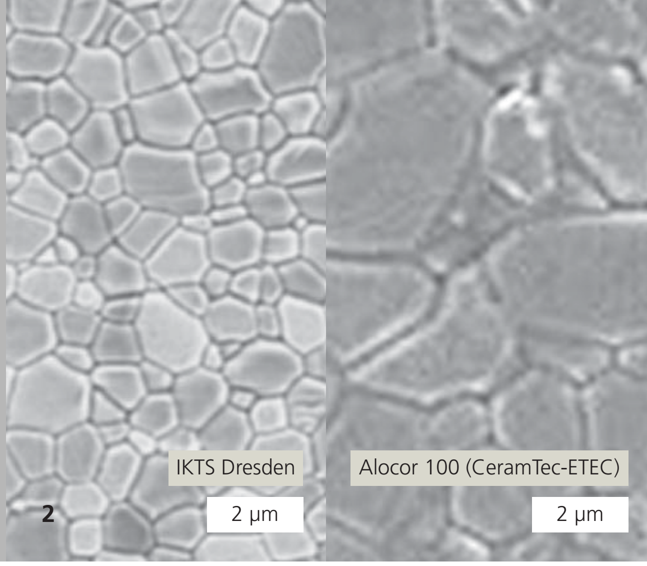


1 Plasma coating system for components up to 5 m in length.

2 Components with different, plasma-sprayed ceramic coatings.

3 FESEM of a faulty titanium nitride layer on a stainless steel sample.

4 FESEM of a phase-pure, good adhesive titanium nitride layer on a stainless steel sample.



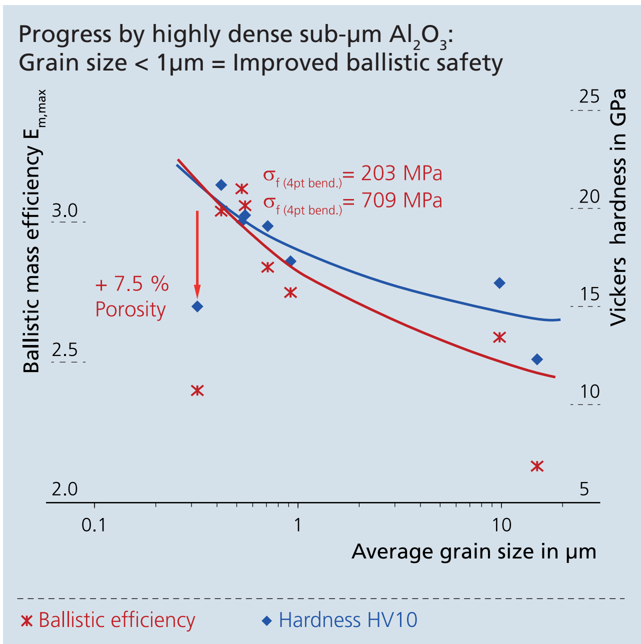
SECURITY BY CERAMIC ARMOR: A GUIDE TO THE TOP

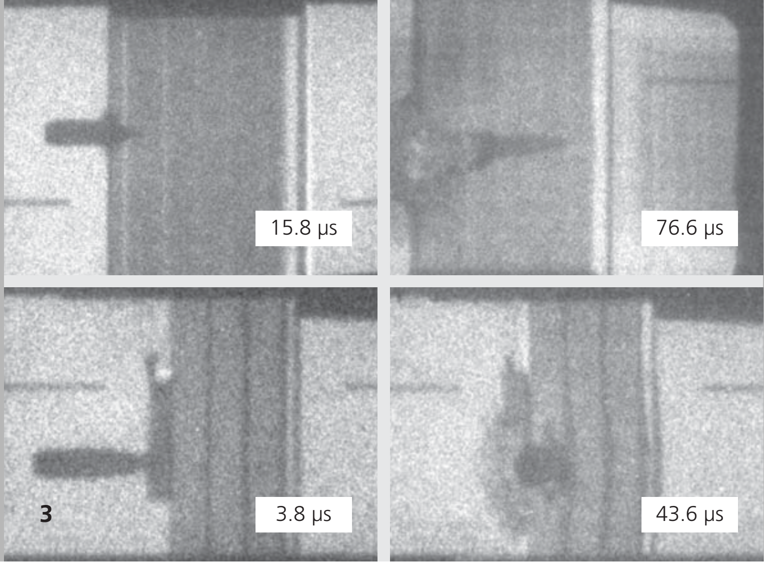
Dr. Andreas Krell, Dipl.-Ing. Thomas Hutzler, Dr. Jens Klimke

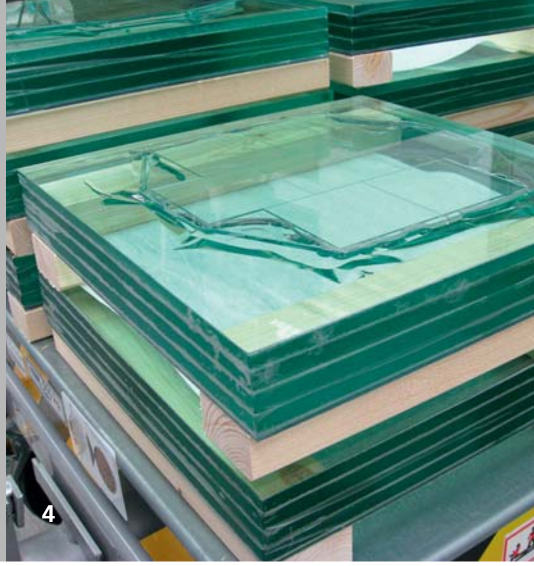
Today´s advertisements of armored cars commonly refer to the use of advanced ceramics by sentences as "Ceramic...materials have been inserted to reduce the excess weight of the armored vehicle and provide the security..." (Mercedes). Typically, the composite design contains a ceramic layer on a metallic substrate (backing) and an outer cover as splinter protection. For transparent windows the backing is made of glass. The special benefit provided by ceramics comes from their failure: their hard and sharp debris abrade the penetrator almost completely. Thus, the final effect of ceramic armor on the penetrator is the same as that of the ceramic grinding grits developed at IKTS Dresden (cp. "Impact resistant oxide ceramics for tools"; p. 50–51). Only a few millimeters of sintered ceramics enable a stronger protection than thick rolled armor steel or than 10 cm thick glass with an areal weight of 150 kg/m^2.
Furthermore, ceramics may reduce the total weight of the ceramic/backing composite by about 50% – with associated benefits for the mobility, range, and safety of car and people. This understanding of the mechanisms of the protective effect explains why with smaller grain sizes the increasing hardness of ceramics also improves their ballistic resistance – whereas, on the other hand, finer microstructures are useless when achieved on the expense of lower sintering and associated with some residual porosity and, therefore, a lower hardness (diagram on the right). Likewise it becomes understand- able why the change of the strength by more than a factor of 3 is without consequence for the mass efficiency of the ceramic armor: we need its failure for an optimum abrasive effect.

The understanding of the importance of a fine grain size and high hardness of the ceramics for further weight reduction and improved safety reliability has enabled first commercial products (Figure 2).
However, our investigations performed together with Fraunhofer EMI also show that hardness only is insufficient as "guide to the top". The finally decisive factor is always the abrasive power of the ceramic debris (Figure 3), i.e. its own mode of fragmentation which governs shape, size and mass of the ceramic particles that abrade the penetrator. On the basis of our investigations it is now possible to determine,

- how ceramic fragmentation can be optimized not only by its intrinsic properties (also by intentionally introduced defect populations) but also by an appropriate selection of the backing, and



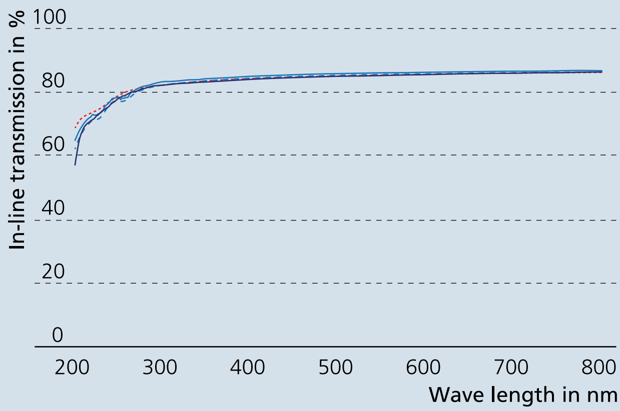




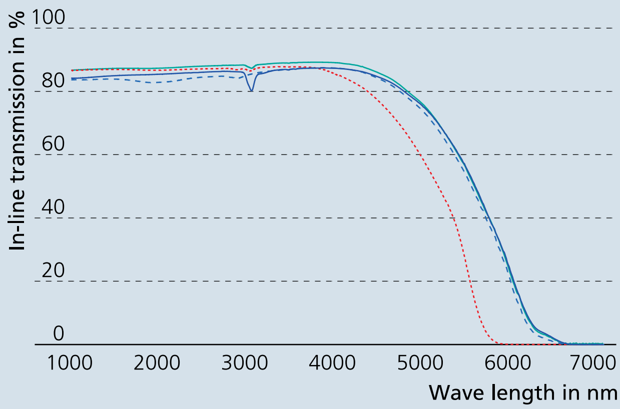
- under which fracturing conditions of the ceramics their general advantage of high hardness and Young´s modulus will contribute to an improved protection – or will be lost.

Another aspect of security is the use of special transparent ceramics for advanced viewing optics, e.g. in periscopes with multi-spectral performance. For spinel ceramics made by Fraunhofer IKTS Dresden the neighboring diagrams give evidence of a transparency from ultra-violet through the visible range up to infrared on a level comparable to the best single crystals. An example of a manufacturing approach is given by the article about gelcasting of transparent spinel ceramics in the Materials and Processes section on p. 36–37.

Broad-band transmittance of spinel ceramics by Fraunhofer IKTS Dresden from ultraviolet to infrared



Single crystal (Saint Gobain, n = 2.7) Thickness ~ 4 mm
IKTS spinel ceramics (n = 1–2.5)



Single crystal (IKZ Berlin, n = 1.0) Thickness ~ 4mm
Single crystal (Saint Gobain, n = 2.7)
IKTS spinel ceramics (n = 1.0–1.3)

Services offered

- Armor ceramics with defined properties as well as development and delivery of complete ceramic/backing composite targets (Figure 4) for specific tests
- Evaluation of ceramic armor in cooperation with Fraunhofer EMI
- Consulting with regard to appropriate materials and design of ceramic/backing armor composites

1 *German cars with ceramic armor. Mercedes S600 and Fennek armed reconnaissance vehicle of the Bundeswehr (Source: bundeswehr.de).*

2 *Microstructures of advanced opaque Al_2O_3 armor: IKTS demonstrator (0.55 µm grain size) and first commercial product (0.85 µm grain size).*

3 *Abrasive destruction of penetrator by few millimeters of transparent IKTS ceramics (lower photos) compared to laminated glass without ceramics (above) (Source: Fraunhofer EMI, all given with same scale).*

4 *Manufacture of transparent ceramic/glass composite targets at Fraunhofer IKTS.*

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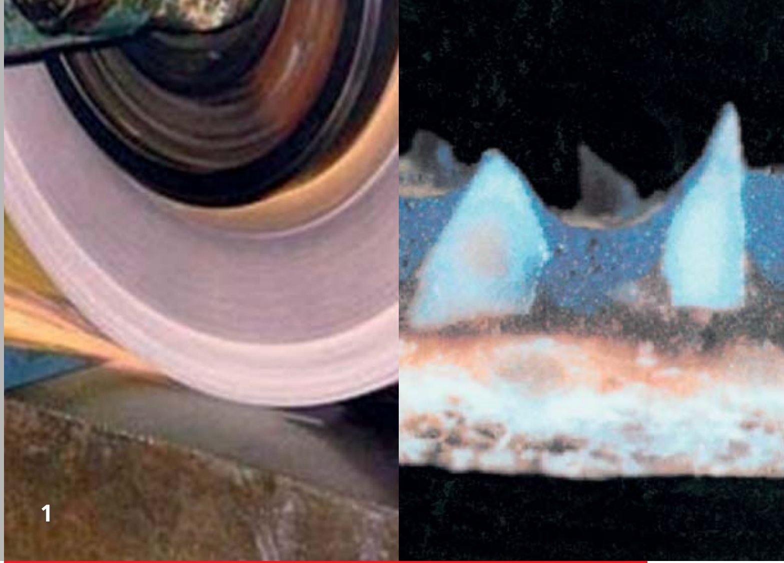
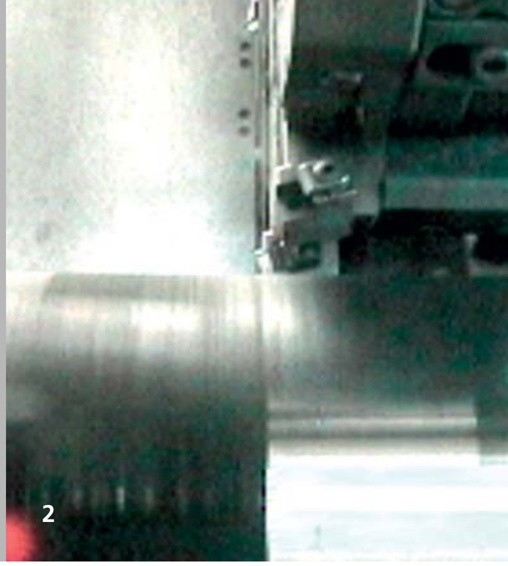




MECHANICAL AND AUTOMOTIVE ENGINEERING

IMPACT-RESISTANT OXIDE CERAMICS FOR CUTTING TOOLS

Dipl.-Ing. Thomas Hutzler, Dr. Andreas Krell, Dr. Jens Klimke

Ceramics, even so called "fracture-resistant" ceramics, are always brittle and thus are considered as a less impact-resistant material. In some cases, it is possible to counteract this property by a ceramic-compatible design. However, this method fails if a tool is directly subjected to impact stress and if just this tool has to be made of ceramics and not from metal due to the high demands on hardness, abrasion resistance, high-temperature resistance and chemical inertness against the workpiece material. Oxide ceramics and especially ceramics on the basis of sintered corundum (α-Al_2O_3) meet the mentioned ceramic-specific advantages in a special way, but belong to this group of structural ceramics which has the lowest "fracture toughness" values and should, thus, be particularly prone to impact stress.

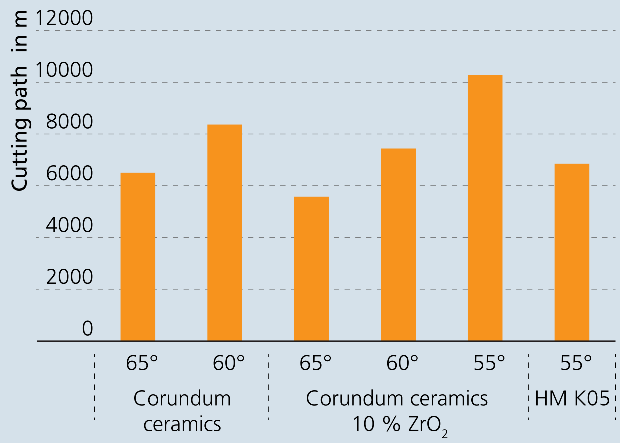
However, the latter deficit does not always apply as grinding tools prove which are subjected to enormous and thousand-fold impacts and thermal shock (Figure 1). The "Oxide Ceramics" group at Fraunhofer IKTS Dresden has been working in this field for more than 20 years. Research results show that it is possible to combine the above mentioned general ceramic advantages with a high impact resistance in single-phase Al_2O_3 ceramics if specific geometrical conditions (the technically usable strength depends on the size) are combined with the following specifications:

- High sintered density > 99 % (or residual porosity < 1 %),
- Mean particle size < 1 µm,
- Preferably a purity > 99% Al_2O_3. Some examples are shown in figure 1 to 4.

This not only allows for particularly high hardness values HV10 > 20 GPa, but also for minimal wear and chipping in the direct process zone of the cutting tool.

It is not always necessary to achieve the highest possible hardness, e.g. for specific grinding processes or the machining of particularly abrasive, but rather soft chipboards or fiber Boards. The following diagram shows the tool life of submicrometer cutting ceramics with different cutting wedge angles in comparison to standard hardmetals.

Maximum cutting path length of sub-µm IKTS cutting ceramics in milling laminated chipboards
(Source: TU Braunschweig, IFW)



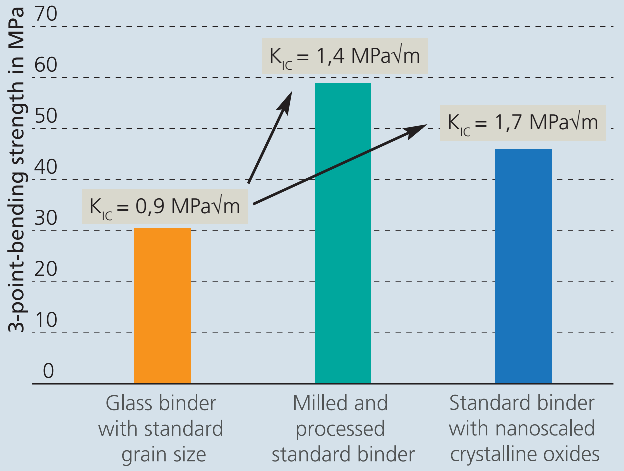
According to the particular machining process, Fraunhofer IKTS developed multiphase oxide ceramics based on Al_2O_3, the properties of which are modified by the following:

- Transformation-strengthening effect of ZrO_2 additives,
- Effects of non-isometric microstructural constituents,
- Improved machining effectiveness by a specific design of the ceramic aggregate.

However, it is often not sufficient to only consider the tool components which are "active" during the machining process. For composite tools such as grinding wheels, in particular, it is absolutely necessary to consider all material components involved in the cutting process. Within the framework of application-related research already lasting for several years, comprehensive material and technological competencies were gained in the manufacturing of grinding wheels.

Based on commercially available abrasive particles and bond constituents, Fraunhofer IKTS succeeded in significantly improving the mechanical properties of the grinding wheel by a specific modification of the mainly amorphous bond. By means of a specific milling process highly disperse, homogeneous bond powder mixtures are realized. Due to their better flow and wetting behavior during the sintering process, the abrasive particles can be better embedded into the bond of the grinding wheel. As a result, for example, the bending and fracture strength of the grinding wheel is doubled. Similar positive effects can also be achieved without using a specific milling process. Instead, nanoscaled crystalline oxide particles are added (see diagram on the right).

Grinding wheels with improved mechanical properties due to modification of bond components



1 Grinding of metal, left: grinding wheel, right: polycrystalline Al_2O_3 ceramic particle in abrasive belt.

2 Turning of hardened steel with interrupted cuts using single-phase Al_2O_3 cutting ceramics of Fraunhofer IKTS Dresden.

3 Milling of abrasive chipboards (based on wood): cutting tool with integrated ceramic cutting edge.

4 Test with cutting edge made from sub-µm Al_2O_3 (Fraunhofer IKTS): after milling a steel screw.

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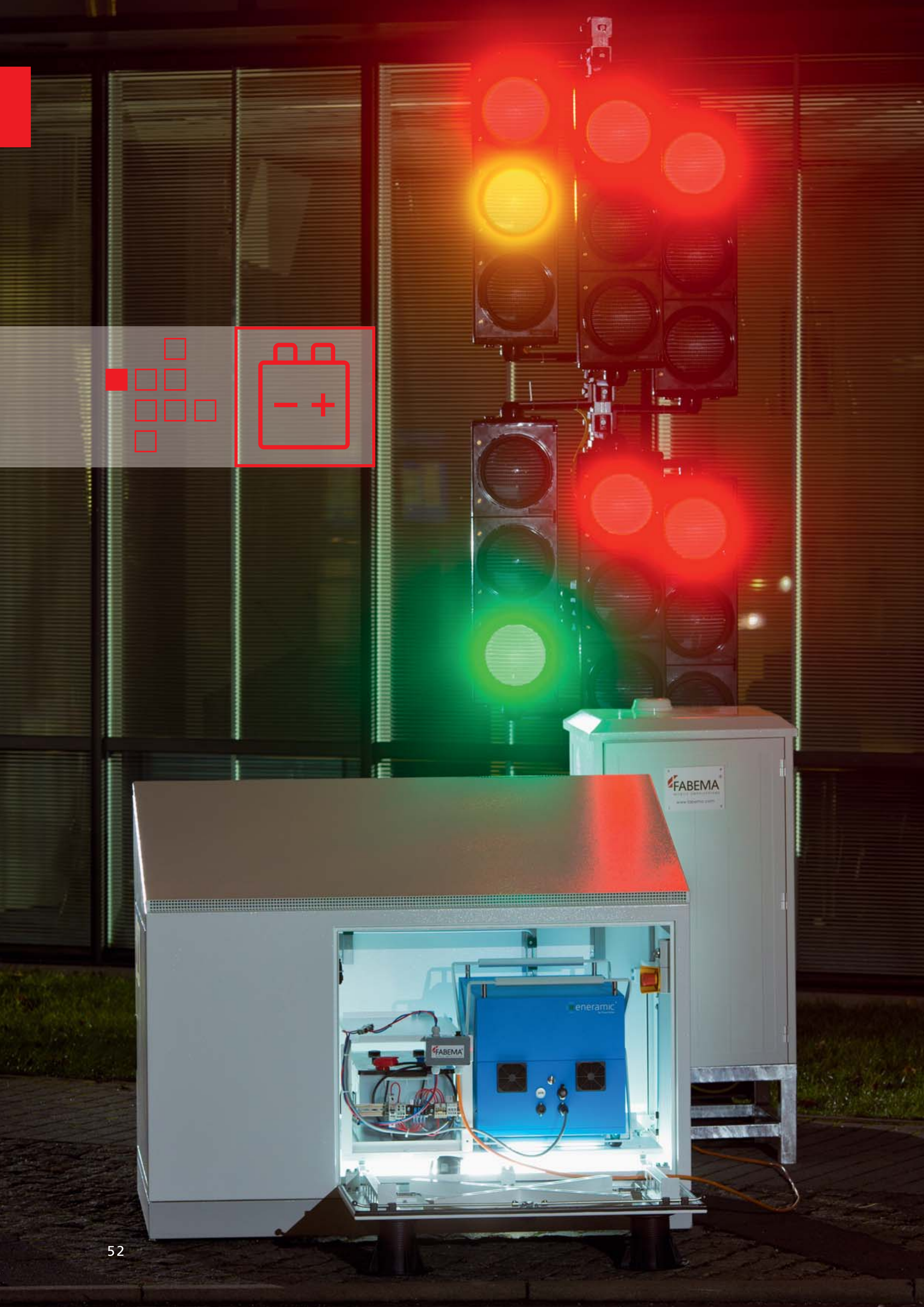
FABEMA
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DIVISION

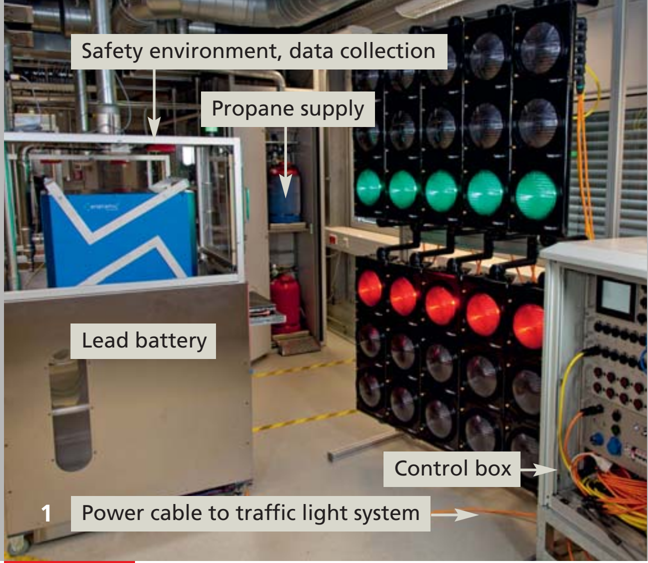
ENERGY

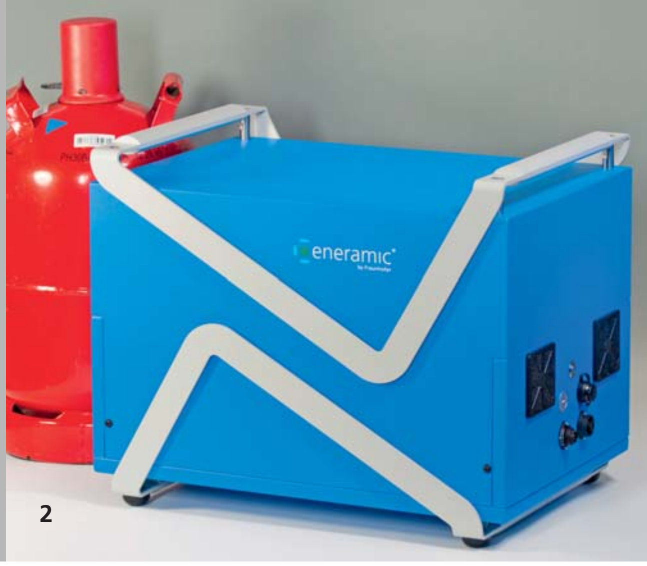
Project reports

In the "Energy" division, we engineer, build, and test innovative components, modules and complete systems – based on ceramic materials and technologies – in the primary fields of application: battery technology, fuel cell systems, thermoelectric generators, photovoltaics, energy harvesting as well as gas turbines. At the Institute, in addition to energy conversion, we also examine such issues that focus on the processing of biomasses, production of biofuels (also using electrical energy for hydrogen production) and the efficient use of bioenergy in energy conversion systems, which results in close collaboration between the "Energy" and "Environmental and Process Engineering" divisions.

The transition to a sustainable energy supply is one of the key tasks in the 21st century. To achieve a successful energy transformation, renewable and conventional energies must be developed that are financially able to compete and are highly efficient, taking environmental aspects into account. With regard to the transformation and storage of electric and thermal energy, both the robustness and the lifetime of the systems are relevant, as well as their economic production costs.

As a full-range service provider (or "one-stop shop"), Fraunhofer IKTS has a comprehensive overview of these problems which forms the basis for innovative solution approaches that promise competitive advantages precisely in the dynamic market segment of energy production and storage. In order to ensure cost-effective use of specific characteristics of innovative ceramic components in a systems context, materials and component parameters are simulated and then optimized for integration into energy converters and systems. We are actively able to bridge the gap between component and systems engineering, in order to enable an accelerated transfer to the application. In cooperation with industry partners, Fraunhofer IKTS operates multiple technical systems in which entire process chains for modern production are mapped, and developed materials and processes can be tested and optimized with customers in the semi-industrial environment.





ENERGY

eneramic® – START OF THE COMMERCIALIZATION

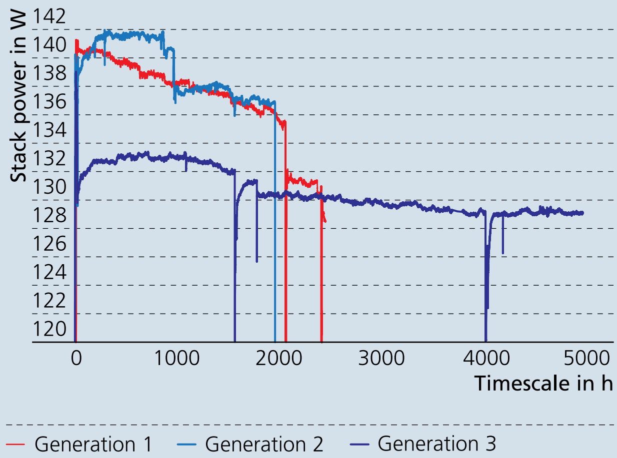
Dipl.-Ing. (FH) Sebastian Reuber, Dipl.-Ing. (FH) Jens Baade, Dr. Christian Wunderlich

Under the trademark of eneramic®, Fraunhofer IKTS has developed a complete, SOFC-based technology platform for mobile power supply from commercially available liquefied petroleum fuels (LPG). Starting from the vision of an efficient and robust off-grid power supply device and based on the wide range of SOFC competence of Fraunhofer IKTS, a new, patented system solution in the power range from 50 to 500 W_{el} was developed with financial support of the Fraunhofer Future Foundation. During the technological development phase, the demands of potential entry-level markets were defined for the first prototypes with the help of industrial partners. Now, the system is going to be tested under real life applications. The test experiences will be considered in the first eneramic® product which will be commercially available in 2015.

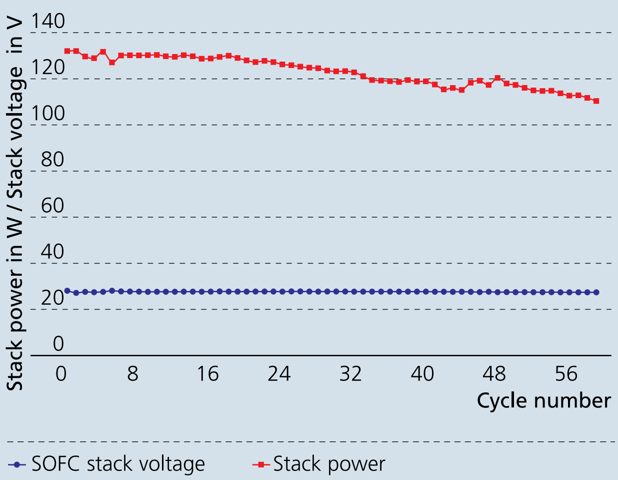
Development status of the technology platform

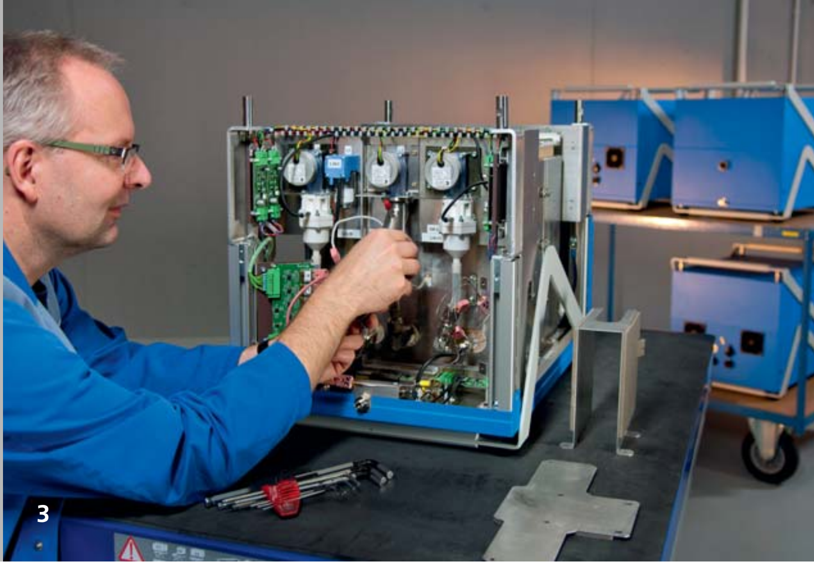
The prototypes have repeatedly shown a high degree of maturity in the laboratory scale. Stationary long-term tests of the system platform up to 5000 hours show little losses due to aging, and offer advantages over competitive technologies such as lead batteries. In the meantime, the third generation has a performance degradation of less than 1 % per 1000 hours. So, the requirements with regard to lifetime (10,000 hours with P_{el} > 100 W) can be met. Considering the start-stop capability, the lifetime of the system prototypes has been enhanced up to 65 cycles with low power losses by adjusting the operation mode (Figure 2). The prototypes are assembled using reliable and reproducible processes including the necessary quality assurance for the components and complete systems.

Comparison of different system generations in terms of operation-related power losses



Power losses of the prototypes due to SOFC ageing during start-stop cycles





Field test phase

As battery hybrid, the system is suitable for different leisure and industrial applications, and represents an efficient and long-living alternative to existing technologies as well as other fuel cell types. In 2014, the promising results obtained from tests in the laboratory and outdoor will be validated for different entry-level markets by means of field tests. For this purpose, the eneBox (figure 4) was built containing the gas bottles and buffer batteries. Additionally, it is a protection against vandalism and other outside influences.

Start of the commercialization

Within the scope of technology development, the requirements for the commercialization of the technology and potential products were extensively evaluated. The analysis included:

- Technical and functional specifications for commercial standard products as basis for the evaluation of maturity and as development interface of the market needs
- Market segmentation and analysis
- Comparison with competitors
- Consideration of value chains and make-or-buy decisions in the production process
- Design to cost – introduction of a value-engineering process to identify and analyze cost reduction potentials

As a result of the analysis it was found that the market segment of 100 W electrical power is a very attractive starting point for the market launch. Commercial standard products can be a cost-effective solution for off-grid power supply in this power range due to the selected LPG fuel, the good electrical efficiency, the long lifetime and the low maintenance costs.

1 *System lab-tests with traffic light application.*
2 *System prototype of the third generation.*
3 *Prototype production.*
4 *System demonstration during presidential visit of Mrs. Park.*

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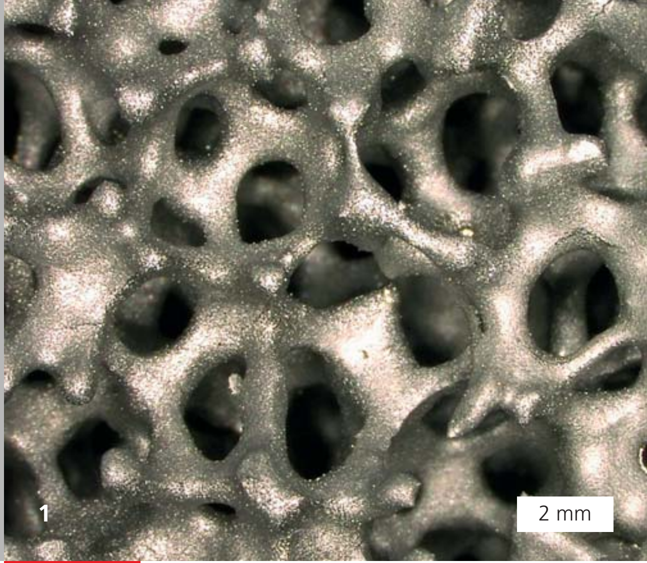
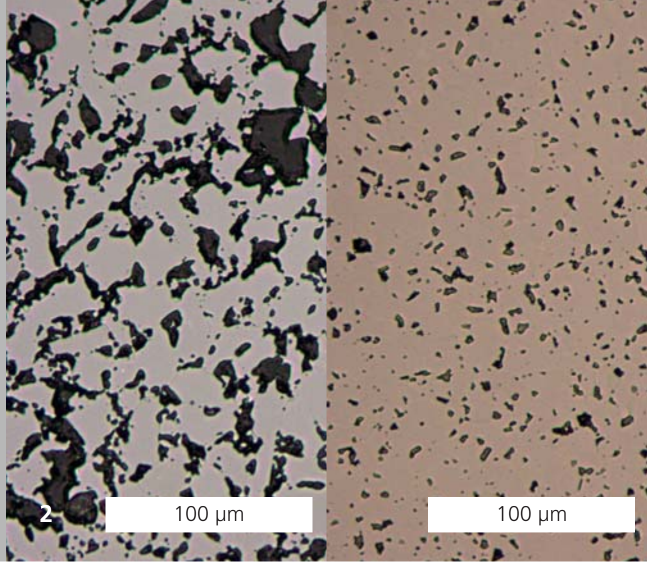




ENERGY

LONG-TERM STABLE CELLULAR SIC CERAMICS FOR COMBUSTION APPLICATIONS

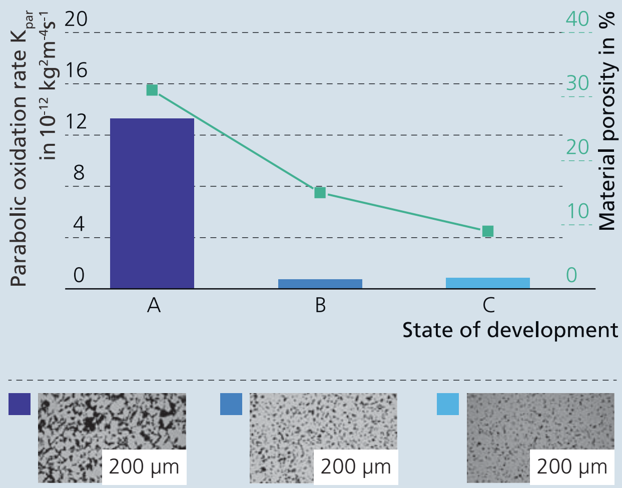
Dipl.-Ing. Alexander Füssel, Dipl.-Krist. Jörg Adler

Open-celled structures are of great interest for applications in chemical processing technology and especially for the combustion in porous media. To benefit from the advantages of this combustion technology, which has already been known for a long time, like high modulation capability, low pollutant emission and high power density, the used materials have to meet high requirements in terms of thermal and mechanical stability. For the application in porous burner, the mechanical stability over the entire operating time is of particular importance, since partial or complete failure of the structure may be critical for the periphery of the burner or the heated products in industrial drying applications.

Pressureless sintered silicon carbide (SSiC) is a well-proven high-temperature material. Due to the formation of a passivating silica layer at the surface, it can withstand high temperatures up to 1350 °C in oxidizing atmospheres over a technically relevant period of time. Using the replication technique developed by Schwartzwalder, open-celled ceramic foams can be manufactured from SSiC. They are usually characterized by a sufficient mechanical stability, but a high amount of microstructural porosity of up to 32 % as well. The resulting inner oxidation reduces the life-time significantly.

It is of great importance to avoid inner oxidation as the silicon dioxide occuring in the pores leads to mechanical stress and crack formation due to the different coefficient of thermal expansion, particularly under varying thermal stress. The effect of inner oxidation is connected to a fast degradation of the microstructure resulting in a loss of macroscopic strength of the ceramic foam. It was the aim of the further development of SSiC ceramic foams at Fraunhofer IKTS to increase the life-time. Based on a systematic adjustment of coating and heat treatment process, the amount of microstructural pores was reduced below 10 % (see diagram below).

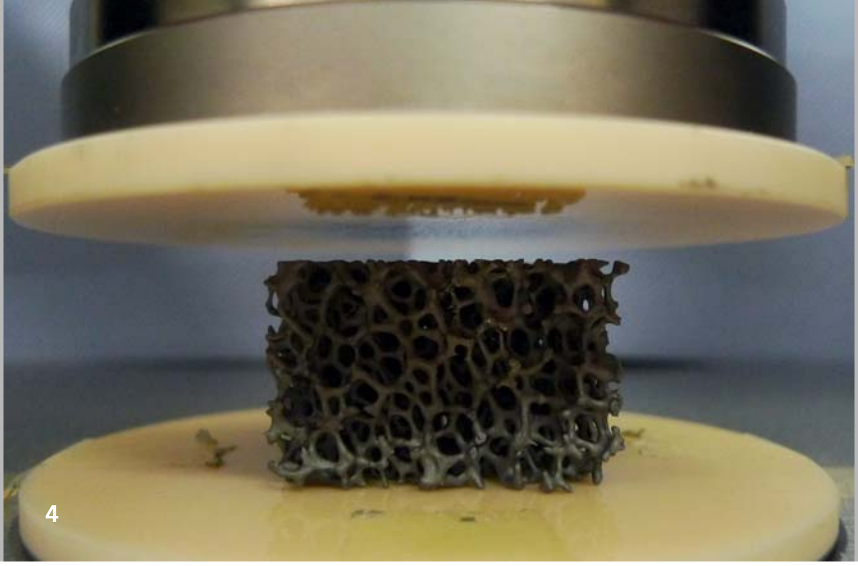
Variation of oxidation with microstructural porosity



Oxidation at 1200 °C in dry air.

Due to this development, the oxidation rates determined after oxidation in dry air at 1250 °C have found to be significantly reduced. In addition to the optimization of the microstructure, a second coating step was implemented into the processing route in order to enhance the mechanical stability of the ceramic foam.

In a project supported by the Free State of Saxony the influence of the oxidation time on the mechanical strength was



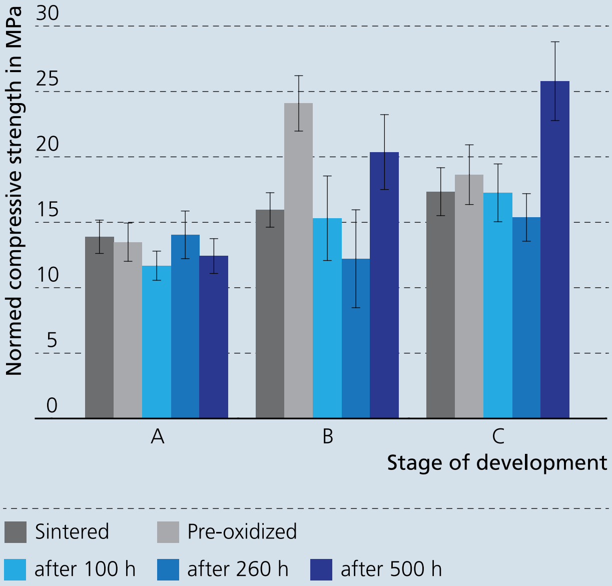
investigated at Fraunhofer IKTS. For this purpose, a newly developed test rig was used combining the gas flow and composition of a natural gas powered porous burner with the homogeneous temperature distribution of an electrically heated tube furnace. Samples of three stages of development were oxidized over a period of 100 h, 260 h and 500 h, each at a temperature of 1200 °C under nearly realistic porous burner conditions. No significant degradation of the mechanical strength was detected (see diagram). The determined oxidation rates are about $118*10^{-12}$ $kg^2m^{-4}s^{-1}$ for development stage A, $63*10^{-12}$ $kg^2m^{-4}s^{-1}$ for B and $5*10^{-12}$ $kg^2m^{-4}s^{-1}$ for C representing a reduction of the oxidation rate by two orders of magnitude from stage A to C.

Foams made of alternative materials (iron-chromium aluminum and alumina) failed in burner rig tests due to extreme oxidation or crack formation caused by thermal shock. SSiC ceramic foams, thus, are the most promising material for long-time application in porous burners. Future development will be focused on the behavior under thermal cycling and the optimization of the coating technique.

Services offered

- Development of ceramic foams for combustion applications and chemical processing
- Investigation of the material behavior at high temperatures in air and in combustion environments

Change of compressive strength after application in porous burner rig



1 Ceramic foam made of SSiC.

2 Optimization of the microstructure.

3 Burner test rig.

4 Compressive strength test.

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

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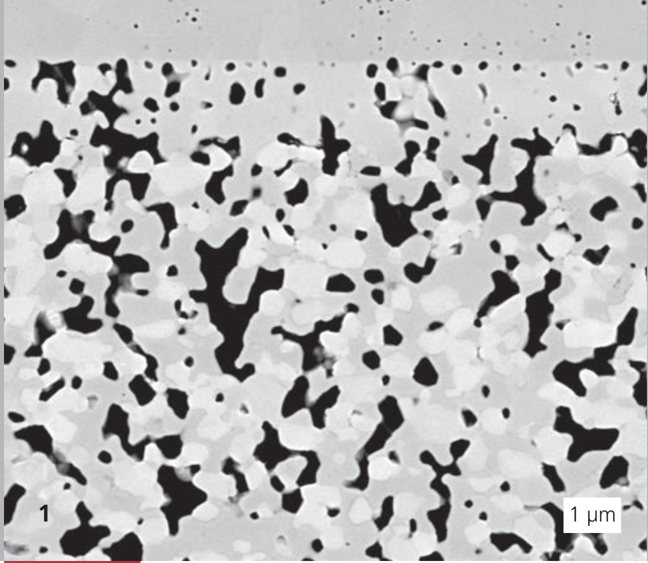

ENERGY

CFY STACK TECHNOLOGY FOR HIGH-TEMPERATURE ELECTROLYSIS

Dr. Stefan Megel, Dr. Nikolai Trofimenko, Dr. Mihails Kusnezoff

CFY stacks with electrolyte supported cells made of fully stabilized zirconia (10ScSZ) and CFY interconnects (Cr5Fe1Y) made by Plansee SE have proven to be robust and efficient in different systems. The stacks were easy to integrate into systems with a power range < 2 kW_{el}. For higher power ranges, stack modules were developed and handled as a single component for system integration. A natural gas powered, modular stationary SOFC system with an electrical output of > 5 kW_{el} was successfully tested in a joint project between German and Austrian companies. In the near future, power outputs of 20 kW_{el} are possible by connecting of stacks to modules.

By continuous development of the CFY stacks the long-term stability ($\Delta P/P0 = 0.7$ %/1000 h) and cyclability ($\Delta P/P0 = 1$%/ 10 thermal cycles) were improved and further improvements are expected in the future. The focus is set to a cost-effective production in order to reach readiness for mass production and to be competitive to conventional power generators. While the electrical power generation by SOFC systems with CFY stacks will be launched soon, high-temperature electrolysis is a key feature for the next generation of energy supply and distribution. The use of renewable energies like geothermal, water and biomass energy can be controlled and adjusted to the consumption, which it is not possible with tidal, solar and wind energy. In Germany, the share of renewable energies is currently about 20 % of the gross consumption electricity (source: BMWi 2013). Because of the difference between energy consumption and occurrence of renewable energies the complex control has to secure grid stability. In 2020, the renewable energies will expand to more than 35 %, which will lead to an increased discontinuity of the grid. By smart controlling of thermal power plants, the discontinuity can be balanced, but storage for fluctuation power production will be needed. For the planned increase of renewable energies, energy storage devices for excess electrical power will be essential. Storing electrical energy into batteries is good for short term but for long-term storage only chemical energy is a possibility.

The existing gas grid has the potential to store the excess of energy. For conversion of excess electrical power into hydrocarbons, high-temperature electrolysis (SOEC) is suitable. It has a lower specific energy input than alkali electrolysis, which is operated at temperatures under 120°C. By using high-temperature heat an allothermal SOEC operation with a further reduction of energy consumption is possible.

The existing CFY stack technology suits perfectly for electrolysis operation. The I-V curves of a 30-cell stack are shown in the diagram and have a linear behavior over a wide temperature range up to high current densities from 700 to 850°C. The area-specific resistance (ascent of the I-V curve) in the SOEC mode is equal to the SOFC mode, which shows the possibility of bi-directional operation. Special investigations of cells, the cathode contacting and the delamination of the cathode show that contacting has a main impact on degrada-

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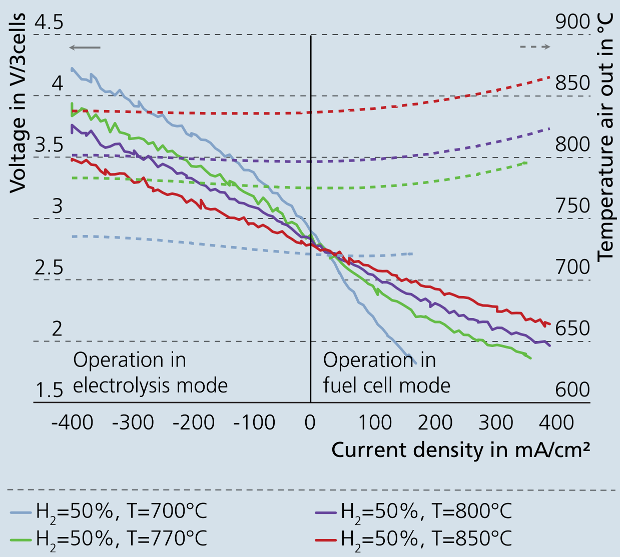
tion. Particularly high current density increases the degradation rate. New pastes for contact layers were developed and tested at cell and stack level. It is expected that all components can be optimized for long-term stable electrolysis operation.

I-V curves of a 30-cell CFY stack in a furnace in SOFC and SOEC operation, air: 100 sl/min, η_{FU_end}=0,75% (electrolysis)



The existing know-how at Fraunhofer IKTS in the development of cells, pastes and sealing glasses enables fast cycles for design and material iterations. The development of single components and the efficient assembly of modules with several stacks enables a fast upgrade to SOEC modules which is essential for future storage technologies.

Services offered

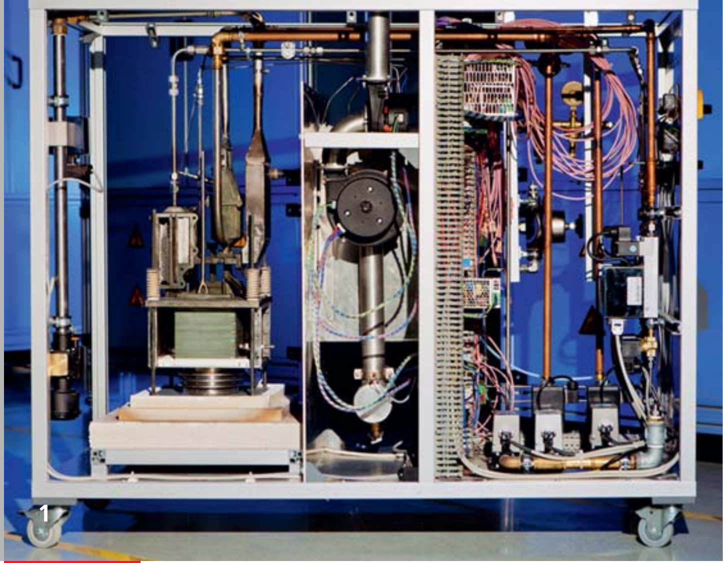
- Test of components in stacks under real SOFC/SOEC conditions
- Integration of stacks into modules
- Supply of SOFC/SOEC stacks or modules in the power range of up to 10 kW_{el}

1 Optimized structure of a cathode from Fraunhofer IKTS.

2 Assembly of CFY stacks.

3 New lab for stack sealing, initialization and preparation for shipment.

4 Module of eight 30-cell stacks in the test rig at Fraunhofer IKTS.



ENERGY

SYNTHESIS GAS FROM BIOMASS FOR MATERIAL AND ENERGY UTILIZATION

Dr. Matthias Jahn, Dipl.-Chem. Dorothea Männel, Dipl.-Ing. (FH) Erik Reichelt

Motivation

Due to the finite nature of fossil ressources, the material and energy utilization of biomass is of growing interest. Anaerobic fermentation for biogas production is a widely-used and established process. But coupling with a gas engine CHP ($\eta_{el} \approx 38$ %) leads to an overall electrical efficiency of just about $\eta_{el} \approx 25$ %. Thus, the objective of process and reactor development at Fraunhofer IKTS is to make novel efficient conversion processes for material and energy utilization of biomass applicable. A key step of the process chain is the synthesis gas production from biomass.

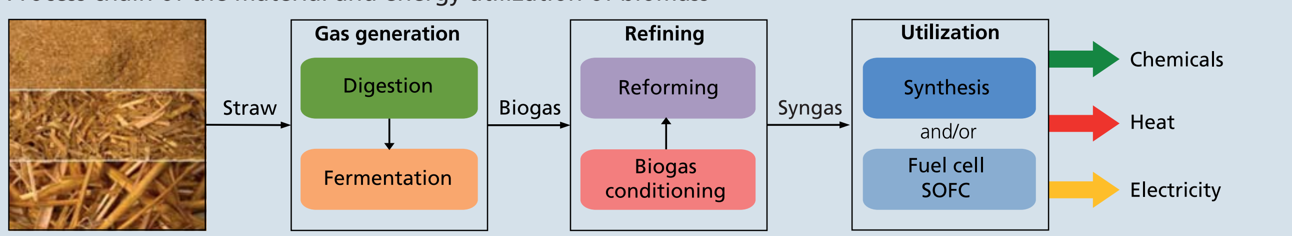
Process development

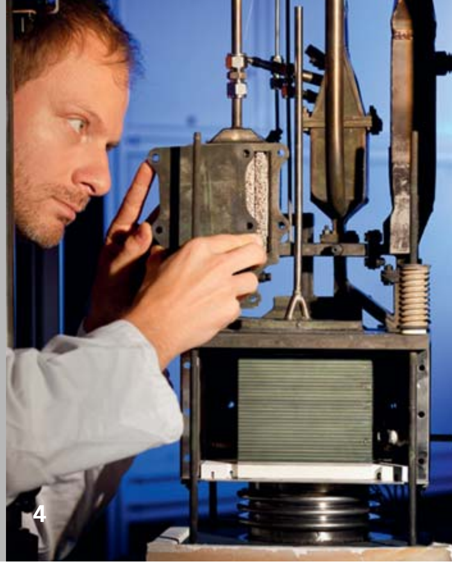
First step of the process chain is the production of biogas by disintegration and fermentation and the subsequent conditioning of raw biogas. By means of a novel process, residues with high lignocellulose contents that are difficult to degrade, e.g. straw, can be utilized for wet fermentation.

In the reforming step, purified biogas is converted to synthesis gas. Without an additional carbon dioxide separation step, it is possible to yield a synthesis gas rich in hydrogen and carbon monoxide by catalytic partial oxidation. This is a cheap and easy reforming procedure. This step can be conducted at low air ratios $\lambda < 0.1$, and thus, a combination of partial oxidation and the so-called dry reforming is achieved. Because of the highly endothermic nature of this process step, heat integration of the reformer is of great importance for system development.

Component	Range of variation
Methane	37–75 %
Carbon dioxide	25–50 %
Nitrogen	0.01–17 %
Oxygen	0.01–2,6 %
Hydrogen sulfide	0.002–2 %
Ammonia	0.01–3.5 ppm
Water vapor	100 % relative humidity
$\vartheta = 20$ °C, p = 101,3 kPa	3.1 %

Process chain of the material and energy utilization of biomass





Material and energy utilization

A direct energetic utilization of the produced synthesis gas is possible by generating electricity in a solid oxide fuel cell (SOFC). In comparison to conventional electricity generation in combustion engines, an electrical efficiency of $\eta_{el} > 50$ % can be achieved. Therefore the overall efficiency based on the chemical energy of the biomass can be increased to $\eta_{el} \geq 35$ %. In addition to the generation of electrical energy, heat on a high temperature level can be provided and utilized.

Besides direct energetic utilization chemical storage of energy is another possible route, e.g. by conversion of synthesis gas into long-chain hydrocarbons by Fischer-Tropsch synthesis. Using this process, fuels like diesel or gasoline as well as important platform chemicals can be produced. Here, carbon dioxide separation is also not necessary what leads to an increased efficiency of the process.

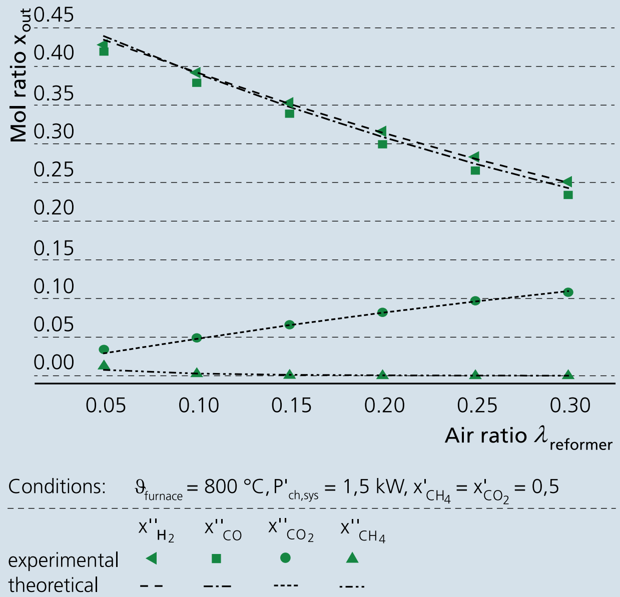
Advantages of the process

In contrast to other processes for biomass utilization like pyrolysis or gasification, synthesis gas production via the fermentative route leads to less harmful byproducts and lower clean-up efforts, and thus, to an increased efficiency. Moreover the digestate produced can be utilized as a product in agriculture. The process developed at Fraunhofer IKTS also offers the advantage that carbon dioxide does not have to be separated from biogas, because it can be used as a reforming agent for synthesis gas production. This synthesis gas has high hydrogen and carbon monoxide fractions of $x_{H2} = x_{CO} = 40$ %, thus offering a high specific energy content that is suitable for chemical synthesis.

Services offered

- Process and reactor design
- Multiphysics simulation of chemical and electrochemical processes and reactors
- Development and operation of systems
- Chemical reactor analysis
- Development of catalyst and ceramic support materials as well as full ceramic reactors
- Long-term stability tests for components and systems
- Analyses of gases and liquids (FID-GC, WLD-GC, PFPD-GC and GC/MS)

Comparison between experimental results and thermodynamic equilibrium



1 Biogas fueled SOFC system.

2, 3 Application of the system for energetic utilization of sewage gas.

4 System components.

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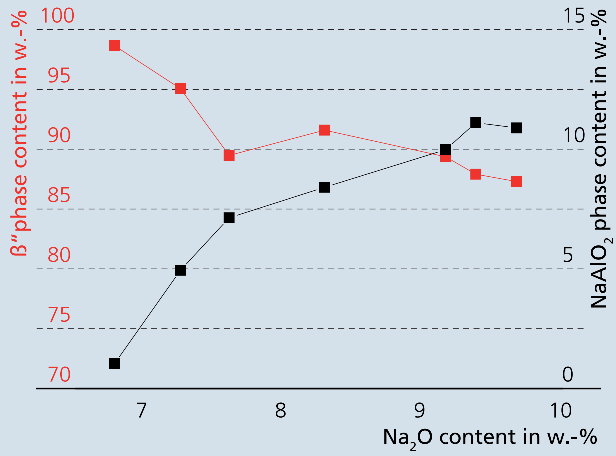
ENERGY

ß“-ALUMINA CERAMICS FOR $Na/NiCl_2$ BATTERIES

Dr.-Ing. Matthias Schulz

Stationary energy storage in the MWh range has to be inexpensive and durable. High-temperature batteries, such as $Na/NiCl_2$ and Na/S, are based on the ion conducting sodium ß”-alumina and can be manufactured economically with strategic abundant raw materials. Due to their high energy density and their possibility to realize safe and large systems, $Na/NiCl_2$ batteries are highly attractive. In order to establish this battery type for stationary applications, Fraunhofer IKTS implemented a long-term project. The cell performance and the economy is predominantly influenced by the ceramic sodium ß”-alumina solid electrolyte. Fraunhofer IKTS develops this core component with a focus on material science, production engineering and quality management.

ß“- and $NaAlO_2$ phase content at 1300 °C of calcined sodium ß“-alumina



Ceramic synthesis of sodium ß“-alumina

Research activities regarding $Na/NiCl_2$ batteries started at Fraunhofer IKTS about two years ago with a focus on the synthesis, the shaping and the sintering of sodium ß”-alumina. Variations of the raw materials and the chemical composition were carried out in the lab and the semi-pilot scale to realize a micro crystalline and dense ceramic structure with a high ß”-phase content. Beside different stabilizing elements, the Na_2O content was systematically modified towards an optimizedsynthesis. Undesirable phases such as ß-alumina and $NaAlO_2$ were largely eliminated. Figure 1 illustrates the phase content of calcined materials with different Na_2O content of the raw materials.

Shaping and sintering

Based on free-flowing granules, discs with different diameters and thicknesses were formed by uniaxial dry pressing. At present, one-side closed tubes with diameters between 20 up to 30 mm and lengths of about 120 mm are manufactured by isotactic pressing. The density of the sintered ceramic bodies amounts to more than 97 % of the theoretical value. A fine and microcrystalline low defect structure with strengths of 200 MPa were reached.

An economic analysis revealed low target costs for the ceramic part that cannot be realized by conventional ceramic processing. Based on its ceramic competence, Fraunhofer IKTS is on the way to explore innovative ceramic technologies to realize production rates of above 100,000 pieces per year with an automated in-line quality management.

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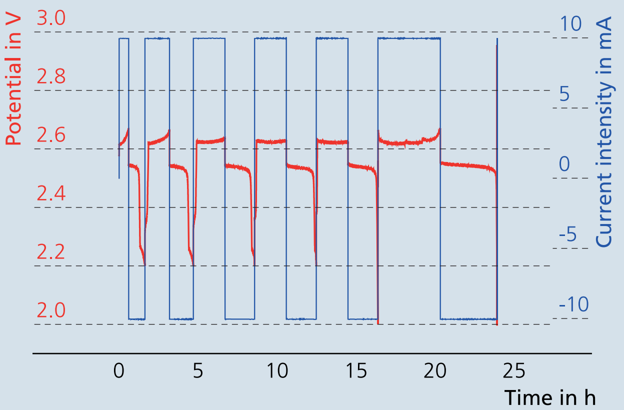
High-temperature cells and electrochemistry

The performance of $Na/NiCl_2$ batteries is significantly defined by the electrochemical properties of the ceramic sodium ß"-alumina electrolyte. Particularly, the sodium ion conductivity is an important limiting parameter. To determine this characteristic variable, several methods and corresponding high-temperature test cells are available. In addition to high-temperature solid state impedance analysis, DC resistance measurements are carried out in symmetric sodium/sodium test cells. The allover performance and the stability of the ceramic electrolytes is investigated in $Na/NiCl_2$ cells. Therefore, the sodium ß"-alumina is joined to a recipient, assembled in test cells and treated with cyclic charge/discharge experiments. Figure 2 exemplifies some charge/discharge cycles of a planar $Na/NiCl_2$ test cell at 300 °C. Optimized designs for stationary energy storage by $Na/NiCl_2$ batteries are going to be developed at Fraunhofer IKTS based on the lab-scale experiences.

Charge/discharge cycles of a $Na/NiCl_2$ test cell at 300 °C



Services offered

- Lab-scale synthesis of sodium ß" alumina up to quantities of 10 kg
- Pilot-scale powder and granules synthesis up to quantities of 100 kg
- Manufacturing of discs and one-end closed tubes of ß"-alumina by uniaxial and isostatic pressing
- Sintering of sodium ß"-alumina electrolytes using sodium stable crucibles
- Characterization of sintered sodium ß"-alumina (phase content, structure, strength)
- Electrochemical determination of the sodium ion conductivity
- Characterization of planar and tubular sodium ß"-alumina electrolytes in $Na/NiCl_2$ cells

Acknowledgments

The presented results were obtained in a Thuringian research group, which was supported by funding from the European Social Fund (ESF) and the Free State of Thuringia.

1 Translucent Na ß"-alumina disc.

2 $Na/NiCl_2$ test cell and Na ß"-alumina disc joined to a recipient.

3 One-end closed Na ß"-alumina tube.

4 Na-covered sample after conductivity measurement.

ESF EUROPA FÜR THÜRINGEN EUROPÄISCHER SOZIALFONDS

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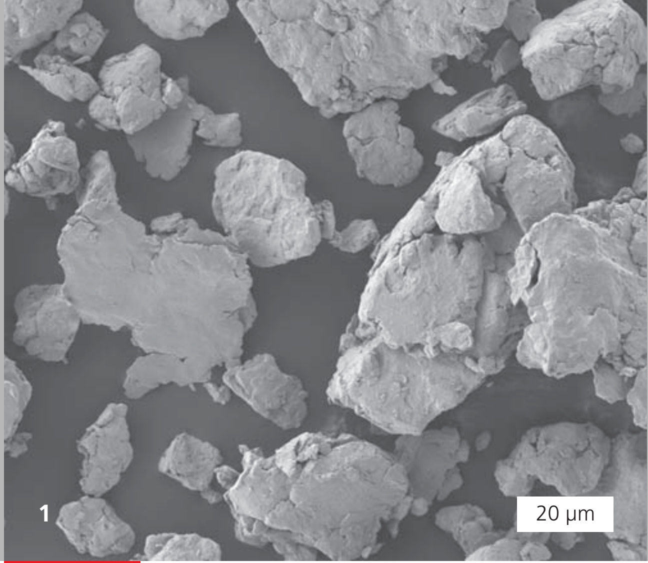
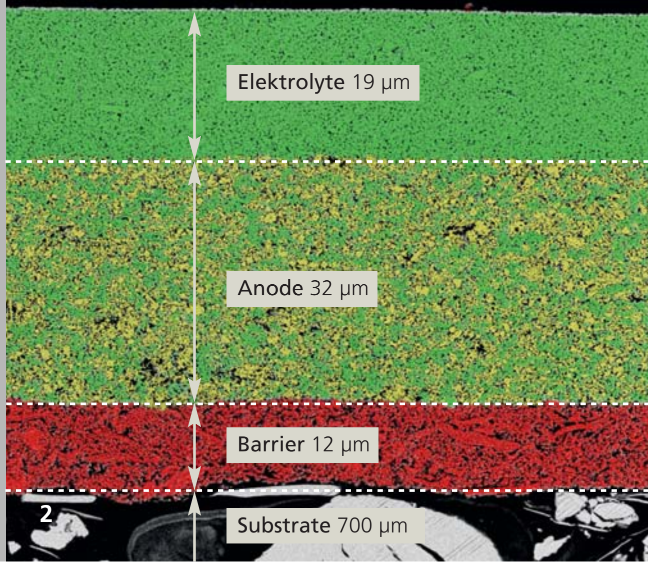




ENERGY

METAL-SUPPORTED FUEL CELL MADE BY PAPER TECHNOLOGY

Dipl.-Ing. Tim Slawik, Dipl.-Ing. Charif Belda, Dr. Roland Scholl, Dr. Tassilo Moritz, Dr. Mihails Kusnezoff

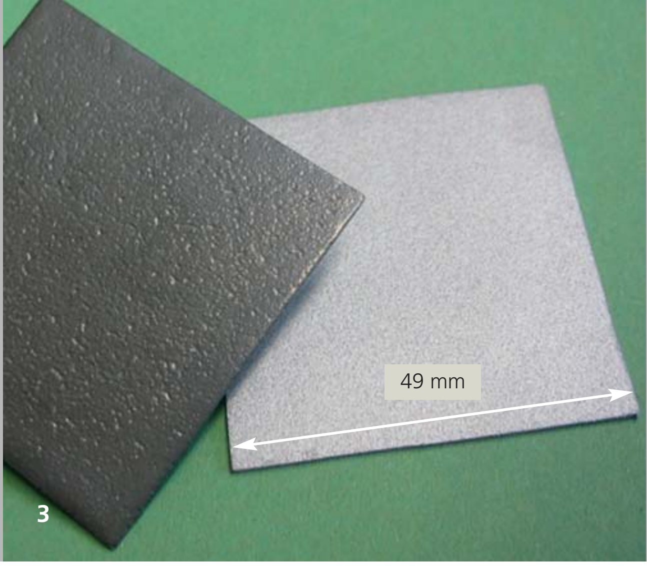
The metal-supported high-temperature fuel cell (MSC) is a promising and cost-effective supplement to ceramic high-temperature fuel cells. The manufacturing process of MSCs typically includes a sequential assembling of commercially available components (porous metal substrate, electrolyte) and functional layers (barrier, anode). This approach demands different joining and coating techniques and several thermal treatment processes. As the manufacturing process consists of very different technologies with separate thermal processes, it is very difficult to automate the manufacturing process. Thus, necessary cost savings can only be achieved by reducing the processing steps and adjusting the manufacturing techniques.

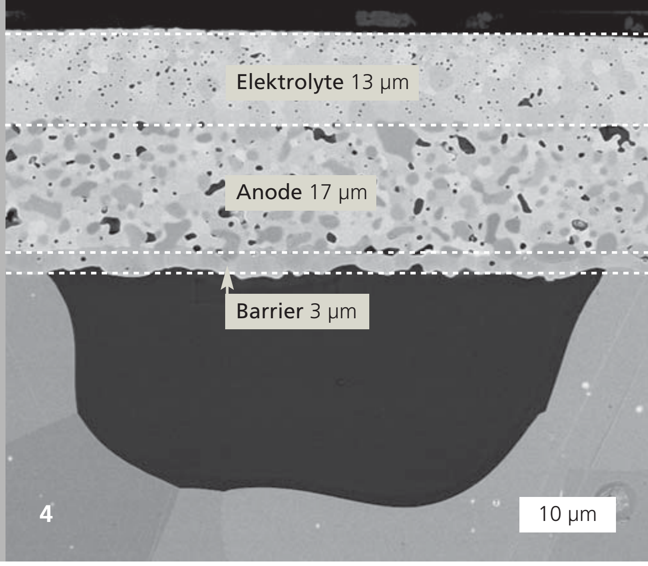
A very important step was achieved by simultaneously processing metal, metal-ceramic and ceramic starting powders using paper technology. This offers the possibility to establish a highly productive manufacturing process. A simplification and reduction of the process chain [1] has a high potential to reduce manufacturing costs in comparison with the state-of-the-art. A joint shaping of all structural (metal substrate) and functional (ceramic, cermet) layers, followed by combined heat treatment (co-sintering) leads to a minimization of production efforts. However, a narrow process window for the processing of the different starting materials is necessary.

Commercially available ceramic and metal powders often have different strain rates and absolute values of shrinkage. This may result in high mechanical stress leading to deflections, cracks and delaminations during co-sintering. To overcome this challenge the newly developed high-energy milling method is used to modify the morphology of commercial gas-atomized metal powders (Figure 1). So, it is possible to adjust the sintering properties to the functional layers.

The solution includes the formation of a sequence of four layers [2], which consist of metal, ceramic and metal-ceramic particles in the green state (Figure 2) built up by paper technological coating of aqueous or organic particle suspensions.

Furthermore, simultaneous formation of a dense electrolyte layer free of cracks and a defined porous metal substrate was achieved by optimally adjusting the sinter shrinkage of the ground metal powders with this of commercially available ZrO_2 powders. The ZrO_2 powder starts with a material density of approx. 48 % of the theoretical density (TD), whereas the metal powder starts with approx. 30 % TD. After sintering at 1350 °C the electrolyte reached a density of 6.0 g/cm^3 (approx. 99 % TD). By contrast, the metal substrate shows an open porosity of 30 % with the same shrinkage, as the starting density of the metal was clearly lower. Therefore, the requirement for sufficient gas flow is met. If a suitable powder for the barrier and the Ni-ZrO_2 anode layer is used and the metal substrate and electrolyte layer are sufficiently adapted, it is possible to manufacture in situ the 4-layered compound structure with nearly no deflection after the co-sintering (figure 3). Figure 4 shows an electron micrograph of a MSC half cell, having a dense electrolyte layer (13 µm), a fine porous anode (17 µm), a fine porous barrier layer (approx. 3 µm) and





a large porous metal substrate (500 µm). Measuring of He leakage rate of the single and 4-layered composite indicates a sufficient porosity in the anode layer and an outstanding gas tightness of the electrolyte (> 10–9 mbar*l/s).
First electrochemical tests prove the operational capability of the cost-effectively manufactured MSC dedicated to solid oxide fuel cell (SOFC) applications. A power density of 320 mW/cm^2 at 750 °C was achieved.

Services offered

- Development of a metal substrate cell (MSC) manufactured by paper technique for a defined metal substrate material
- Proof of cost reduction and operational capability of the developed MSC

Acknowledgments

The results are part of sub-issue C3 (CeraDuct/CerMetComp) of the ECEMP project supported by the European Union (EFRE) and the Free State of Saxony.

Sources

[1] Slawik, Tim: Diploma Thesis: "Manufacturing and Characterization of MSC-layered compounds by use of paper technological coating techniques", TU Dresden, Germany, 2011
[2] Krüger, Holger: Diploma Thesis: "Use of paper technique for production of semi-finished products dedicated for flat functional metal- and nonmetal layered compound structures", TU Dresden, Germany, 2012

1 *Metal powder for substrate layer modified by high-energy milling.*
2 *Electron micrograph of the 4-layered composite.*
3 *Ceramic electrolyte (left) and metal substrate (right) after co-sintering.*
4 *Electron micrograph of the co-sintered MSC half cell.*

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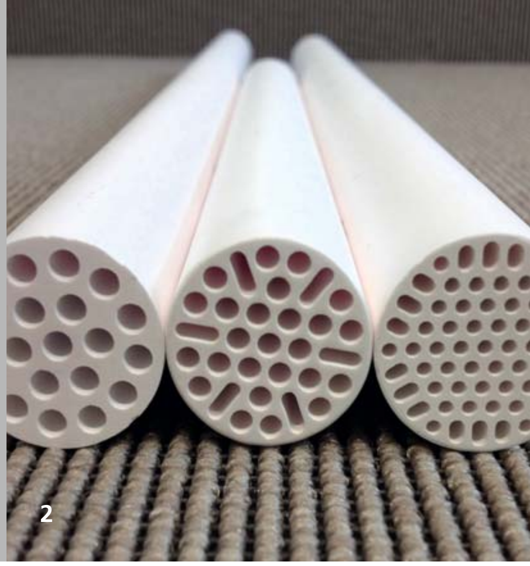


ENERGY

CONTINUOUS SACCHARIFICATION IN A MEMBRANE REACTOR

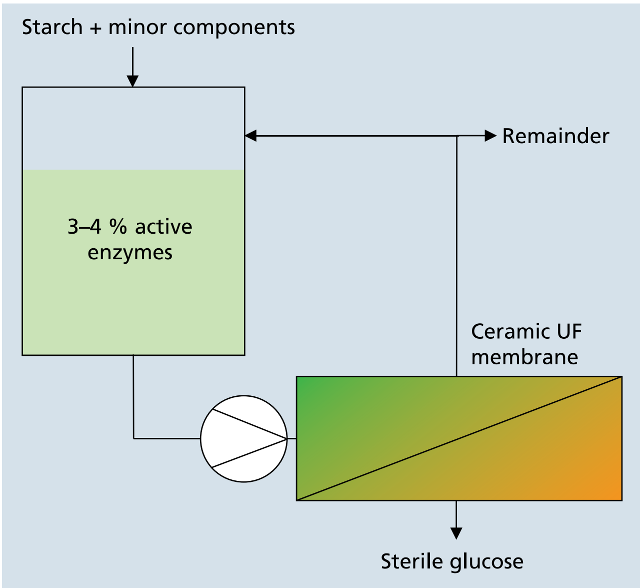
Dr. Marcus Weyd, Dr. Ingolf Voigt

In Europe, corn starch is frequently used as raw material for ethanol production. The starch has to be liquefied and saccharified into glucose before it can be converted into ethanol by fermentation. The enzymatic liquefaction and saccharification processes strongly influence the efficiency of ethanol production as the costs are mainly determined by the volume of the installed reactors and the quantity of the used enzymes.

According to the state-of-the-art, the enzymes remain in the saccharified solution. They are consumables and have to be replaced for the next treatment cycle. Furthermore, they hinder the ethanolic fermentation process. In order to limit enzyme costs, they are used in low concentrations of typically 0.5 %. This leads to long saccharification times of 72 h and requires large reaction volumes [1]. It would be favorable to selectively retain enzymes and unconverted starch in the reactor. Thus, it would be possible to recycle enzymes, to work with higher enzyme concentrations, to establish a continuous regime and to reduce the reactor size.

Using ceramic ultrafiltration membranes of Fraunhofer IKTS, pilot tests on the separation of glucose by membrane filtration from enzymatic saccharification were performed. Industrial scale membranes (1.2 m long multichannel tubes) of different pore sizes were used, and the membrane performance as well as enzyme retention were determined. Additionally, suitable pore sizes were chosen that allow for the permeation of water and glucose, and the retention of unconverted starch and enzymes. The pilot plant is schematically shown in the following figure.

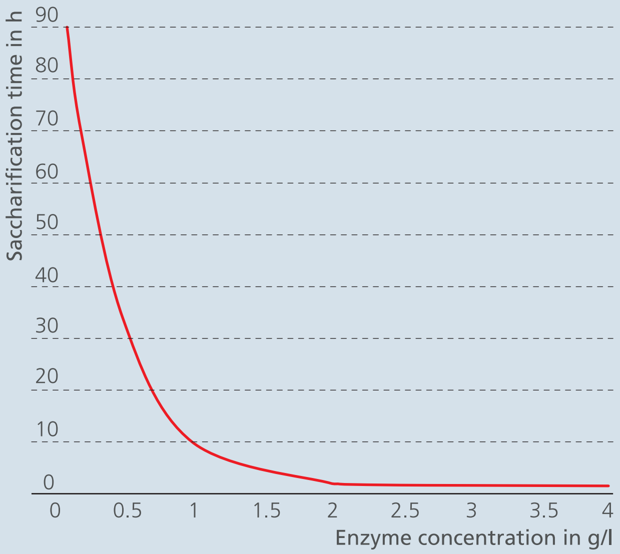
During pilot tests lasting several months the filtration behavior and the influence of process parameters (particularly cross flow velocity and feed pressure) were studied. Additionally, different qualities of starch were used.



Membranes of several geometries were applied and different ways of membrane cleaning were tested. A sterile permeate containing pure glucose was always extracted from the saccharification by the membranes. Enzymes and starch were completely hold back in the saccharification. Due to the retention of the enzymes they can be used in high concentrations leading to short saccharification times. Furthermore, a pure glucose-water mixture is extracted and fed to fermentation. So, the fermentation is not strained by associated materials and a high grade yeast is formed as byproduct. After further

pilot scale tests in May 2012, the proven technique was implemented in a large-scale demonstration plant (GFT Membranes Systems GmbH) with a membrane area of 640 m², split in four lines, each line equipped with four modules of 40 m². Three lines are running in parallel, the fourth line is in standby. An enzyme concentration of 4 % is applied leading to a saccharification time of about 4 h. The plant produces 32 m³/h glucose (30 DE). Further research aims at a transfer of this technology to other saccharification processes.

Minimal saccharification time as a function of enzyme concentration



Services offered

- Customer and application-specific membrane testing and process development
- Customer and application-specific membrane development
- Engineering, construction and equipment of membrane (test) plants
- Supply of membrane prototypes

Reference

[1] I. Voigt, H. Richter, M. Weyd, E. Tusel, H.E.A. Brüschke, "Membrane enhanced biofuel production", 3rd International Conference on Energy Process Engineering ICEPE, June 4-6, 2013, Frankfurt, Germany.

1 *Feed, permeate and retentate samples of glucose filtration.*

2 *Ceramic membranes.*

3 *Feed tank of pilot filtration plant.*

4 *Industrial scale demonstration plant (640 m² membrane area).*

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DIVISION

ENVIRONMENTAL AND PROCESS ENGINEERING

Project reports

The "Environmental and Process Engineering" division deals with the development of materials, technologies, and systems for efficient, secure, and cost-effective environmental protection. The focus here lies on the sustainable improvement of recovery, conversion, transportation and storage processes in the field of conventional energy and bioenergy. Furthermore, the division engineers strategies and processes for water and air purification and control, as well as the recovery of valuable raw materials made from residues/waste materials.

On the basis of its ceramics expertise, Fraunhofer IKTS develops innovative technical process solutions that can be transferred into defined systems. Materials, technology, and process expertise are deeply intertwined and facilitate the development of complex process engineering systems for liquid filtration, pervaporation, vapor permeation, gas separation and particle filtration. In this regard, the membranes, filters, and catalytic systems at Fraunhofer IKTS play a decisive role in the processes of catalytic exhaust gas treatment, waste water and water treatment. In the development of combustion and gasification processes, the use and collection of oxygen, as well as the production and use of synthetic and alternative fuels benefit from these components.

Knowledge of the process technology for the comminution, disintegration, and mixing of biogenic substrates represents another core competency of Fraunhofer IKTS in the area of biochemical and thermochemical biomass conversion. By using technical systems in the field of applied electrochemistry, we additionally respond to materials-specific questions in the area of deep geothermics.

Our broad wealth of skills covers all relevant issues for feasibly establishing resource-friendly, process engineering-based processes. We model, validate and optimize thermofluid, electrochemical and thermomechanical materials transportation and reactions for membrane processes and reactors in both pilot systems and customer systems. With numerous laboratories, technical systems, and the applications centers for membrane technology and bioenergy, the division possesses an outstanding infrastructure in order to realize projects of various scopes and scales.

1

MEMBRANE CONTACTOR BASED ON CERAMIC HOLLOW FIBER MODULES

Dr. Thomas Hoyer, Dr.-Ing. Hannes Richter

Ceramic hollow fiber modules

Liquid separation is a key process in chemical industry. Many separation processes are very energy intensive such as distillation. Extraction, for example, is an energy-saving separation method: a substance is transferred from one solvent into another. Classic extraction methods are only successful if both liquid phases have a different density and do not form stable emulsions. The extraction process can be performed by intense mixing and subsequent phase separation. Even in systems not fulfilling these requirements an extractive separation is possible using membrane contactors. Here, the two liquid phases are not dispersed. They remain separated by a porous membrane.

Hollow fiber contactors that consist of polymer materials fail in many separation tasks: aggressive solvents attack the polymers, the extraction temperature is limited or the surface energy of the polymer leads to an unfavorable position of the phase boundary.

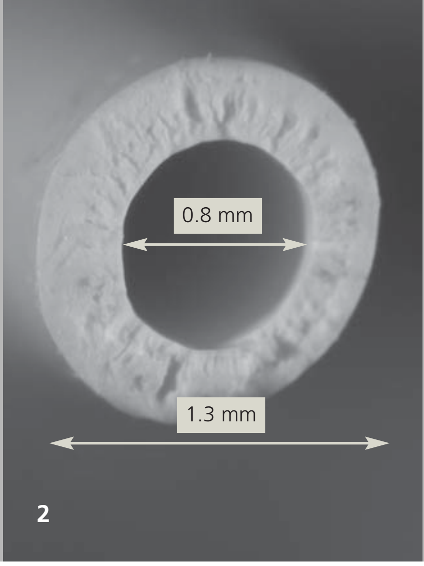
Ceramic membranes can be an alternative because their unique stability allows the use under extreme process conditions. The position of the liquid-liquid phase boundary can be influenced by pore size and pore surface modification.

Ceramic hollow fibers were prepared by the Thuringian Institute of Textile and Plastics Research e.V. (TITK) using the patented ALCERU® technology. At Fraunhofer IKTS, the fibers were sintered between 1320 °C and 1350 °C. The hollow fiber quality was significantly improved in various spinning tests by using dispersing agents, an improved preparation technique for the spinning solution, a modified nozzle flow and an adjusted sintering process (Figure 2).

For fiber bundeling porous alumina plates of two different diameters were used: 27 mm with square channels and 53 mm with hexagonal channels.

To improve the fixing of the fibers and the channel plates a special device was constructed. After fixing, the fiber ends in the channel plates were sealed with a highly viscous glass paste. After different optimization steps (type of glass, position during glass melting, heat treatment regime) modules of different lengths and diameters were produced with only a few defects (Figure 1 and 4):
length 115 mm, membrane area 0.23 m^2,
length 250 mm, membrane area 0.06 m^2,
length 500 mm, membrane area 1 m^2.

The surface of the hollow fiber bundles was modified by a postprocessing step in order to adjust hydrophilic and hydrophobic properties.



Membrane extraction

For functionality tests and the determination of the extraction performance of the modules an extraction test set-up was constructed. Membranes with different surface modifications were tested with different solvent systems. The application potential was demonstrated for two systems:

a) Hydrophilic bundle; butyl acetate and water as solvents, extraction of succinic acid,
b) Hydrophobic bundle; 1-butanol and water as solvents, extraction of acetone.

Numerical simulation showed that the test set-up had to be improved with regard to solvent flow, dead volume in the modules and thermal design. With these improvements, the test equipment is now available for the evaluation of membrane and process parameters for customized separation tasks.

Services offered

- Development of customized ceramic hollow fiber modules
- Adjustment of surface properties (hydrophilic/hydrophobic surface modification) by postprocessing
- Membrane extraction tests to solve customized separation tasks
- Process development for
  - Biotechnology: aqueous two phase systems (ATPS)
  - Systems with small differences in density
  - Systems with extreme phase ratios
  - Systems with aggressive substances

1 Hollow fiber module with 1000 alumina fibers, a membrane area of 1 m^2, a length of 500 mm and a diameter of 53 mm.

2 Ceramic hollow fiber (fracture surface).

3 Test set-up for membrane extraction experiments.

4 Hollow fiber bundles in different geometries.

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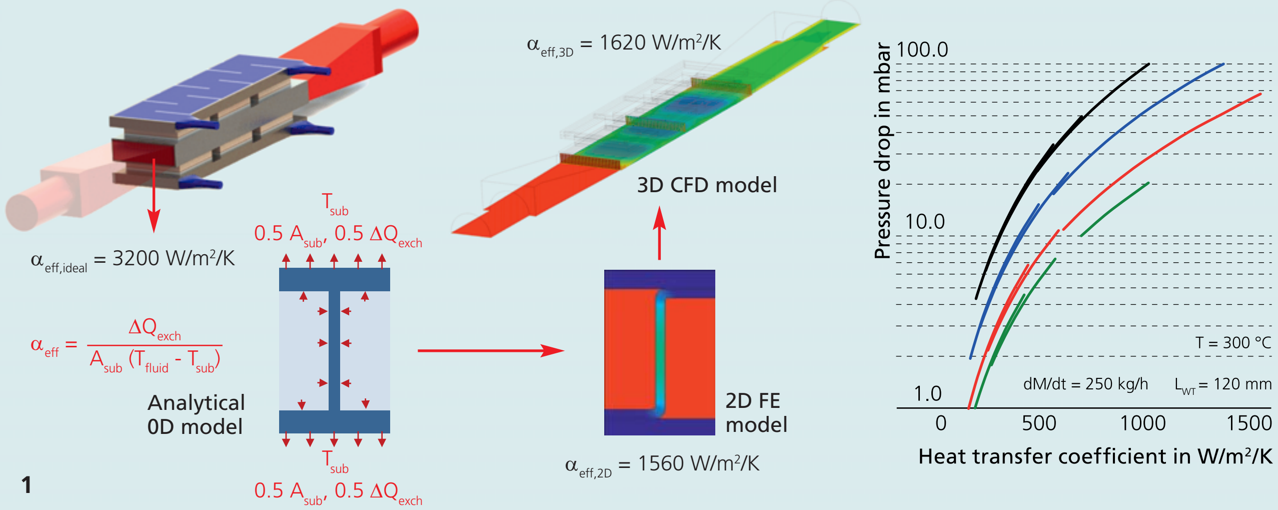


1

ENVIRONMENTAL AND PROCESS ENGINEERING

SIMULATION OF HEAT TRANSFER IN HIGH-TEMPERATURE SYSTEMS

Dipl.-Inf. (FH) Gregor Ganzer, Dipl.-Ing. (FH) Marcel Dannowski, Dr. Wieland Beckert

The development of innovative energy conversion systems, like high-temperature fuel cells (SOFCs) or thermoelectric generators (TEGs), are an important field of activity of Fraunhofer IKTS. For energy systems, the thermal management is crucial because it ensures the stable and efficient operation over the whole range of operation. The heat transfer is an essential process, which is responsible for heat dissipation and for heat recuperation between the different media (inlet and exhaust gases, cooling media). Heat transfer takes place inside the active components (fuel cells, reactors) as well as in specific heat exchanger components.

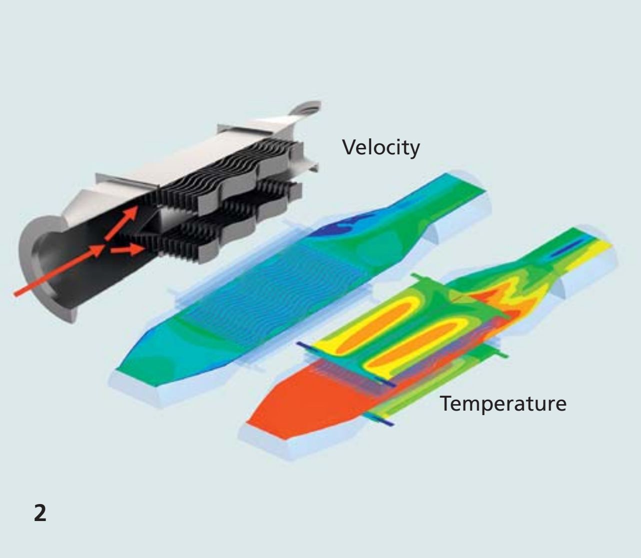
During the development of such components, simulation and modeling are efficient and effective tools for the conception, design, optimization and fault analysis. In highly integrated systems with multifunctional and coupled components, there is often the need for specialized components adjusted to the needs of the systems instead of using purchased standard components. The model description of heat transfer processes in a high-temperature field is a complex task due to the coupling with the fluid flow and radiation heat transfer which cannot be neglected.

Thermal interaction between the components or processes (e.g. thermoelectricity, heat of reaction) needs to be considered in the models. The modeling team of Fraunhofer ITKS offers the competence for model development for the above mentioned components, representing all relevant aspects. This has been proved in various projects at Fraunhofer IKTS, where modeling made significant contribution to the design and optimization of various highly specialized and integrated heat transfer devices.

Thermoelectric (TE) generators show a high potential for the recovery of exhaust heat. For high-temperature applications (> 300 °C), commercial TE modules are still very rare. It is the aim of several projects (HiTEG, TECer, TEMatKomp) to develop ceramic-based high-temperature TE modules used for exhaust heat recovery. A heat exchanger with integrated TE modules is the core of a TEG. Modeling revealed that the thermal adjustment between the heat exchanger and the TE modules offers a high potential for maximizing the generated electric power leading to an economical operation of the TEG. Here, the thermoelectric coupling as well as the complex, highly turbulent fluid flow inside the heat exchanger need to be included into the models.

Based on a hierarchical modeling strategy, a first rough design of a TE heat exchanger using an idealized 1D model is created, resulting in information about the overall dimension, cross sections and module coverage which are needed to meet the constructive (installation space), economic (number of modules) and process-related (pressure drop) demands. In the final step, a detailed 3D CFD model of the favored heat exchanger design is performed (without coarse idealizations) to validate the heat transfer coefficients, pressure losses and electric power rates and, if necessary, to trigger a new design iteration.

The second example shows a model of a heat exchanger for heating up process air in a SOFC micro system (eneramic®). The geometric and process-related specifications of the heat exchanger are defined by the high integration of the system, and the thermal coupling to the SOFC stack. Based on a detailed 3D CFD model performed in ANSYS Fluent, a robust and economic design of a planar heat exchanger (crossflow design,



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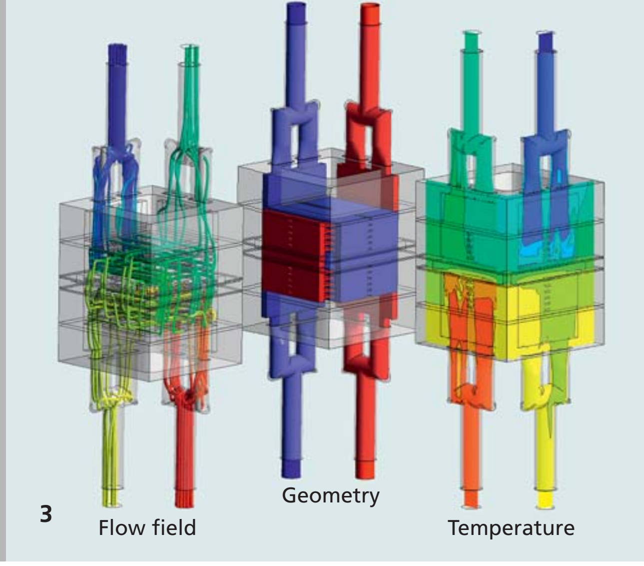

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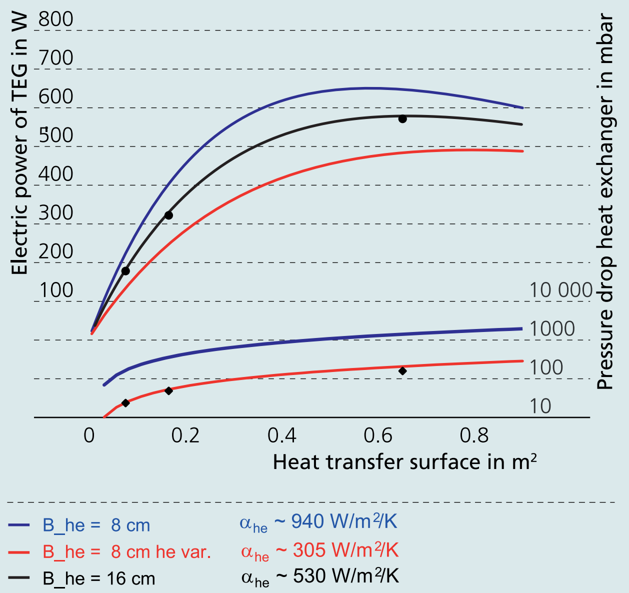
Example for thermal adjustment of thermoelectric generator and heat exchanger



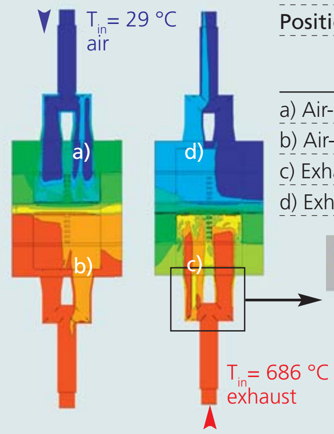
internal manifolding, scalable modules) was developed which satisfies the process-related specifications (heat exchanger performance of 400 W, pressure drop < 5 mbar, starting time < 30 min).

A hierarchical model strategy was applied with a first simplified simulation step resulting in the conclusion that a simple cross-flow design satisfies all given specifications. With the help of a detailed 3D CFD model, it was furthermore found that a design with an internal insulating layer separating both modules enhances the heat exchanger performance. A well instrumented test component was used to validate the model with deviations of measured to calculated temperatures of less than two percent. The model showed that thermal radiation cannot be neglected. The proposed design iteration based on the model results was proved in experiments.

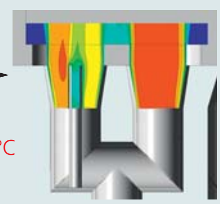
Services offered

- Model-based development support for component design and optimization of integrated heat exchangers
- Model analysis of the thermal management of reactors and energy conversion devices

Comparison of CFD simulations vs. experiment for SOFC heat exchanger



Position	Temperature Experiment	Temperature Model
a) Air-in	81 °C	78 °C
b) Air-out	481 °C	470 °C
c) Exhaust-in	602 °C	606 °C
d) Exhaust-out	314 °C	301 °C



1 Hierarchical modeling strategy for component design of a TE heat exchanger.

2 Example of detailed 3D-CFD analysis of an integrated TE heat exchanger.

3 Geometry and results of a 3D-CFD simulation of an integrated heat exchanger for a micro SOFC system.

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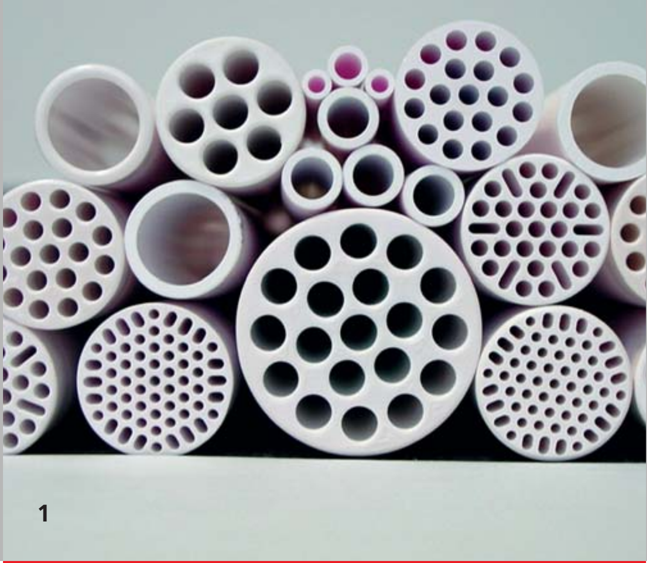

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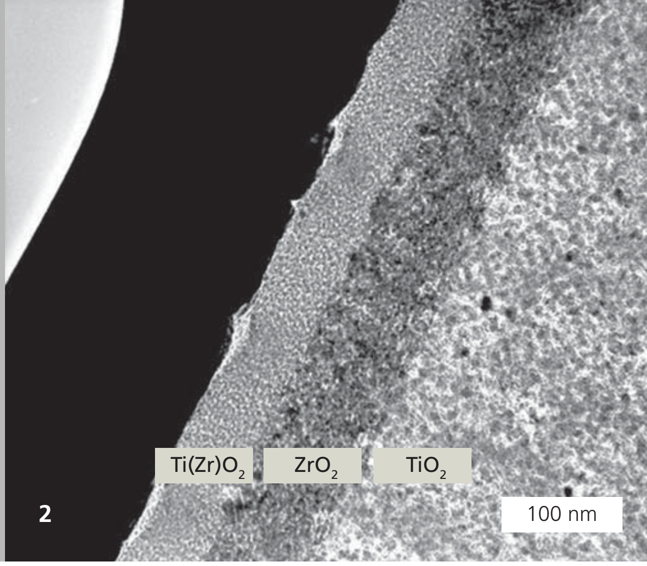

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ENVIRONMENTAL AND PROCESS ENGINEERING

CERAMIC NANOFILTRATION MEMBRANES WITH A CUT-OFF OF 200 Da

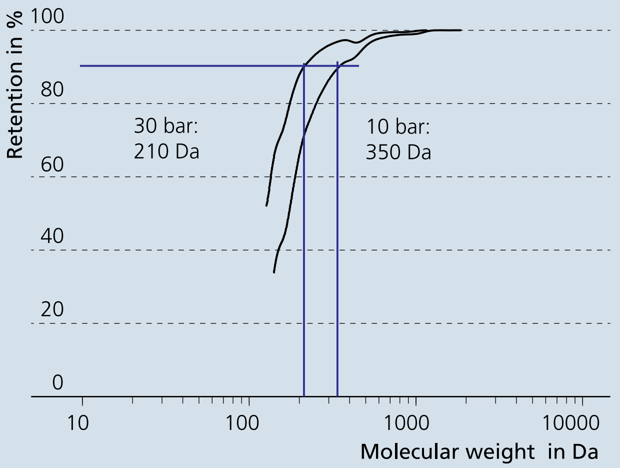
Dr. Ingolf Voigt, Dipl.-Chem. Petra Puhlfürß

Membrane processes are low energy consuming, environmentally friendly and gentle separation methods. Ceramic membranes are already established on the micro- and ultrafiltration level and are used at high temperatures, strong pH values and in abrasive media. Ceramic nanofiltration (NF) membranes with a cut-off of 450 Da were successfully developed together with Rauschert Kloster Veilsdorf GmbH in the years 1997–2000 and are commercially available since 2006 through Inopor GmbH (100 % subsidiary of Rauschert GmbH). Many applications in the field of water treatment, product purification, treatment of biomass and the retention of catalysts have been realized since then. However, a growing interest in NF membranes with a smaller cut-off and higher stability as well as for the use in organic solvents can be seen. Therefore, such membranes were developed and tested in the "nanomembrane" project together with ten partners from industry and research.

The membranes were prepared on single and multichannel tubes of a length of up to 1200 mm (Figure 1). The NF membranes were prepared by using a modified polymeric sol-gel technique based on titanium and zirconium alcoholates. The hydrolysis was controlled by means of protecting groups. The subsequent heat treatment under inert conditions led to the pyrolysis of the protecting groups and the formation of composite membranes consisting of TiO_2/ZrO_2-C with a layer thickness of approximately 50 nm (Figure 2). By varying the carbon content it was possible to adjust the wetting properties of the membrane. So, an application in organic solvent nanofiltration (OSN) is possible.

The study of the hydrophilic membranes in water showed a cut-off of 350 Da at a transmembrane pressure of 10 bar. With increased transmembrane pressure of 30 bar the smallest pores seemed also to be flowed and the cut-off decreased to 210 Da. Average water fluxes of 10 l/(m^2·h·bar) were achieved.

Separation behavior of the hydrophilic NF membrane at a transmembrane pressure of 30 bar and 10 bar



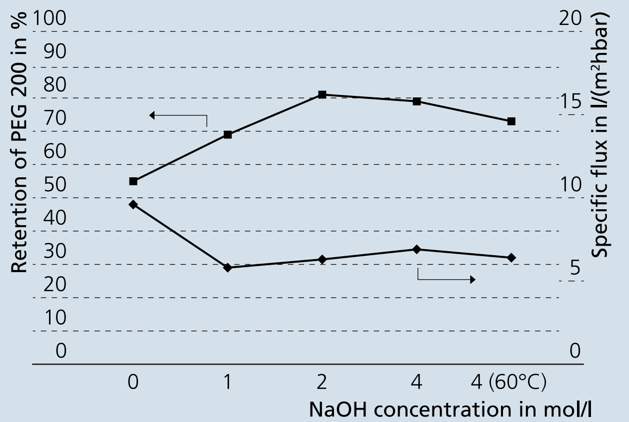
The study of retention in organic solvents was performed at Merck KGaA using polystyrenes as molecular weight standards.
The best retention was achieved in tetrahydrofuran with a cut-off of 350 Da at a specific flow rate of 3.5 l/(m^2·h·bar). It was found that the separation behavior in organic solvents is strongly dependent on the solvent and the history of the

membrane has also significant impact. For more systematic studies in organic solvents, a container system with two test facilities for pressure ranges 25 bar (Figure 3) and 40 bar was established in the Fraunhofer IKTS Application Center of Membrane Technology in Schmalkalden. By means of these plants, experiments with flammable solvents can be performed.

Filtration tests with aqueous hydrochloric acid and caustic soda at 25 °C were carried out to evaluate the chemical stability of the new ceramic NF membranes. After filtration over a period of 2 hours, the membrane was rinsed. Afterwards, the retention of polyethylene glycol with a molecular weight of 200 g/mol was determined. The membranes showed a stable behavior up to 4 M NaOH (16 wt%) at a temperature of 60 °C. In hydrochloric acid the membranes were stable up to 2 M HCl (7 wt%).

Besides the experiments in organic solvents, extensive application tests were carried out for water treatment with partners from textile industry, paper and pulp production and metal processing. The membranes were successfully tested by the partners in cleaning of mercerization solution as well as cleaning and recycling of wash water from textile finishing, treatment of cleaning baths from electrochemical metal treatment and treatment of bleaching (Figure 4).

PEG 200 retention of the new NF membrane after filtration of caustic soda



Acknowledgments

The BMBF and Project Management Jülich are gratefully acknowledged for their support and all project partners of nanomembrane (FKZ 03X0080) for good cooperation.

Services offered

- Delivery of membrane samples
- Customer-specific membrane development
- Membrane testing in the Application Center of Membrane Technology
- Tests with mobile systems at the customer site
- Plant design, piloting

1 Ceramic membranes with different geometry.

2 TEM image of an NF membrane.

3 Test facility for organic solvents.

4 Samples in the treatment of bleaching lye.

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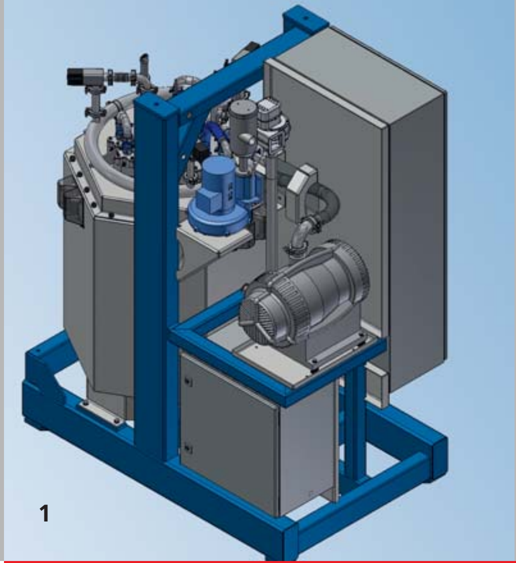


ENVIRONMENTAL AND PROCESS ENGINEERING

ENERGY DEMAND OF OXYGEN MEMBRANE PLANTS

Dr. Ralf Kriegel

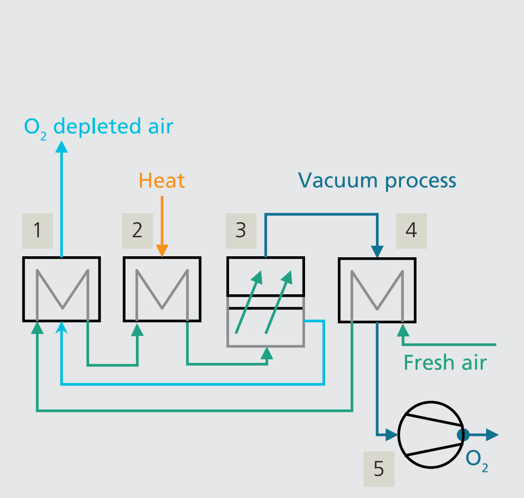
The production of pure oxygen (O_2) currently amounts to appr. 120 billion m³ STP (standard pressure and temperature) per year at a growth rate of 5.5 % per year. Main consumers are steel and chemical industry (ethylene oxide, partial oxidation etc.). O_2 is locally used for sewage treatment plants, hospitals, for welding and flame cutting, fish breeding etc. Furthermore, O_2 has a huge application potential for biomass gasification, for efficiency improvement in combustion processes and combustion engines as well as for oxyfuel processes. However, a reduction of the production costs is necessary for these applications.

Today, industrial O_2 production is carried out in cryogenic ASUs (air separation unit) using the so called Linde® process. A minimal energy demand of 0.36 $kWh_{el.}/m^3$ STP O_2 is possible for energetically optimized ASUs at high O_2 throughput. Plants with a production capacity below 1000 m³ STP O_2/h are not built, as PSA and VPSA plants (pressure swing adsorption, VPSA – vacuum PSA) are more competitive at smaller production rates. Small PSA plants need approx. 0.9 $kWh_{el.}/m^3$ STP O_2 reaching a maximal O_2 content of approx. 95 vol% O_2. A decentralized O_2 production using PSA plants is not profitable for many potential applications for small and medium oxygen demand, since energy costs dominate the O_2 price. O_2 supply using gas flasks or liquid O_2 tanks is usually still more expensive.

An alternative process for production of pure O_2 is based on gas separation using mixed conducting ceramic membranes (MIEC – mixed ionic electronic conductor). The material, which is in fact gas-tight, transports O_2 as oxide ions and electronic charge carriers (electrons or holes) at sufficiently high temperature. Since the end of the 1980s, a variety of ceramic materials was investigated regarding their O_2 permeation and other relevant material properties. Promising materials like BSCF ($Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$) were used for first O_2 generators at Fraunhofer IKTS as shown in Figures 1 to 3.

The energy demand of O_2 membrane plants depends primarily on the process route. At Fraunhofer IKTS, the vacuum operation route depicted schematically in Figure 4 is being developed. The alternative overpressure process needs the compression of the total air amount, but the ratio of air throughput to O_2 flux is typically ≈ 10:1. Therefore, an efficient operation needs a recovery of the compression energy. However, this is not necessary for the vacuum process, since only the O_2 amount has to be compressed. In addition to the electrical energy needed for compression, thermal energy for air heating and O_2 cooling is required. As depicted in Figure 4, the process heat should be recovered as much as possible using heat exchangers so that only the heat losses have to be compensated.

Compression energy is determined by the specific energy demand of the vacuum pump (≈ 0.18 kWh/m³) and increases with decreasing vacuum pressure. The thermal energy demand depends on the degree of heat recovery of the heat exchangers and on the air throughput. Oxygen recovery, an auxiliary value representing the oxygen share separated from the feed air, makes it possible to normalize the energy demand on the O_2 volume produced and to calculate the maximal vacuum pressure applicable for the process. These values



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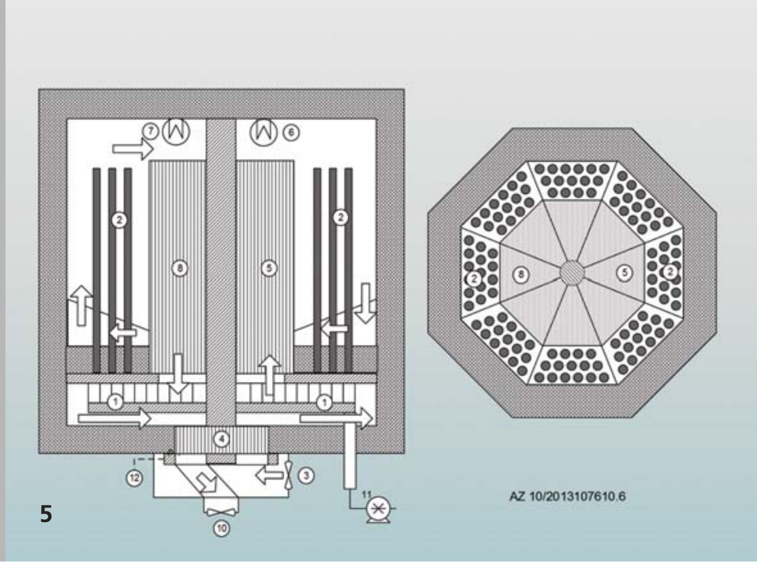

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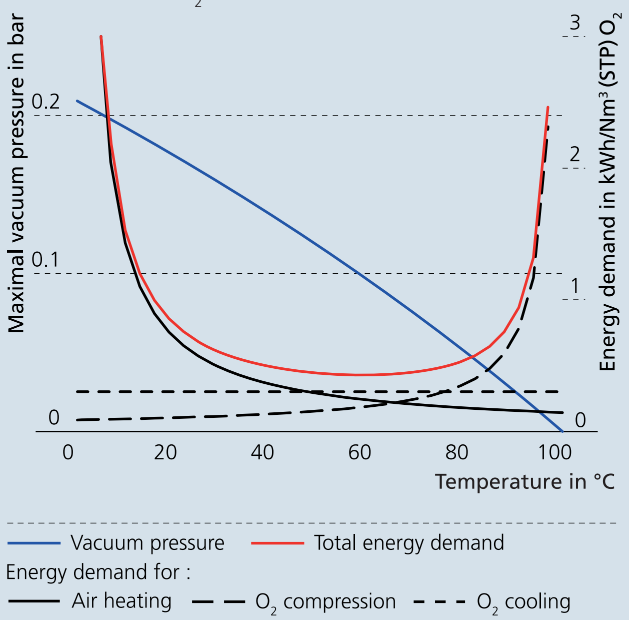
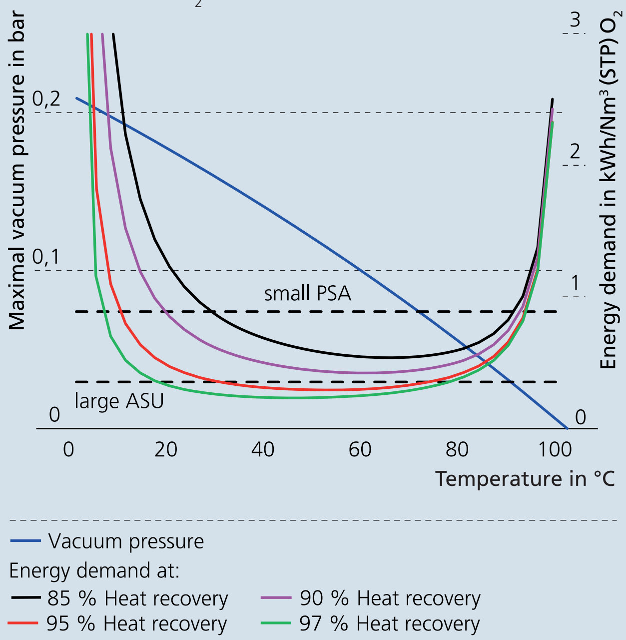
are shown as a function of O_2 recovery in the diagram on the left. The thermal energy demand was calculated for balancing the thermal losses at a heat recovery of 90 %.

significantly using such plants, especially for small and medium O_2 production rates.

Vacuum pressure and energy demand for O_2 membrane plant (90 % heat recovery)
Vacuum process using BSCF tubular membranes at 850 °C, cross flow of air/O_2



Energy demand and vacuum pressure depending on oxygen recovery and heat recovery
Vacuum process using BSCF tubular membranes at 850 °C, cross flow of air/O_2



Obviously, there is a broad minimum of total energy demand at medium O_2 recovery. In contrast to previous work, the energy demand does not depend on the O_2 permeation performance and, thus, not on the kind of material. In addition, the diagram on the right shows that the total energy demand depends essentially on the heat recovery of the heat exchangers. The membrane plant needs less energy than a cryogenic ASU if a heat exchanger with more than 92 % heat recovery is used. RTO plants (regenerative thermal oxidizer) with a heat recovery up to 98 % are state of the art. Therefore, a concept for an energy efficient O_2 generator as shown in Figures 5 and 6 was developed and patented. Compared to the state of the art, it should be possible to decrease the O_2 production costs

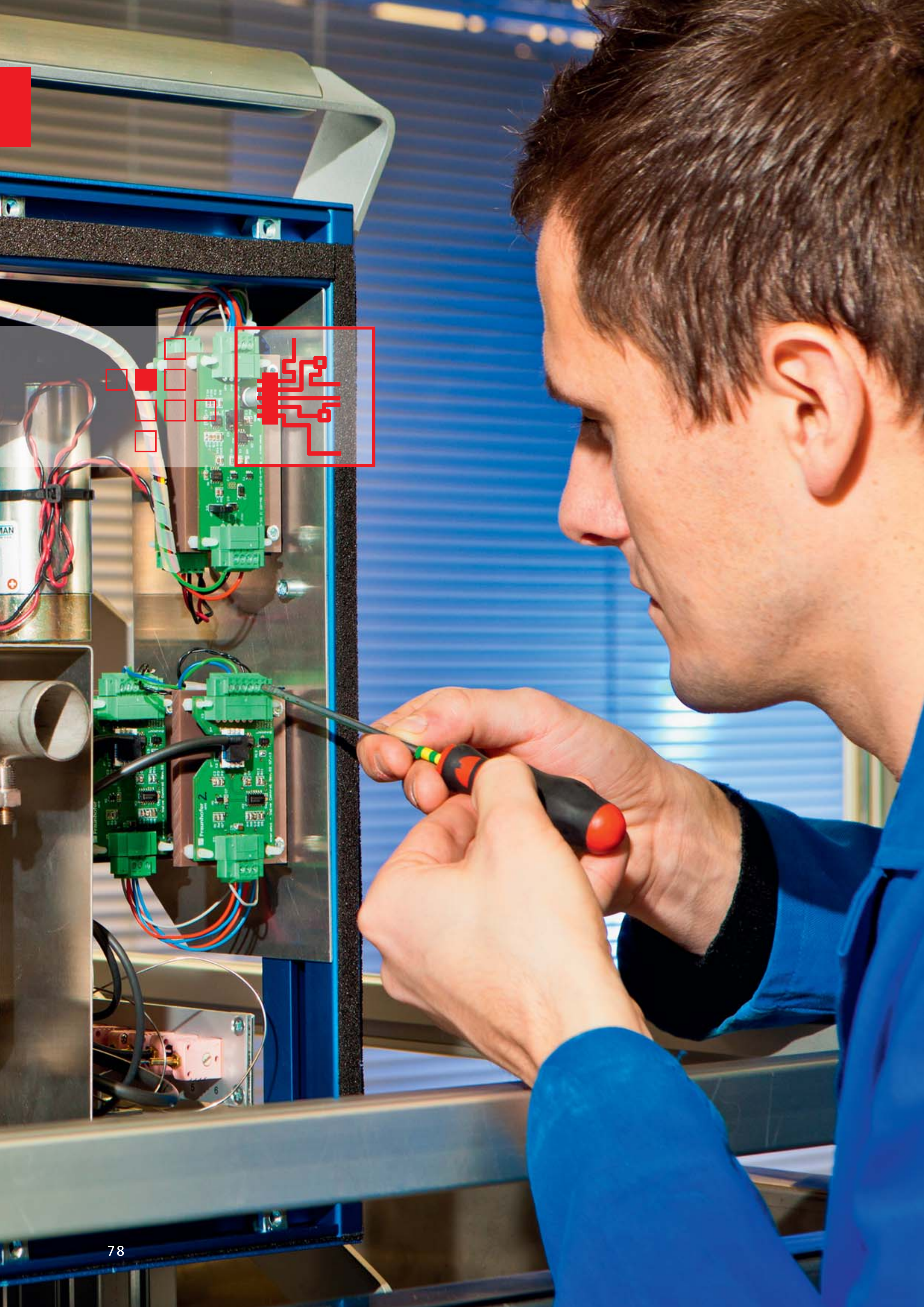
1 *CAD model of O_2 generator.*

2 *Membrane segment.*

3 *Prototype for 2kg O_2/h.*

4 *Scheme of vacuum process: 1) air/air heat exchanger, 2) air post heater, 3) membrane module, 4) O_2 cooler, 5) vacuum pump.*

5 *O_2 generator with regenerative heat exchangers.*



DIVISION

ELECTRONICS AND MICROSYSTEMS

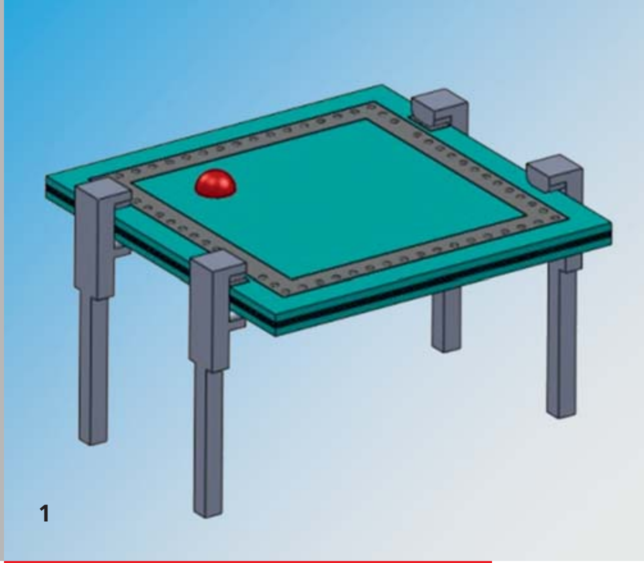
Project reports

Within the "Electronics and Microsystems" division, components and microsystems are developed for high-performance electronics, sensors and actuators, as well as energy technology on the basis of ceramic hybrid technology. In doing so, Fraunhofer IKTS is using a broad technological basis of assembling, joining and structuring technologies, using the most modern ceramic materials and effective configuration and characterization methods.

In the future, microsystems will not only become substantially more complex, more powerful, and smaller, but will also increasingly interact directly with their environment thanks to enhanced functionalities, such as sensors, actuators and wireless networking. This will result in growing demands for the development of more cost-effective, robust, and reliable material and manufacturing technologies for miniaturized component groups and their energy supply. This challenge can only be overcome through an integrated approach to material, process and packaging. Within the "Electronics and Microsystems" division, these closed technology chains therefore create the foundation for the microsystems engineering of the future, from material through to characterization.

Fraunhofer IKTS has been a partner for years in the development of innovative electronic, sensor and microsystems. The basis for this is a comprehensive appreciation of the production, characterization, and processing of the functional materials in closed technological chains. On particular skill in terms of materials is the synthesis of complex perovskites, which form the basis of ultrasonic transducers and adaptronic systems, as well as specialized glasses that are used in joining and thick-film technology. Fraunhofer IKTS is the global leading technology service provider in thick film and multilayer technology, as well as in the development, characterization, and processing of functional ceramic pastes, inks and slurries.

The comprehensive technical infrastructure as well as subject-specific centers of expertise guarantees an industry-oriented development process and an efficient transfer of know-how and technology to the customer.



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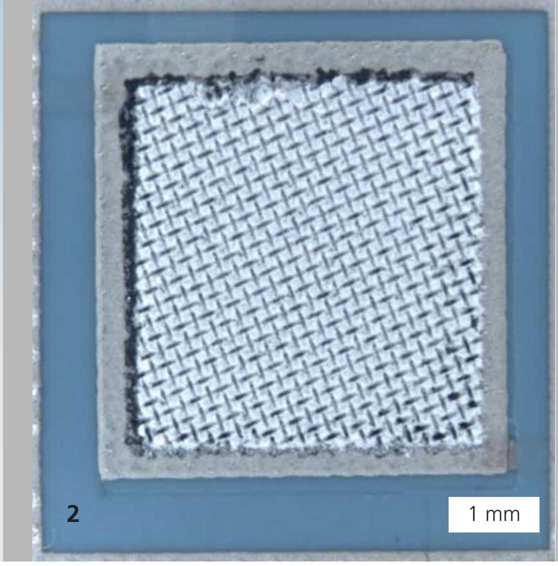


2

MICROBATTERY WITH MULTILAYER CERAMICS

Dr. Mihails Kusnezoff, Dr. Steffen Ziesche, Dr. Ulrike Langklotz, Dr. Lars Rebenklau

In the next ten years, a further reduction of energy consumption for digital electronics as well as for transmitters for electronic devices in the range of one order of magnitude is expected. Thus, microsystems will be realized in the near future which can be powered by an energy storage device of several mm^3 in size. The costs of such systems can be reduced by hybrid system integration and miniaturization providing access to new applications. In addition to their miniaturization, energy-self-sufficient applications require long life time and cyclic durability, negligible self-discharging and high power density for pulsed operation of the storage device. Nowadays, this spectrum of properties can only be covered by button cells or solid state thin-film batteries. The capacity of the last-mentioned is strongly limited due to a small electrode thickness (in the range of hundreds of nanometers). Furthermore, their production is very expensive due to the high costs of vacuum processing. Therefore, a broad market penetration is limited.

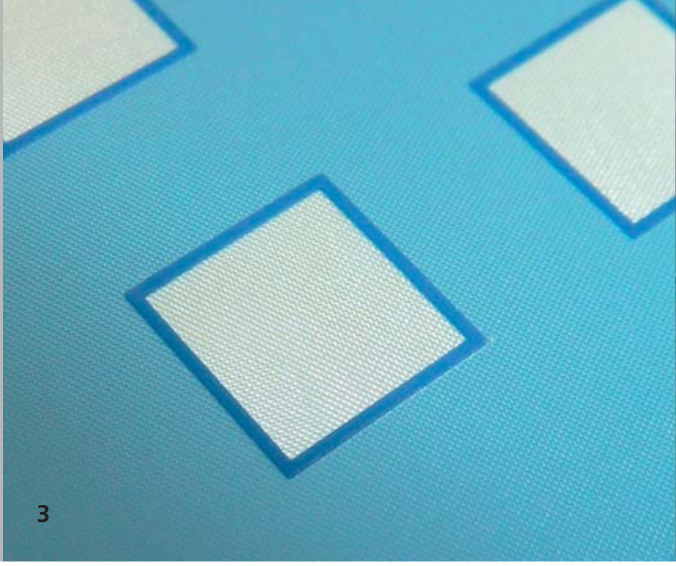
The joint research of the Fraunhofer Institutes IIS, IKTS and IZM has the aim to develop a new technology platform for cost-effective and easy-to-assemble microbatteries with a capacity of up to 2 mAh. At Fraunhofer IKTS, a battery design based on ceramic technologies is intended as SDM element for an efficient and ready-to-use integration on electronic boards. Furthermore, it is suited for mass production.

Ceramics are inert, corrosion resistant and fulfill all requirements to be used in battery housing and for the integration of active layers. Using multilayer technology (LTCC or HTCC) a compact design suitable for mass production can be realized. However, conductors (Ag, AgPd, Au) typically used in multilayer technology cause a number of challenges in terms of their chemical compatibility with the liquid electrolyte (normally with $LiPF_6$ as salt component) and with standard current collectors such as Cu and Al.

To solve these problems, the chemical and electrochemical compatibility of materials was optimized and suitable material combinations were identified. Particularly, the interaction was reduced between the different glass components of the in-house developed conducting pastes and the commercial LTCC tapes as well as between the different metals during sintering. The developed planar battery design allows for step-by-step printing of active layers into the cavities of two symmetrical LTCC caps and their sealing. The sealing process is one of the most challenging manufacturing steps. Here, two approaches were pursued: the use of polymer glues and glass seals. Systematic investigations have shown that only particular glues are stable in the electrolyte solution.

Long-term investigations show (Figure 1) that the adhesive joints not only fulfill the requirements for gas tightness but also for their continuous operation in microbatteries due to their appropriate mechanical properties.

The cathode materials (Cu-NCM and NCM powders) were synthesized to achieve the desired particle size distribution. For the anode, commercial materials were used. Both electrodes were printed into the cavities using thick-film technology and finally covered with a separator layer consisting of an ion conducting glass. For the printing process, the properties of the pastes are important. Cu-NCM material was used as active material for the



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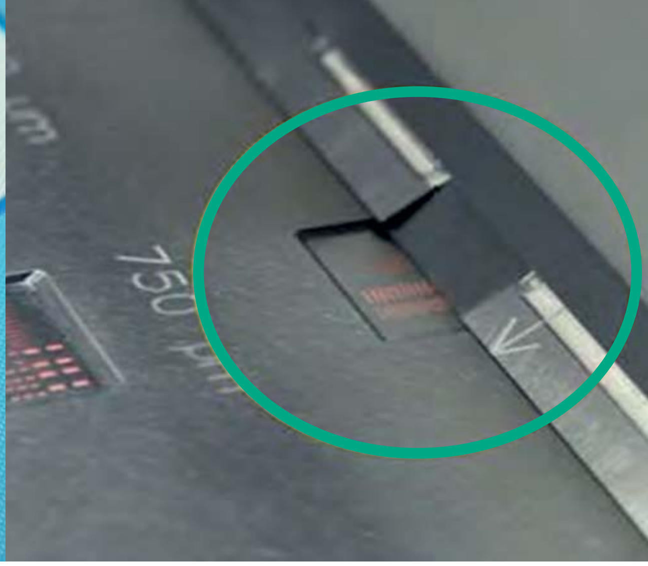
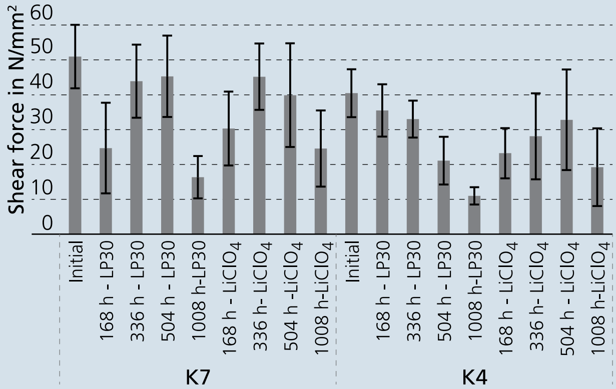
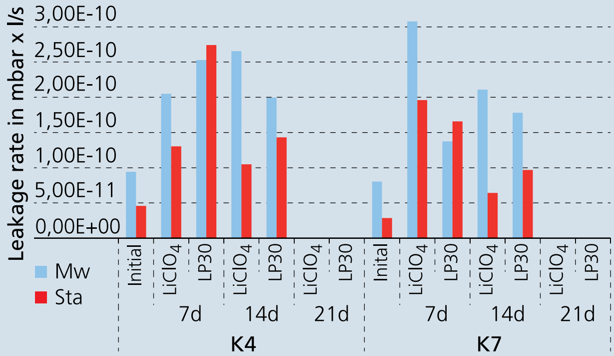


Bond strength glues on LTCC; shear test K4, K7, after 1008 h ageing in LP30 and $LiClO_4$



Leakage rate tests for glues K4, K7; after ageing in LP30 and $LiClO_4$



cathode and graphite for the anode. The pastes were printed in ambient air conditions. Charging/discharging characteristics of the printed electrodes on Al or Cu current collectors show good performance and cycling stability (Figure 2). The optimization of the rheological properties of the pastes for printing in cavities is in progress.

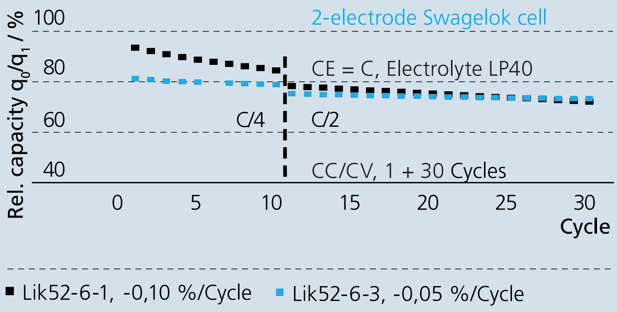
First experiments focusing on electrolyte filling of joined LTCC caps showed that a simple filling through a hole in one of the caps leads to working samples. Currently, several methods for bubble-free filling of LTCC microcavities in gloveboxes are under testing in cooperation with Fraunhofer IZM.

For small amounts of electrolyte, the quality assurance of the filling process is important for the reliability and stability of the microbatteries. Due to good wettability of electrode and separator layers with the electrolyte a large electrochemically active area can be realized. Further work in this joint project should result in the manufacturing of first microbattery prototypes.

Services offered

- Development of hermetic multilayer housings for energy storage devices, electronics and sensors
- Development of sealing technology for microbatteries
- Pastes for Li battery electrodes
- Electrochemical tests on electrodes and batteries

Charging/discharging characteristics of electrodes



1 *Design of a microbattery.*
2 *Electodes and separator in LTCC cavity.*
3 *Printing into cavities.*

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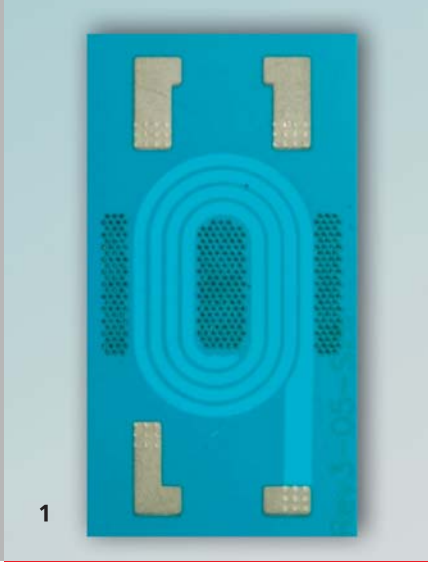

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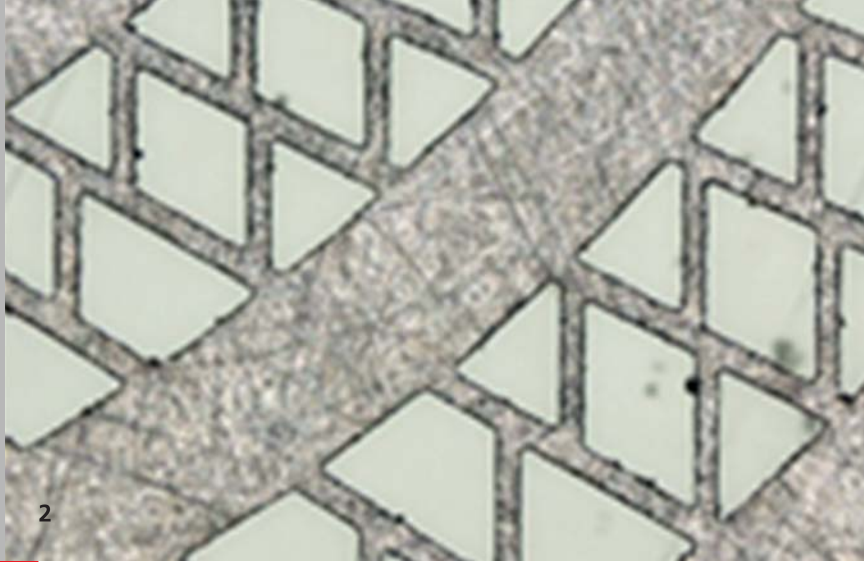


2

LTCC-EMBEDDED HIGH-POWER INDUCTORS FOR SENSORS OR POWER ELECTRONICS

Martin Ihle, Dr. Steffen Ziesche, Dr. Stefan Barth, Dr. Markus Eberstein, Dr. Uwe Partsch

LTCC-based multilayer ceramics (MLCs) are state-of-the-art substrates for high-temperature stable electronics e.g. for automotive applications, but they are usually not used for power electronics. For MLCs, the conductor lines – having a layer thicknesses between 10 and 20 µm – are typically screen printed. Normally, silver and gold pastes are used. For this reason, there are disadvantages regarding the maximum ampacity of the conductor lines due to high resistive losses in comparison to other substrate technologies (PCB, DCB). One goal of the ALFERMO (Advanced LTCC Ferrite Modules) project was to overcome this situation.

In the project, the ampacity of the embedded conductors was significantly increased using the new laser/fill technology. Here, a special stencil printing process was used for the metallization of the channels which have been formed by UV laser technology or embossing before. For the filling process special high solid phase content (SPC) silver pastes were developed.

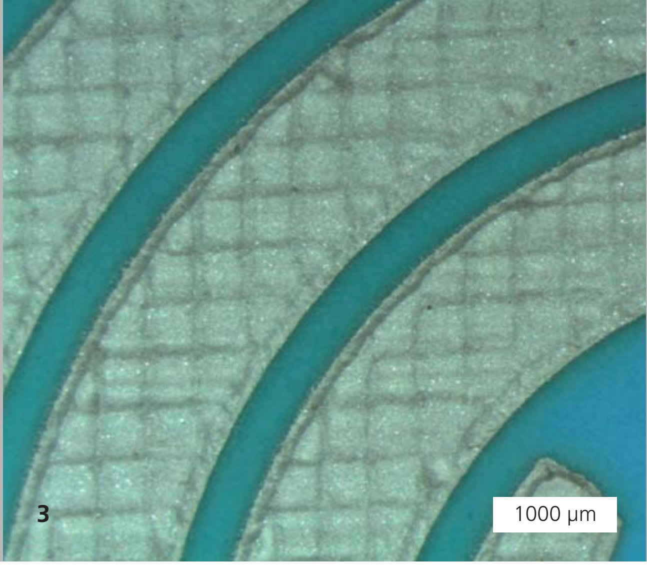
Due to the fact that the shrinkage rates of the LTCC material and the silver paste differ significantly, the LTCC substrate with embedded conductor lines of > 50 µm was subject to extreme warping. To overcome these problems different high SPC silver pastes were developed and tested. Additionally, the sintering process was optimized. In the framework of the project, different sintering procedures like self-constrained sintering and pressure assisted sintering were tested. For pressure assisted sintering, a special furnace was used, which allows to apply an uniaxial force on the ceramic multilayer during sintering. For self-constrained sintering, a non-shrinking green tape was embedded into the LTCC multilayer. Both technologies, therefore, prevent the ceramic multilayer from shrinking into x-y direction. Both technologies allow to integrate multilayer high-power inductors into LTCC without warpage. These integrated inductors show a significant reduction of resistive losses.

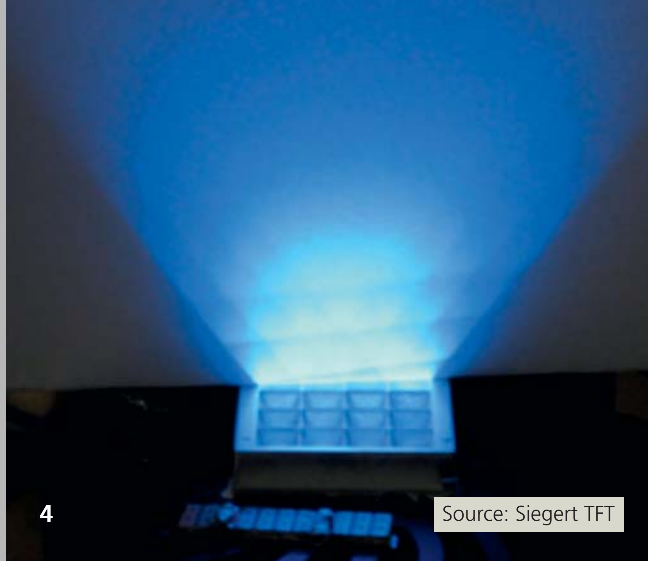
Comparison of transformers
manufactured in the newly developed laser/fill technology (self-constrained and pressure sintered) with conventionally screen printed transformers

Transformer type	R_p (Ω)	L_p (µH)	R_s (Ω)	L_s (µH)	η (%) @ P = 100 W
Screen printed	1.18	10.90	0.11	1.30	81.0
Self-constrained	0.31	8.90	0.04	1.10	89.5
Pressure sintered	0.28	15.60	0.04	1.90	92.0

Within the ALFERMO project high-power multilayer inductors (eight metallization layers) were interconnected to assemble an ultra-compact planar LTCC transformer for driving a 100 W power LED array. Compared to conventional transformer solutions the size could be reduced up to 90 %. Furthermore, LTCC-compatible ferrite tapes and low pressure injection molded ferrite cores were developed to increase the inductivity of the multilayer inductors.
The ferrite tapes were used as top and bottom layers, whereas the molded cores were directly integrated into the multilayer and cofired during the sintering process.

The table shows high ampacity transformers with their characteristic values which were realized in the ALFERMO project. The resistances and inductivities on primary and secondary transformer site in combination with the achieved efficiency were investigated. All transformers were characterized with a





glued-on MnZn-ferrite plate and compared with a standard transformer solution manufactured in screen printing technology. It can be seen that the resistance was reduced by a factor of four and that the efficiency could be increased by about 11 % using the newly developed laser/fill technology.

The pressure-sintered transformers have better inductivity and efficiency values compared to the self-constrained ones what can be referred to the geometry of the LTCC-integrated multilayer coil. The smaller separation distances of the individual multilayer coils of the pressure sintered type result in a better magnetic coupling, and therefore in increased inductivities and efficiency values. The magnetic coupling of the self-constrained type is reduced compared to the pressure sintered type due to the fact that the additional non-shrinking green tapes are placed between the inductor coils and therefore increase the distance between them.

By using the new technology, printed planar coils with a conductor width of 70 µm, horizontal conductor distance of 70 µm, conductor thickness of 70 µm and vertical conductor distance of 50 µm can be integrated into LTCC. For further optimization of the magnetic characteristics, ferritic bodies, like plates or cores, can be monolithically integrated into the LTCC material.

The integration of coils with high conductor cross sections may be the basis for various future applications. It might be a simple passive device for LC-resonant circuits and for filtering applications or a highly integrated, miniaturized transformer device. Furthermore, it is possible to use the integrated conductor coils as active element for sensor applications (like eddy current sensors).

Acknowledgments

The BMBF is gratefully acknowledged for funding the "ALFERMO" project (13N10663).

Services offered

- Construction and manufacturing of client-specific LTCC circuits with integrated conductor coils for passives, transformers or sensors
- Development of joining technologies for the high-temperature stable contacting of those elements
- Characterization of the developed components (electrical parameters, reliability …)
- Manufacturing and test of pre-production series
- Assistance during transfer to series production

1 100 W high-ampacity LTCC-transformer with integrated ferritic vias (volume = 0.8 cm³).
2 Cross-section of a fired LTCC transformer with eight metallization layers and a conductor line thickness of 50 µm.
3 Detail of a conductor coil after stencil printing process.
4 Radiation characteristic of an LED array equipped with a polymer-ceramic reflector unit.

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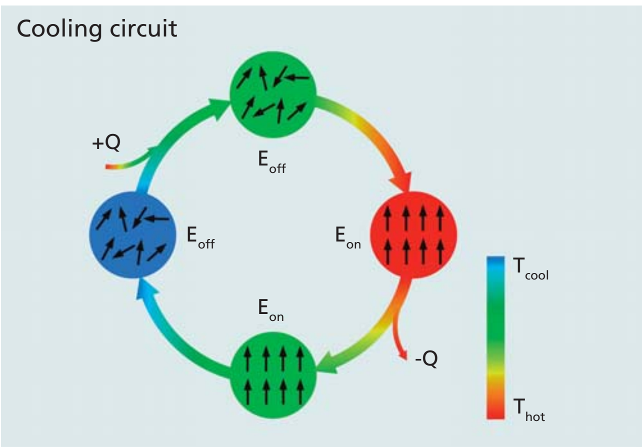
PEROVSKITE-TYPE CERAMICS FOR ELECTRO-CALORIC COOLING ELEMENTS

Dipl.-Chem. Christian Molin, Dr. Sylvia Gebhardt, Dr. Andreas Schönecker

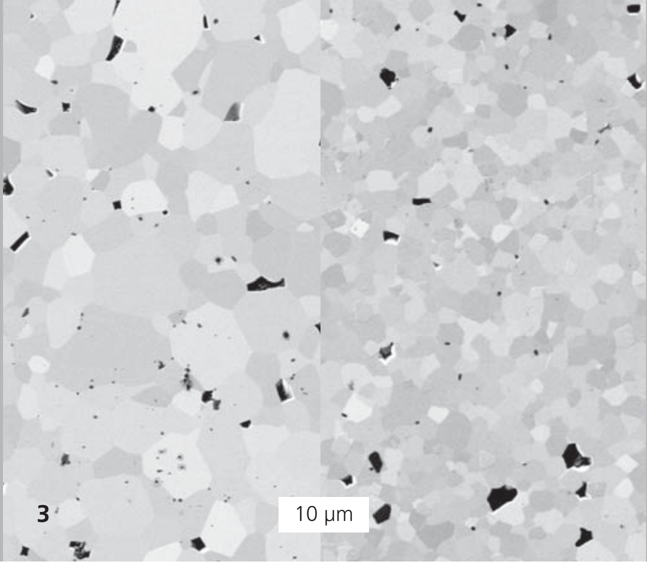
Certain ferroelectric ceramics respond to variations of the electric field in the material with a measurable cooling or heating (electrocaloric effect). Prospectively, this phenomenon could gain great economic importance for realizing active cooling elements in power electronics and for environment-friendly air conditioning systems and refrigerators.

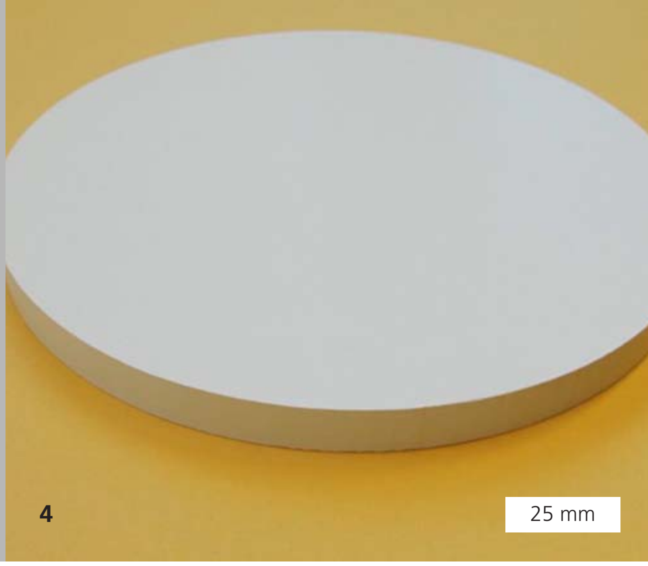
The figure below schematically shows the cooling cycle of an electrocaloric cooling system. Upon the application of an electric field (E_{on}) the dipoles align in the ferroelectric material and the electrocaloric device heats up to the temperature T_{hot}. After dissipation of the heat -Q to a heat sink the electric field is switched off (E_{off}). The material cools down to the temperature T_{cool} and is, therefore, able to dissipate an amount of heat +Q from a heat source. Afterwards, the electric field is applied again and the cycle is closed. As result, the thermal energy Q is transferred from the heat source to the heat sink. In ferroelectric materials a high electrocaloric effect is observed in the vicinity of the phase transition between ferroelectric and paraelectric phase.



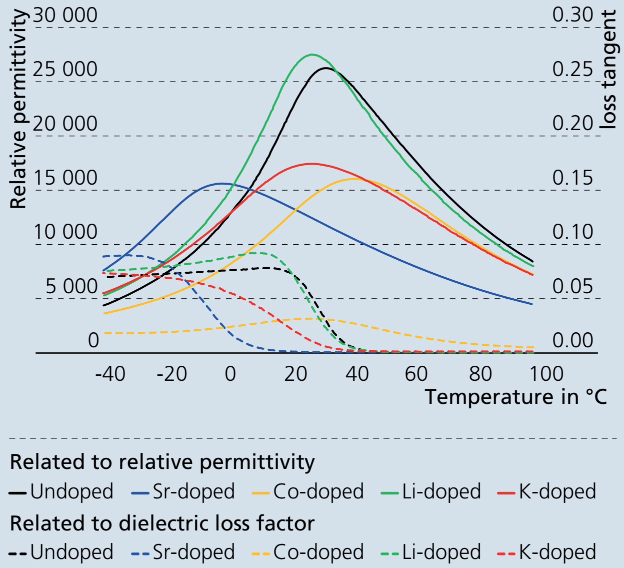
Material composition, effect size and operating conditions are subject of current research within the DFG Priority Programme "Ferroic Cooling" where the Fraunhofer IKTS is involved in developing effective electrocaloric materials and devices. Objective of the work at Fraunhofer IKTS is the development of ferroelectric materials showing large temperature and entropy changes at cooling cycles. Through specific choice and synthesis of materials, an application-oriented adjustment of the phase transition is possible. Special attention is turned to the development of ceramics with low dielectric losses and large dielectric strengths.

For applications near room temperature, the ferroelectric complex ceramic system lead magnesium niobate-lead titanate (PMN-PT) is selected. Through directed changes of the stoichiometric composition as well as addition of different dopants the phase transition can be varied in a temperature range between -30 °C and 175 °C, and the dielectric losses and the dielectric strength can be influenced. For preparation, the raw materials are mixed in the specified ratio using a planetary ball mill. Afterwards, the powders are calcined followed by preparation of free-flowing granules. Using different uniaxial pressing facilities ceramic green bodies of various geometries (d = 10 mm, d = 30 mm, d = 160 mm, l x b = 124 mm x 124 mm) can be prepared. The thickness of the obtained samples can be adjusted between 0.5 mm and 30 mm. Green bodies are sintered in lead containing atmosphere, finished by mechanical treatment and metalized. To characterize the electrocaloric ma-





Dielectric properties of differently doped PMN-PT ceramics



terials the dielectric and ferroelectric properties are measured as function of temperature. Additionally the dielectric strength at room temperature is determined. The electrocaloric properties are characterized by means of a newly developed measurement setup at Fraunhofer IKTS and in cooperation with partners of the Priority Programme "Ferroic Cooling". So far, temperature changes of $1 \cdot 10^{-4}$ K·mm/V have been experimentally proven. Electrocaloric materials are also provided for cooperation partners as target for deposition of ceramic thin films. Available compositions are compiled in the following table.

Overview on prepared and available oxide targets

Material	Composition	Dimensions (green)	Dimensions (sintered)
BST	$Ba_xSr_{1-x}TiO_3$	d = 160 mm	d = 130 mm
		d = 30 mm	d = 25 mm
PMN-PT	$(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3$ - x $PbTiO_3$	d = 160 mm	d = 130 mm
		d = 30 mm	d = 25 mm
KNN	$K_xNa_{1-x}NbO_3$	d = 160 mm	d = 130 mm
		d = 30 mm	d = 25 mm
BT	$BaTiO_3$	l x b = 124 x 124 mm²	l x b = 100 x 100 mm²

Services offered

- Technology development for electrocaloric materials
- Technology development for oxide ceramic targets
- Flexible adjustments of processing and products to suit customer needs
- Preparation and supply of specified prototypes

1 0.92 PMN – 0.08 PT, diameter = 8.5 mm, polished.

2 Calcined PMN-PT powder, potassium-doped.

3 FESEM image of undoped (l) and tantalum-doped PMN-PT (r).

4 PMN-PT target, diameter = 160 mm.

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Temperatur °C
Temperature °C
-52
Vakuum mbar
Vacuum mbar
0.700

DIVISION

BIO- AND MEDICAL TECHNOLOGY

Project reports

Within the "Bio- and Medical Technology" division, Fraunhofer IKTS develops solutions for dental technology and endoprosthetics as well as medical device components and sensors.

For manufacturers of medical products, the long time to market and the highly regulated market itself represent considerable challenges when introducing product innovations. Through access to Fraunhofer IKTS decades of competence in materials and technology, these hurdles can be overcome much more efficiently, and above all, much faster. Long-standing collaborative relationships exist both in the processing of customer-specific tasks, and as part of its expert activities.

As certified research institute, Fraunhofer IKTS is a recognized partner for materials and component developers in the dental industry. It is also continuously developing and expanding its activities in endoprothetics, particularly in the area of bone replacement materials and bio-ceramic surfaces and mold designs. Based on commercially available materials, Fraunhofer IKTS is engineering new ceramic materials and components using improved, modified characteristics that are adapted to new specifications and applications of a continuously aging society. In doing so, scientists use both classic foaming, molding, and slip casting technologies, in addition to functional sol-gel and plasma coatings as well as new kinds of processes.

Based on its broad experience in characterization, Fraunhofer IKTS is also developing special processes, systems and instruments for the stimulation and the monitoring of cells and tissues for the separation, detection, and suppression of microbial organisms and toxins. The services portfolio in this product area comprises the conceptualization, process and software development, construction and building of prototypes through to support with the transfer into the production phase. In this connection, in addition to the biophysical and biochemical testing labs Fraunhofer IKTS also possesses appropriately equipped biomechanical test labs. On the basis of these skills, targeted solutions for mastering medical challenges facing our society are developed and transferred into applications.

Fraunhofer IKTS, institute branch Hermsdorf, is certified according to the standard EN ISO 13485:2003 + AC:2009 for the scope of "Design and development, manufacture and distribution of crown and bridge frameworks made of oxide ceramics".


1

BIO- AND MEDICAL TECHNOLOGY

PLASMAGEL COATINGS FOR MEDICAL APPLICATIONS

Dr. Thomas Hoyer

Plasmagel

At Fraunhofer IKTS a composite material was developed in form of a coating consisting of
- oxides, carbides, metals by atmospheric plasma spraying (APS) and
- nanocomposite materials by sol-gel technique.

By combining the advantages of both techniques – wear resistance of APS coatings and functional variety of sol-gel coatings-tailor-made surface properties can be realized and new areas of applications can be opened up. The coatings were named "plasmagel".

APS has already been used for the improvement of product surfaces for decades, e.g. for higher wear resistance, better electrical insulation or heat insulation, for non-stick or emergency running properties. Ceramics, metals and cermets (ceramic-metal composites) can be used as APS coating materials. Typical coatings are more than 40 µm thick and show a residual porosity of 5 to 10 % which is sealed by epoxy resins.

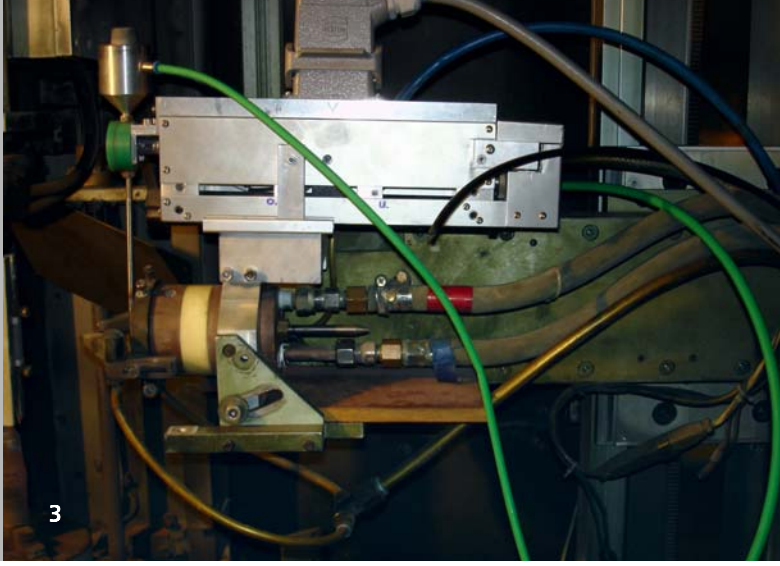
Using the sol-gel technique dense and thin nanocomposite coatings (thickness < 10 µm) can be deposited, in which metal oxides are connected with organic resins and/or silicones.

The great variety of possible substitutions allows for tailor-made coating properties like hydrophobicity, electrical conductivity, index of refraction or color.

Different applications could be opened up with plasmagel coatings:
- Components for wind power plants (chemical and mechanical resistance + electrical insulation),
- Transport rollers (wear resistance + non stick properties),
- Forceps tips for high-frequency surgery (non-stick properties + electrical insulation).

The last-mentioned example from medical technology shows that even small radii of curvature can be coated in high quality (Figure 1). The forceps are used for hemostasis. If there is no immediate blood coagulation the ends of the blood vessels can be pressed by the forceps. Using a pulse modified HF current which flows through the tissue between the metallic tip areas, the blood vessels can be completely closed by dehydration.

Before plasmagel has been used for the forceps, they were coated with a polymer material. After the operation, coagulated blood and tissue very often sticked to the forceps surface. When removing the contaminations, the polymer surface was easily damaged. Such a damage is not be expected anymore using the wear-resistant ceramic coatings. Additionally, the non-stick surface of the sol-gel sealing facilitates the removal of coagulated blood and tissue.



Virucidal coatings

A large proportion of epidemic diseases is caused by droplet or smear infection (influenza, swine flu, HIV, SARS, avian influenza, measles). In health care or emergency medicine, many patients acquire an infection while being hospitalized. An interesting strategy is the reduction of contaminated surfaces or the virucidal surface functionalization of frequently touched objects. So the transmission path may be interrupted.

In 2010, a research project for the development of virucidal surface coatings (EFRE-TNA: AVIRO) started at Fraunhofer IKTS. It is the major challenge to maintain the virucidal material properties during the coating process. The coatings have to be suitable for daily use and the coating processes should be applicable for different substrates at reasonable cost.

By combining the virucidal materials with copper, the developed coatings can destroy not only viruses but also bacteria. The virucidal properties of the materials were tested. The logarithmic virus reduction factor (VRF) of powder-like materials reached VRF > 4 (tested with modified vaccinavirus ankara). That is sufficient for the most applications. For coatings, VRF > 2 has already been achieved.

Different coating processes and materials compositions were investigated. Plasma spraying is one of the favorite methods. In, 2013 two devices were constructed: one that enables the spraying of smallest amounts of powder (few grams, Figure 2) and another that enables plasma spraying in inert gas atmosphere to avoid oxidation of sensitive metallic components. So, it should be possible to maintain the high VRF of the powders during the coating process.

There are many different application areas. In hospitals, nursing and care homes the following objects could be coated: door handles, handholds, floors, medical aids or surgical instruments. In livestock farms viral diseases are also a big problem, e.g. foot-and-mouth disease or avian influenza. Virucidal coatings for the barn equipment could help to block the various transmission paths. In food and pharmaceutical industry several applications are also possible to keep the products sterile.

Services offered

- Development of customized virucidal and bactericidal coatings and appropriate coating processes

1 *Forceps tips, coated.*
2 *Plasma-sprayed coatings with virucidal and bactericidal properties.*
3 *APS dosing device for small amounts of powder.*

EFRE
EUROPA FÜR THÜRINGEN
EUROPÄISCHER FONDS FÜR REGIONALE ENTWICKLUNG

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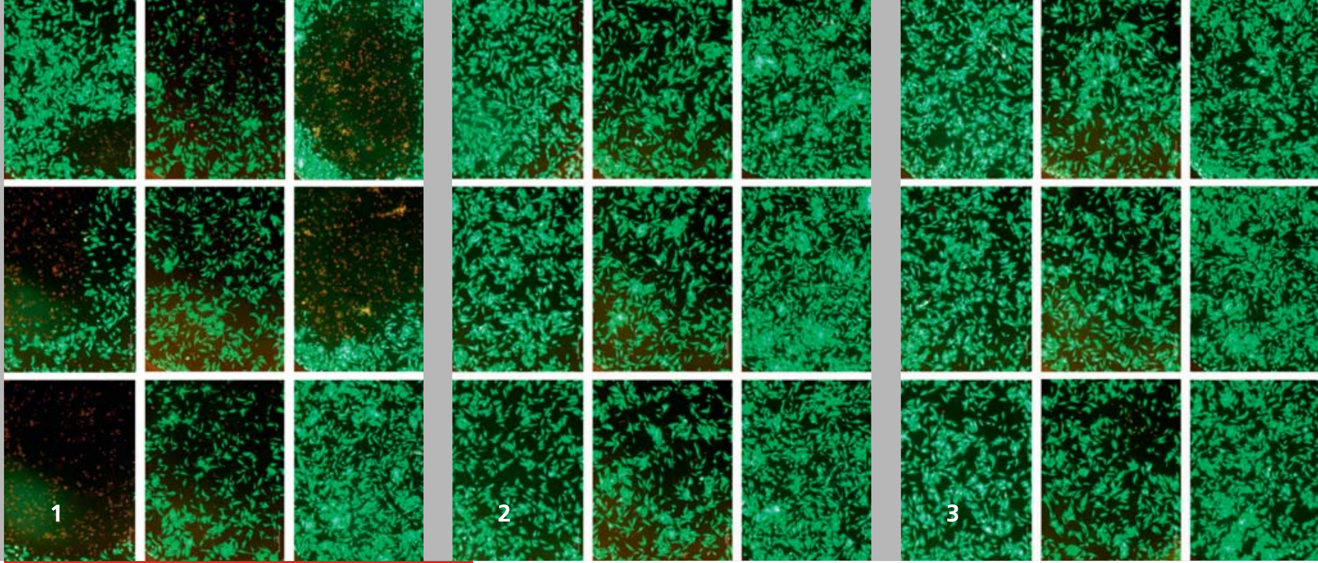


IMPLANT VARIABILITY VERSUS PATIENT'S INDIVIDUALITY

Dr. Holger Lausch, Dr. Michael Arnold, Dipl.-Math. Michael Brand

Motivation

In their search for the optimal implant or its surface, which overcomes problems occurring in clinical operation, the researchers at Fraunhofer IKTS developed different bioceramic materials and surfaces with and without coatings using different shaping technologies.

These materials were analyzed using biomechanical (IKTS) as well as cellular biological investigations (research partner: FORBIOMIT Rostock). Aside from the good biomechanical/bioactive properties, the tests showed significant differences between cellular biological test procedures with primary human osteoblasts as well as osteosarcoma cell lines. Thus, a clear validation of metal or ceramic implant materials and their surfaces or coatings is not possible at the moment.

Sample	Ra value	WST-1*	WST-1 – patient-specific		
			Pat 1	Pat 2	Pat 3
1	4.7653	83	73 %	80 %	96 %
2	1.7873	81	76 %	71 %	97 %
3	3.0728	86	78 %	75 %	104 %
4	7.2313	80	75 %	77 %	88 %
5	3.2831	82	81 %	68 %	96 %
6	5.9647	79	79 %	67 %	92 %
7	4.3968	75	77 %	68 %	80 %
8	2.1607	69	55 %	62 %	89 %
9	5.2654	68	58 %	55 %	90 %
10	6.7751	87	87 %	84 %	89 %
11	0.0293	92	98 %	86 %	92 %
12	0.0259	105	104 %	76 %	136 %

*WST-1 = cell metabolism in %-live-dead staining
Reference cell culture in 6 well = 100 % (values below 80 % are critical, i.e. not to be recommended)

Research approach

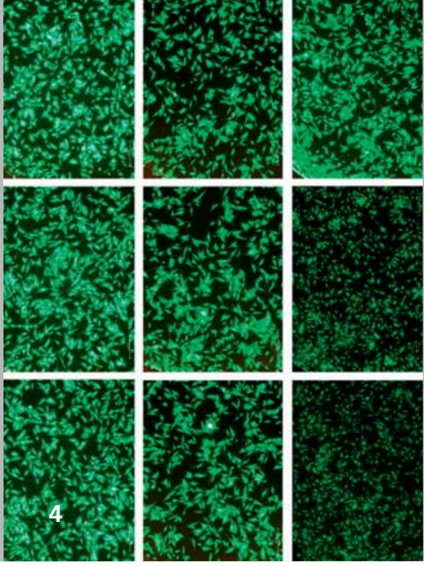
Based on the well-known differences of adhesion, proliferation, migration and differentiation properties of primary human osteoblasts and osteosarcoma cells as well as comparable immortalized cell lines, new in-vitro test methods with different primary human, i.e. patient-specific, non-neoplastic cell lines should be applied.

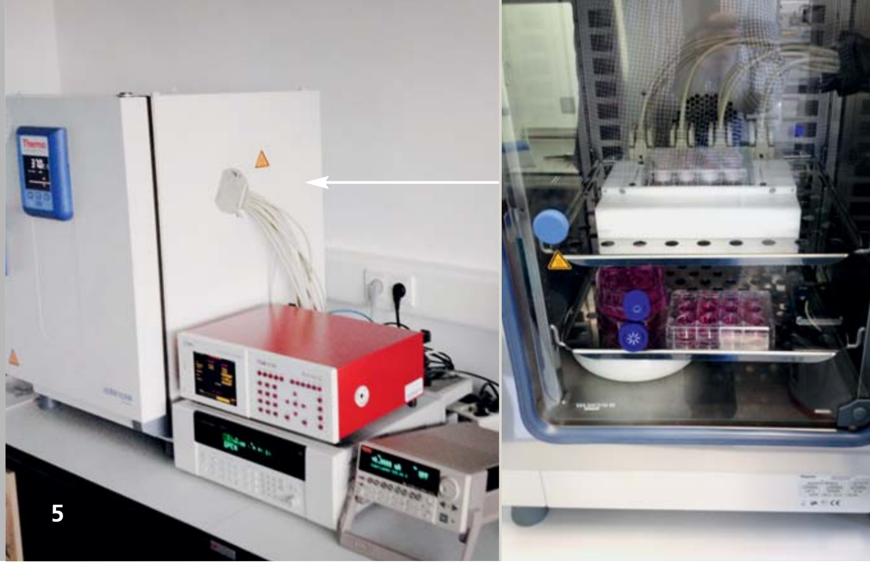
Twelve samples from different metal and ceramic materials of different roughness – with and without coating – were analyzed. Each sample was microbiologically tested with three primary human, patient-specific cell lines.

Results

The variability of the mentioned properties of patient-specific cells with different genetic predisposition or pathological changes (metabolic or cardiovascular disease, diabetes, alcohol, smoking, drugs etc.) is partly more dominant to different bioactive implant surfaces than the variability of the bioactivity of different implant surfaces to primary human cells.

Furthermore, the results and cell images cannot prove a correlation between proliferation, metabolism or adhesion regarding the material and surface of the test implants. In practice this means that there is not only one optimal bioactive surface, but





different surfaces can be optimal depending on the patient. If there is even one general characteristic for a bioactive implant surface then it is a hierarchically structured surface integrating nano-, meso- and microscale structures.

Follow-up projects and prospects

On the basis of these project results, biophysical cell monitoring assays are currently developed at Fraunhofer IKTS within different projects. Using these assays, the adhesion, proliferation and differentiation behavior of patient-specific, primary human osteoblasts and other cells against different materials with different or differently functionalized surfaces can be tested in parallel. It is advantageous that identical test conditions such as identical culture medium, incubation conditions, in-vitro model as well as cell lines can be used.

This approach will be further developed with the aim to establish an implant pretest module for a planned implantation or revision by means of which the optimal patient-specific product can be found out from the available implants within two or three days.

In contrast to patient-specifically manufactured implants high costs can be avoided. Furthermore, a patient-specific implant can be chosen. An integrable cell stimulation does not only reduce the testing period but also evaluates the optimal post-operative stimulation with regard to implant and patient.

Services offered

- Design and customized application-specific adjustment of in-vitro measurement systems for tissue-specific cell monitoring
- Evaluation and validation of metal and ceramic implant materials, coatings and surface structures

Live-dead staining and cell spreading:

1 *Cell test images (horizontal: patients 1–3, vertical: samples 1–3).*

2 *Cell test images (horizontal: patients 1–3, vertical: samples 4–6).*

3 *Cell test images (horizontal: patients 1–3, vertical: samples 7–9).*

4 *Cell test images (horizontal: patients 1–3, vertical: samples 10–12).*

5 *Biophysical assay for cell monitoring on bioactive as well as antimicrobial implant surfaces with human osteoblasts.*

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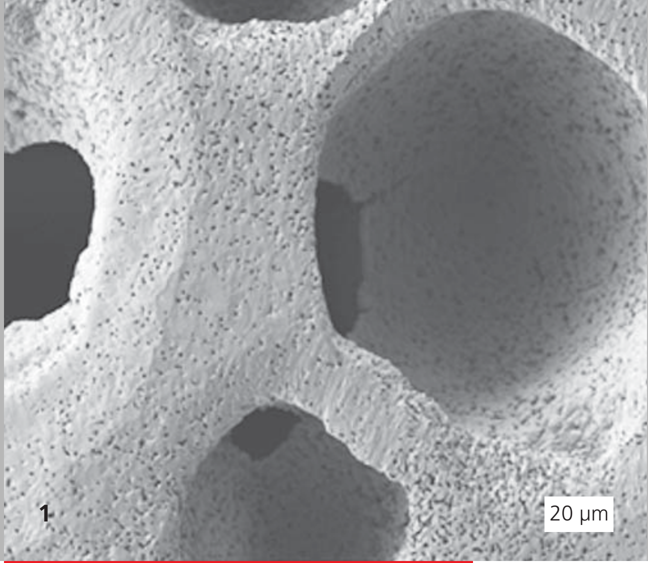
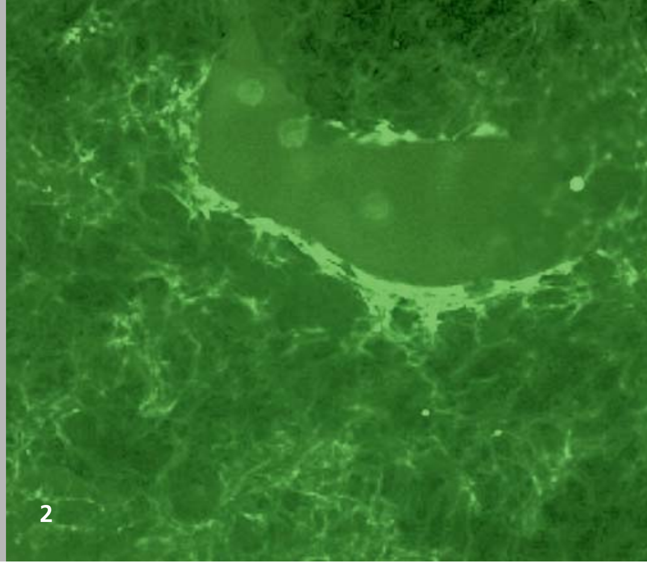




CERAMIC FOAMS AS BONE REPLACEMENT MATERIAL

M. Sc. (Chem.) Matthias Ahlhelm, Dr. Tassilo Moritz

In general, bones in a human organism have a pore size of approx. 100–700 µm that seems to be favorable for cell cultivation. The pore structure consists of macropores as well as micro/mesopores. The inorganic component of bones mainly consists of apatite, a calcium phosphate. Therefore, hydroxyapatite powder (HAp, $Ca_5(PO_4)_3(OH)$) is a suitable material for producing an artificial bone. For the generation of porosity different methods can be used (e.g. replica or placeholder technique, direct foaming).

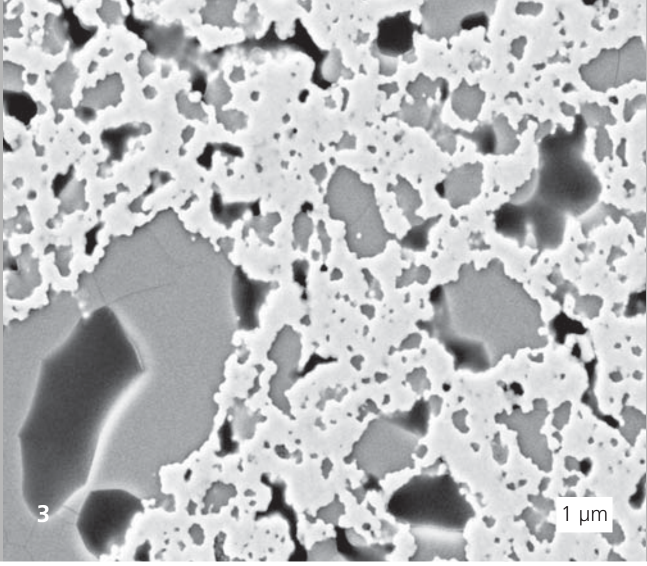
The ceramic foams presented in this article were produced by the so-called freeze foaming method where the ambient pressure around an aqueous, ceramic suspension in a freeze dryer (Christ GmbH, Gamma 1-20) is reduced. As a result, the suspension swells. If the pressure falls below the triple point, liquid water turns to ice (at approx. 6 mbar). Thus, the generated foam is stabilized. Then, the structure dries due to sublimation, the so-called freeze-drying process. After thermal treatment, a solid ceramic foam is obtained which may serve as potential bone replacement material.

Generally, typical freeze-foamed biomaterial structures have a mainly open porosity between 70 and 90 %, pore sizes ranging from micro/meso (0.1–20 µm) to macropores (100–1000 µm) and an interconnectivity. The pore-connecting struts are filled and microporous. So, they contribute to the structure's stability (Figure 1). In cooperation with the Fraunhofer Institute for Biomedical Engineering IBMT, live and dead staining tests with fluorescein diacetate (FDA) were carried out on murine (mouse) fibroblasts to verify the biocompatibility. Alkaline phosphatase (ALP) provides a first indication of a beginning osteogenic differentiation of human mesenchymal stem cells of bone marrow origin succeeds. As immunocytochemical collagen I-staining were detected in and on the porous structures, proliferation was validated. The hMSCs differentiate, i.e. they are able to form different types of cell/tissue (Figure 2).

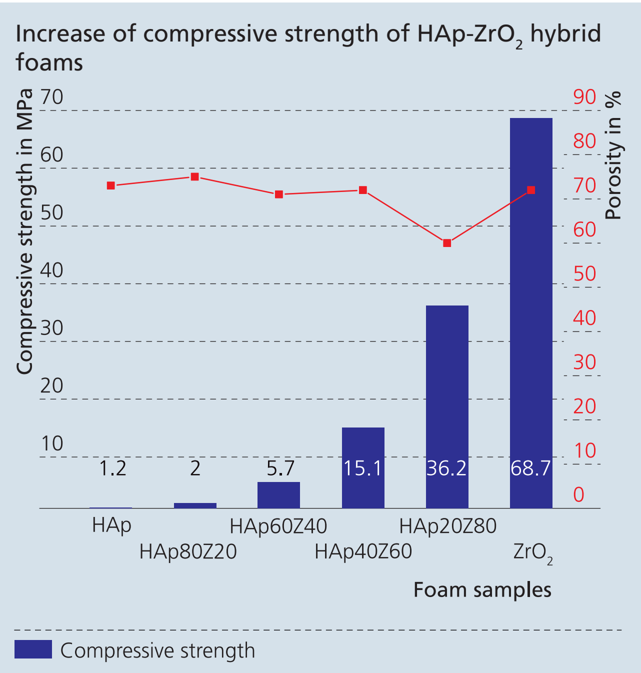
A natural bone withstands relatively high compressive strengths. In contrast, artificial hydroxyapatite per se shows a much lower load tolerance and mechanical strength. This is similar to materials like tricalcium phosphate or bioglass®, all of them suitable non-metallic biomaterials. Accordingly, the compressive strength of highly porous structures is lower.

However, freeze foaming allows not only for foaming completely different materials (e.g. metals) but also for processing two or more materials at the same time, time-shifted and/or interpenetrating or as layers on each other.

Therefore, non-load bearing hydroxyapatite (e.g. by MERCK or SIGMA-ALDRICH) was paired with the likewise biocompatible and provably load-bearing zirconia (ZrO_2, TZ3-Y-E, by TOSOH) in a hybrid mixture. The mixing ratios were varied starting at 20 vol% ZrO2 in HAp up to 100 vol% pure ZrO_2 in order to evaluate the effect of zirconia on the compressive strength of the porous freeze foams. It was demonstrated that the structural compressive strength can be increased to approx. 15 MPa at the ratio of 60 : 40 vol% (ZrO_2:HAp). That effect corresponds to the reached percolation threshold of zirconia in hydroxyapatite. Connected, filigree ZrO_2 scaffolds (white), which enclose solid HAp clusters (grey), lead to the observed increase of strength (Figure 3). A ratio of up to 80 vol% zirconia results



in porous structures which are able to withstand compressive strength of almost 40 MPa (see diagram).



Follow-up procedures of the biocompatibility of the porous structures confirm: all ceramic foams are not cytotoxic and thus biocompatible. Preliminary experiments on osteogenic differentiation deliver positive results for these new, strength-enhanced ceramic hybrid foams.

The use of similar or newly developed materials in combination with near-net shaping by freeze foaming (Figure 4) as well as further process optimization provide a possible scenario for an application as implant.

Services offered

- Development of suspensions for freeze-technological shaping methods like:
  - Freeze foaming
  - Freeze casting
- R&D projects/feasibility studies for producing artificial bone replacement materials and components

1 *SEM images of a HAp foam.*
2 *Collagen I proof on a HAp foam.*
3 *HAp-ZrO_2 hybrid foam.*
4 *Freeze-foamed thumb bone replica of HAp.*

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DIVISION

OPTICS

Project reports

In the "Optics" division, we develop, characterize and produce components for the areas lighting, security, medical and laser technology and for specialized optical and decorative applications, based on commercial and proprietary synthesized materials.

Optical technologies are innovation and growth drivers for resource-saving LED lighting, more efficient laser-based manufacturing processes or medical diagnostic systems. A successful implementation, however, demands that scientific know-how is transferred by means of competitive manufacturing technologies into high-performance and reliable products. This challenge begins with the material, which then fundamentally determines all of the following production steps and characteristics of the finished product.

More than ten years ago Fraunhofer IKTS was already demonstrating completely new ways of producing transparent ceramics using especially fine crystalline microstructures and especially high mechanical indices. This knowledge was consistently built-up and has today enabled the production of polycrystalline ceramics exhibiting a high level of optical homogeneity and mechanical load-bearing capacity with simultaneous minimal absorption and scattered light loss. Quite different demands are placed on optically active materials for which the decisive criteria to success are represented by high quantum yield, thermal stability of the color space, and long light persistence periods. For the engineering of optoceramics, we have been able to bring together our experiences in the area of transparent ceramics and light materials synthesis, in order to secure the homogenous distribution of dopant agents and dispersion in media (polymers and ceramic matrices). Of increasing significance to the division are optical systems that are not based on transmission, but rather reflection, which are used as high-performance components with high stiffness and minimal density, and low thermal expansion coefficients in laser and space technology.

The production of components and materials with the most diverse optical specifications demands innovative materials and production skills that even extend to modification and reengineering of tools. In this capacity, Fraunhofer IKTS provides advice and support through its access to interdisciplinary knowledge in all fields of competence and divisions.

OPTICS

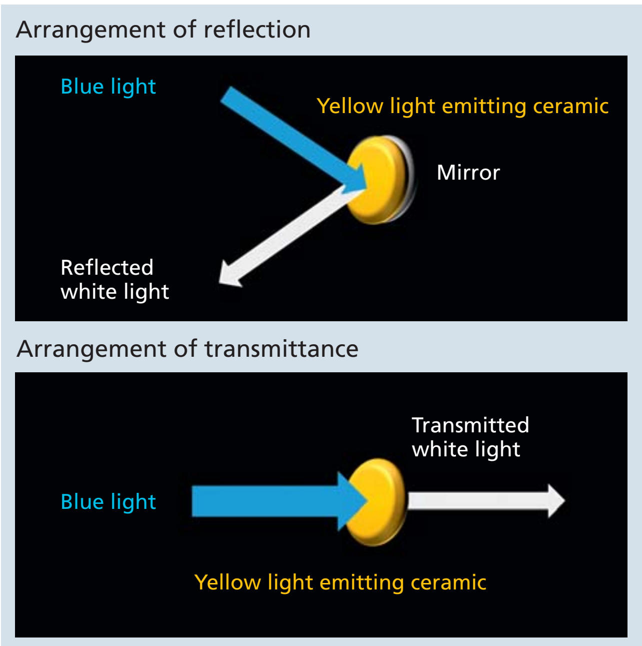
TRANSPARENT YAG:CE CERAMICS FOR CONVERTING BLUE LIGHT

Dr. Katja Wätzig, Dr. Isabel Kinski

Traditionally, LEDs are prepared by applying a silicone-phosphor suspension on a blue light emitting chip. The mixture of the blue transmitted and yellow emitted light is noticed as white light.

With improvement of the energy density in case of high-power LEDs the silicone-phosphor converter cannot be used anymore because of the ageing of the silicone matrix (browning) and a decrease of quantum efficiency by warming the phosphor.

These problems can be solved using optical ceramics, i.e. polycrystalline ceramics made of optically active materials. Their thermal conductivity, in particular, is significantly higher than that of silicone.



Furthermore, scattering effects in optical ceramics can be adjusted by the processing and sintering route of the phosphor powders. Scattering centers such as pores into the bulk or the surface roughness of the ceramics can be controlled. Therefore, the heat transport and the optical performance of optical ceramics can be optimized for the application in LED.

For producing white light in LEDs (made of a mixture of blue transmitted and yellow converted light) yttrium aluminum garnet doped with cerium (YAG:Ce) is used. Because of its cubic crystal structure the YAG:Ce can be prepared as a highly transparent single crystal as well as a polycrystalline bulk material. The degree of transparency and the luminescence are depending on the stoichiometric composition, the content of dopant and the whole processing and sintering route. In the case of application in LEDs, a lower transparency and an optimized degree of scattering centers are desired for a homogenous mixture of blue and yellow light. The generation of white light with blue light of a LED chip or a laser diode is possible as a reflection or transmittance arrangement.

In case of the transmittance arrangement, the light beam passes the ceramic material only once, whereas in the reflection arrangement the light beam goes twice through the polycrystalline material. To create the right chromaticity coordinates, the concentration of dopant, the degree of scattering centers or the thickness of the polycrystalline material have to be changed.

2

3

Prospectively, optical ceramics (also named as ceramic phosphors) have the potential to substitute polymer-phosphor composites in high-power applications as well as single crystals (e.g. as laser material).

The synthesis of usable phosphor powders is a requirement for the preparation of optical ceramics with defined properties. Commercially available phosphor powders have a concentration of dopant that is too high. Furthermore, they are too coarse for the preparation of ceramic bodies. Therefore, inorganic phosphor powders with an optimized degree of dopant, uniform particle size distribution and beneficial processibility are synthesized at Fraunhofer IKTS. Solid-state reaction, spray drying with calcination, sol-gel and hydrothermal synthesis are used to design the properties of the powders.

Offered services

Synthesis and ceramic processing
- Synthesis of fluoridic, oxidic, nitridic, oxynitridic phosphor powders
- Preparation of optical ceramics with different geometrical shapes
- Variation of optical properties by changing dopant concentration, content of scattering centers and thickness
- Industry-oriented pilot production of ceramics

Characterization of transmittance and luminescence (fluorescence)
- Photoluminescence in an excitation range from 250 to 850 nm and an emission range between 250 and 1700 nm wavelength (in arrangement of reflection and transmittance)
- Quantum yield of powders and ceramic bodies
- Phosphorescence (decay time) in range of µs
- Total and in-line transmittance to differentiate transmittance, scattering, absorption and reflection

1 *Transparent YAG:Ce ceramic body of 0.83 mm thickness.*
2 *White light emitting YAG:Ce component excited with blue light (transmittance arrangement).*
3 *White light emitting YAG:Ce component excited with blue light (reflection arrangement).*

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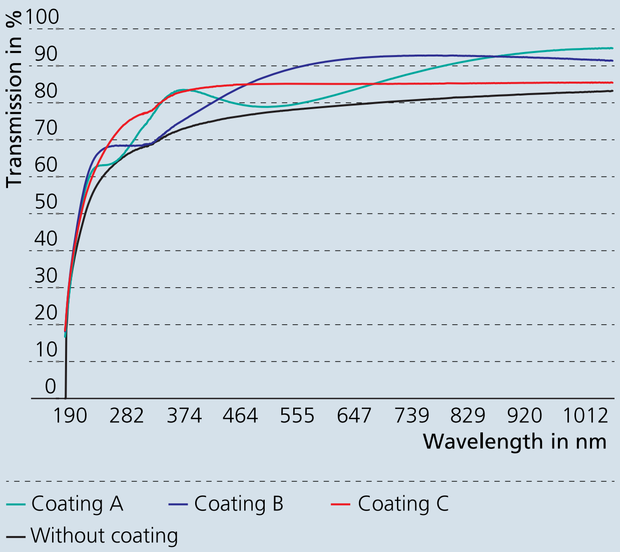
OPTICS

TRANSPARENT CERAMICS WITH NANO-SCALED METAL FLUORIDE ANTIREFLECTIVE COATINGS

Dr. Uwe Reichel, Prof. Dr. Erhard Kemnitz (Humboldt-Universität Berlin)

In the 2011/2012 annual report it has already been described that transparent $MgAl_2O_4$ spinel ceramics can be manufactured by automated uniaxial pressing. In the present report, Klimke and Krell describe the method of gel casting to manufacture large-sized and defect-free components from spinel (page 36/37).

Transmission measurements on spinel discs coated with MgF_2 sol (thickness 1 mm)



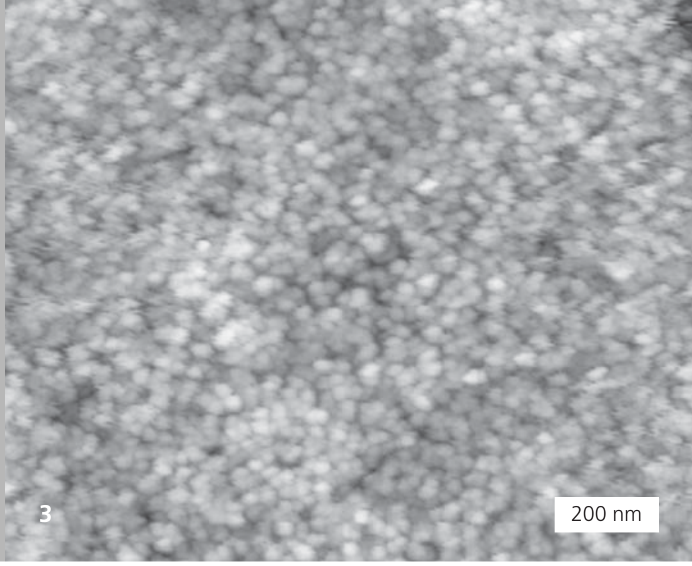
Advanced transparent $MgAl_2O_4$ spinel ceramics are characterized by a high in-line transmission in a broad wavelength range (from UV to IR). To achieve a maximum of transmission in addition to a homogeneous structure free of defects, surface conditioning in optical quality and optical antireflective coatings are necessary.

Mechanism of antireflective coatings

By introducing porosity into a film, its index of refraction decreases. For materials such as SiO_2, Al_2O_3 und TiO_2, commonly used in sol-gel processing, porous λ/4 films can be manufactured for a variety of substrates if the respective refractive indices are took into consideration. For standard glasses (n ~ 1.46–1.65), SiO_2 turns out to be most suitable [1] because the required porosity of about 50 % provides sufficient mechanical stability.

With n = 1.38, magnesium fluoride has a significantly lower index of refraction than SiO_2 (n = 1.5). MgF_2 films with lower porosity and therefore higher mechanical stability allow for better transmission.

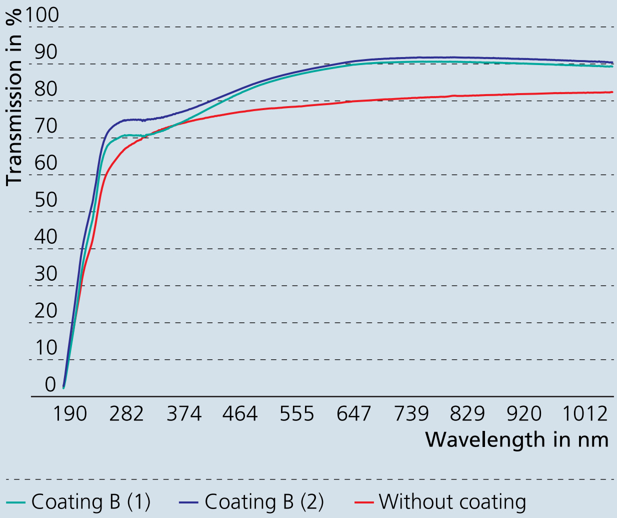
It was investigated whether nano-scaled metal fluorides synthesized by new methods of fluorine sol-gel synthesis are suitable for the optical coating of transparent ceramics and the enhancement of transmission.



Method

High transparent $MgAl_2O_4$ spinel ceramics were analyzed in terms of their manufacturing technology and optical properties. Using fluorine sol-gel synthesis different nano-scaled metal fluorides were synthesized and applied on spinel ceramics by dip coating. Then, the optical properties were determined and compared with those of uncoated ceramics.

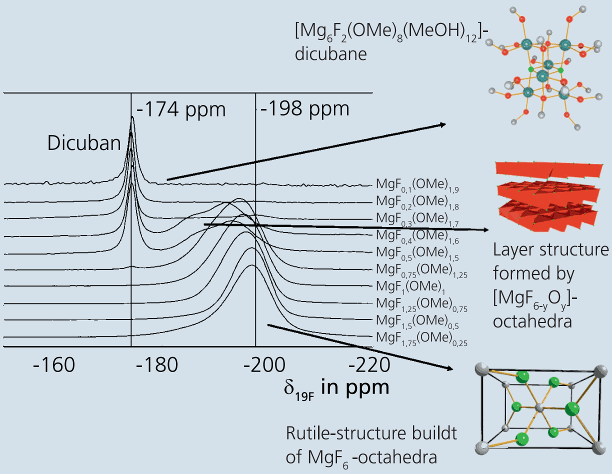
Transmission measurements on spinel discs (thickness 3 mm) coated with CaF_2 sol



Results

With the newly developed and metal fluroide coatings, a significant increase of in-line transmission by up to 10 % (absolute) in different spectral ranges and in dependence of different metal fluorides was achieved. It was shown that nano-scaled metal fluorides, synthesized by fluorine sol-gel synthesis, are suitable for optical coating of transparent ceramics and provide new possibilities for specifically improve the spectral transmission of these materials.

Sol-Gel-synthesis of MgF_2:
^{19}F-MAS-NMR of $MgF_{2-x}(OMe)_x$ -xerogels



Source: J. Mater. Chem. 2011, 21, 15015-15021.

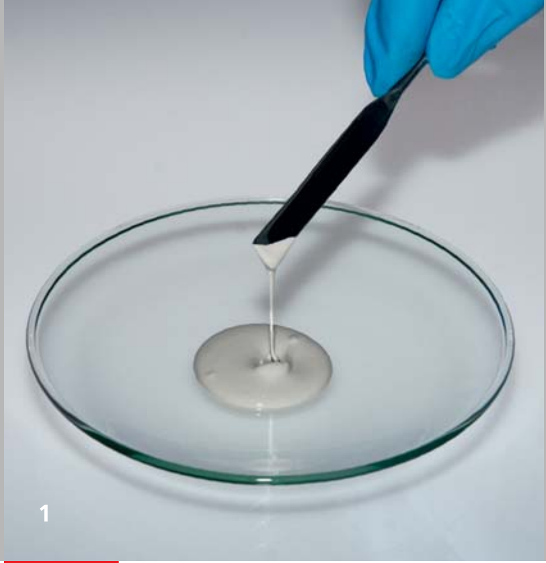
Sources

[1] A. Krell, J. Klimke: Fraunhofer IKTS annual report 2006, p. 23.

1 Spinel discs (3 mm thickness) without (left) and with (right) coating.

2 MgF_2 nano sol.

3 AFM micrograph of a sample three times coated with MgF_2 and calcined at 300 °C.



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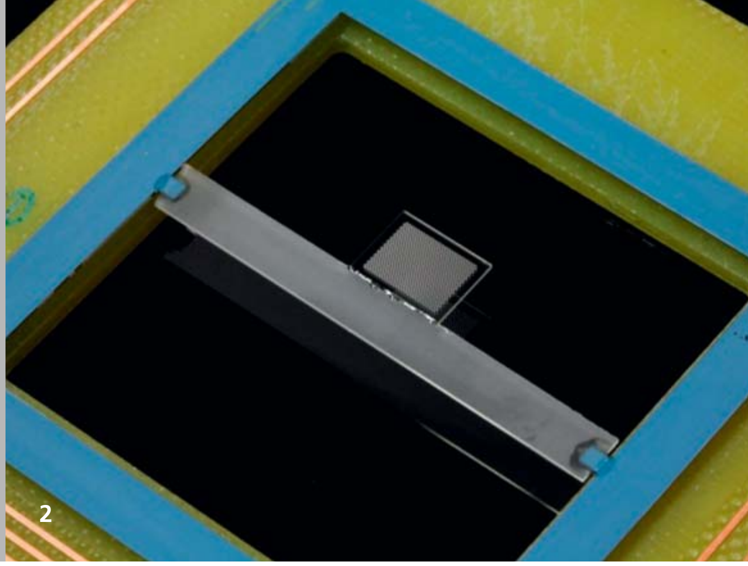


2

OPTICS

PIEZOELECTRIC THICK-FILM ACTUATORS FOR OPTICAL SYSTEMS

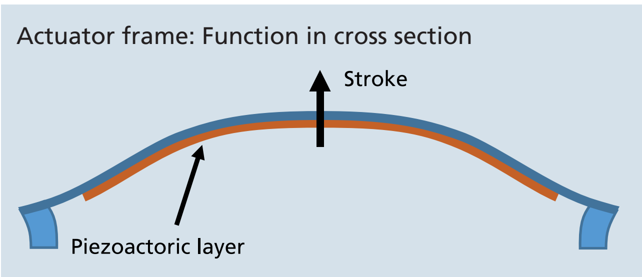
Dipl.-Phys. Bernhard Bramlage, Dipl.-Ing. (FH) Dörthe Ernst, Dr. Sylvia Gebhardt

Motivation

The integration of piezoelectric actuators in optical systems is advantageous for positioning and beam shaping applications. Particularly in cases in which miniaturization, complex actuator structures or a high degree of integration are aimed for, conventional piezoelectric devices are limited. A technology is required that performs well in a minimal space and, with minimum efforts, allows for the integration with the surrounding electronic components and other functional elements.

Technology

The basis for low-profile actuator solutions are piezoceramic thick-film pastes developed at Fraunhofer IKTS. Applied via screen printing onto substrates, they can be combined with other functional films, e.g. electrodes, isolators and resistors. Standard microelectronic substrates, such as Low Temperature Cofired Ceramics (LTCC) and alumina (Al_2O_3), but also silicon (Si) and zirconia (ZrO_2) can be used. During sintering a rigid bond is formed between the functional layers which is free of adhesives and solvents. By applying an external electrical field, the piezoceramic layer can be either stretched or compressed, warping the substrate to form a bending actuator for example. Standard SMD elements can be included directly on the ceramic substrate by hybrid integration, while multilayer technology allows for further functionality inside the substrate.

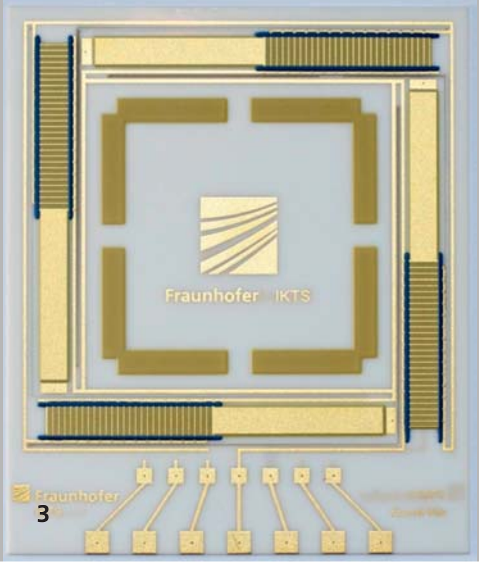


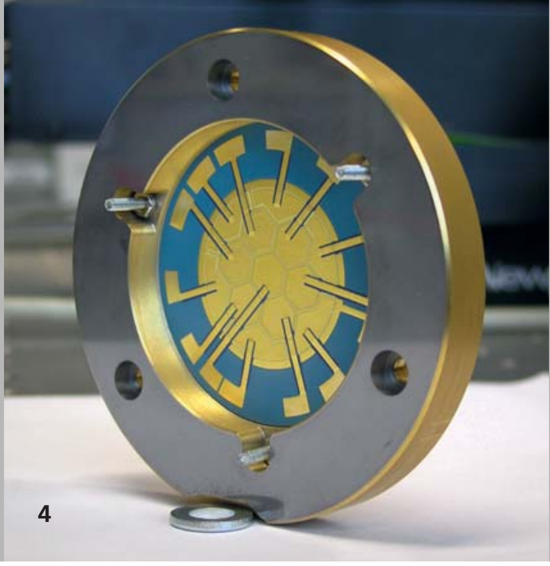
Results

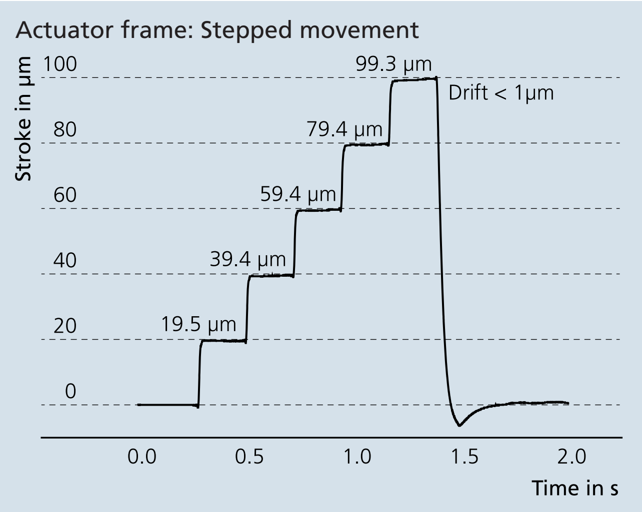
In order to expand the working range of a plenoptic camera, an actuator module was developed allowing for controlled positioning of a micro lens array. Screen printed thick-film actuators on an LTCC frame provide a stroke of ~100 µm for the optical element. The application requires a stepped movement that was clearly demonstrated.

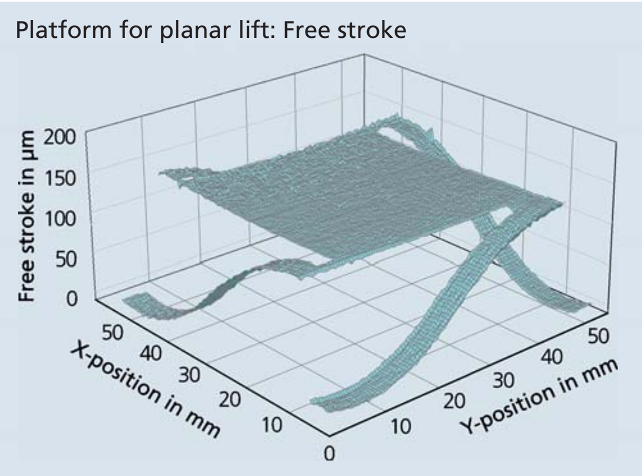
Structuring of the electrode allows for a combined bending movement both upwards and downwards on the same substrate, creating an s-shaped bending curve. Using this method an actuator platform was developed that lifts a load without inducing torsion.

Layer-shaped piezoelectric actuators can not only be used to create bending elements but also to morph optical surfaces. For example, an arrangement of hexagonal-shaped piezo elements was printed onto an LTCC substrate to morph a mirror surface on the opposite side of the substrate. By individually addressing the elements, aberrations can be corrected in the optical path or a laser beam refocused (Figure 4).









Acknowledgments

We gratefully acknowledge the cooperation with the Fraunhofer IOF regarding optical systems within both the DFG Priority Programme "Active Micro-optics" and the BMBF project "Kompetenzdreieck Optische Mikrosysteme".

Services Offered

- Development of tailored sensors, actuators and ultrasonic transducers based on piezoceramic thick-films
- Design of planar sensor and actuator systems and simulation of system behavior
- Prototyping

1 *PZT thick-film paste.*
2 *Actuator frame with micro lens array.*
3 *Actuator platform for planar lift.*
4 *Adaptive mirror for laser beam shaping.*

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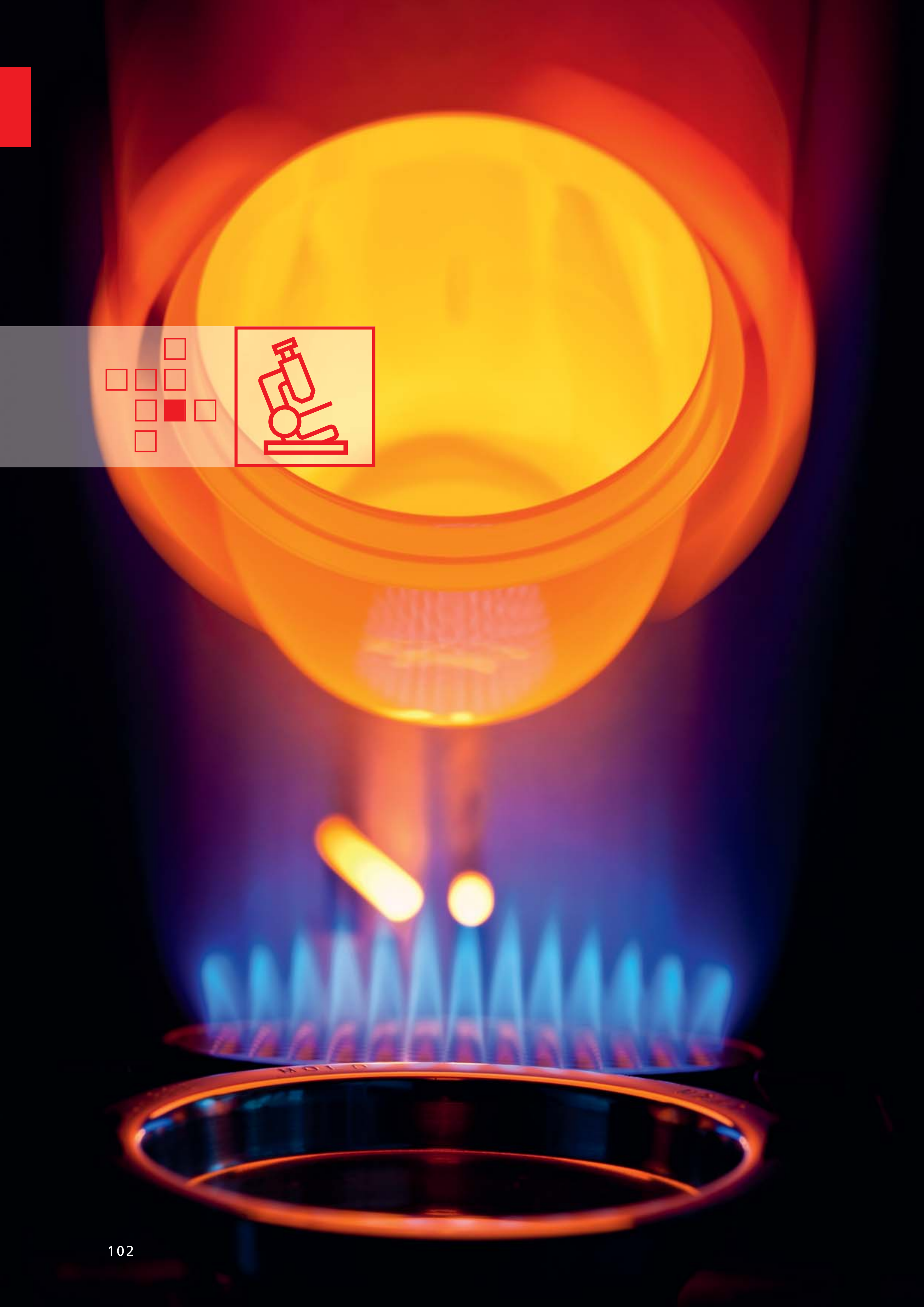


DIVISION

MATERIALS AND PROCESS ANALYSIS

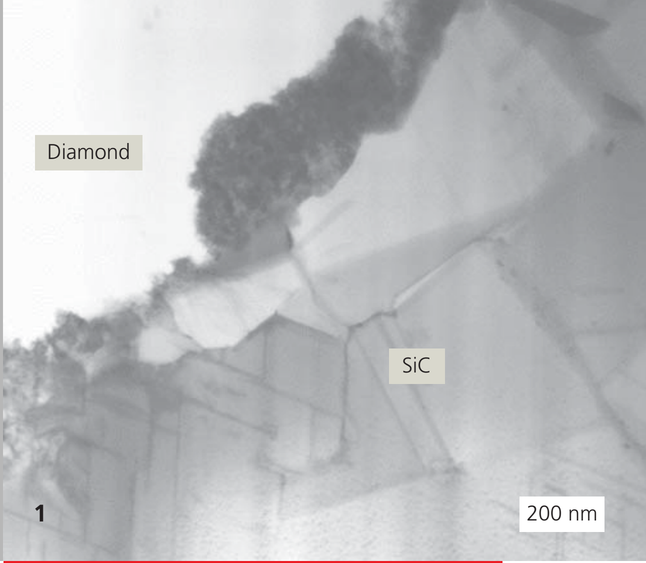
Project reports

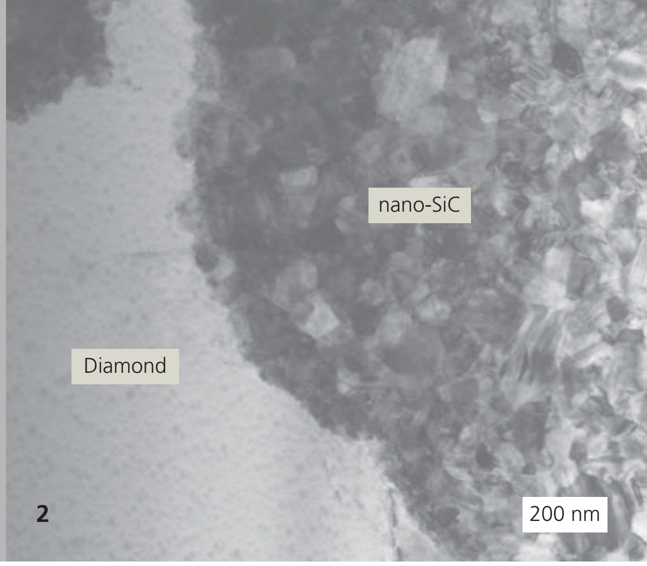
In the "Materials and Process Analysis" division, Fraunhofer IKTS offers users and producers a comprehensive portfolio of testing, characterization and analysis methods, in order to characterize and evaluate the properties of ceramic and powder metallurgical materials, raw materials and components and processes.

How can we set up a stable production process? Can I substitute an existing material with a more inexpensive one, without having to diminish the quality of my product? How does the microstructure influence the properties of my material? What quality standards do we have to uphold? In order to answer these questions, the complex interrelationships between raw materials, production technology, material structures and properties as well as operating conditions and component configuration must be looked at as a whole, and key indicators must not only be determined, but also interpreted.

Fraunhofer IKTS sees itself as a central contact point for all matters related to chemical, thermal, microstructural, mechanical, tribological, electrical and electrochemical analyses, valuation and optimization of materials produced using ceramics and powder metallurgy, as well as the production processes associated with them. In addition to all the necessary standard methods, the most unique testing options worldwide are available, especially for the testing of super-hard and ceramic high-temperature materials. On the basis of comprehensive process, material, and analysis expertise, Fraunhofer IKTS supports and advises customers on the development of new materials and products, clarification of complex failure mechanisms, and the achievement of legal and qualitative standards. The accredited labs for determining key indicators for powders, suspensions, thermophysical and electrical/di-electrical properties of materials, electrical components, and partial systems are therefore able to relieve customers of various tasks relating to quality assurance and the certification of products and processes, as well as prototype testing.

Based on its scientific expertise and longstanding experience, Fraunhofer IKTS is a reliable service provider for the implementation of diverse measurement processes and the joint development of innovative characterization and analysis solutions.





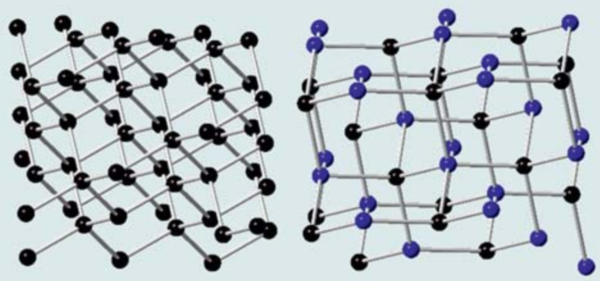
HIGH-RESOLUTION ANALYSIS OF INTERFACES BY FIB/STEM AND EBSD

Dipl.-Ing. Björn Matthey, Dr. Sören Höhn

Motivation

Super-hard materials based on silicon carbide bound diamond increasingly meet the demand for wear-resistant materials. Due to the increasing mechanical requirements standard monolithic ceramics tend to fail more often. By infiltrating diamond containing preforms with liquid silicon [1], superhard SiC diamond composite ceramics can be cost-effectively manufactured.

Local crystal orientation of diamond (left) and cubic silicon carbide (right) at the interface

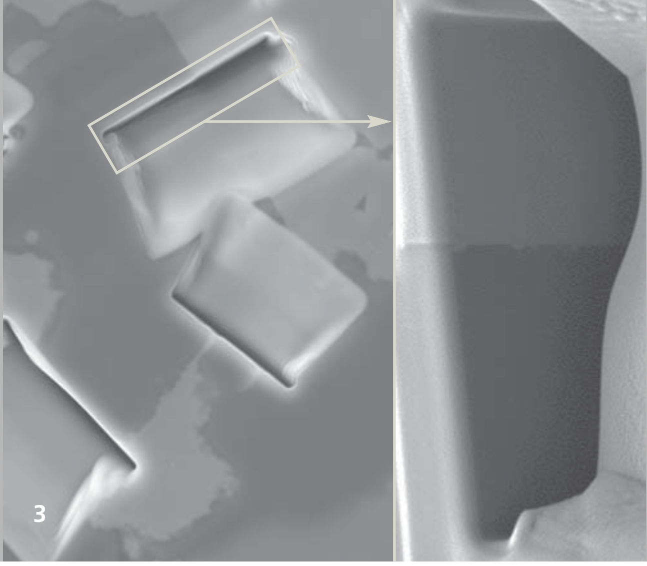


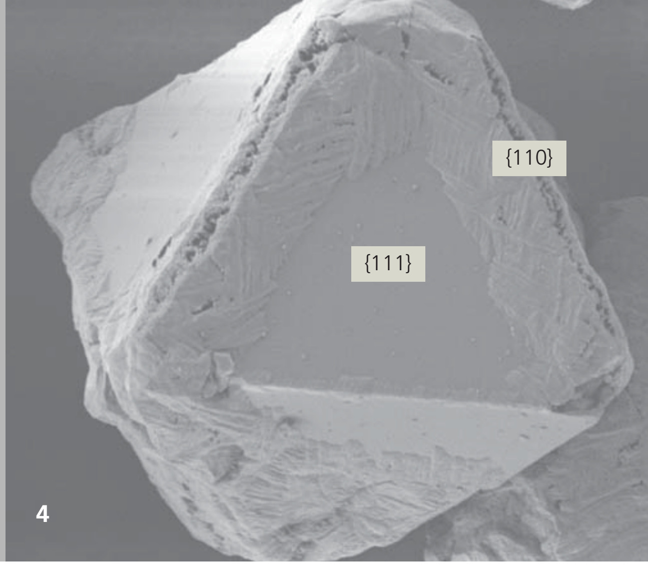
High-resolution analysis of interfaces

During infiltration, complex processes take place when silicon carbide is developed at the diamond's surfaces. The developing interfaces between diamond and SiC are of great interest as the embedding of the hard material phase into the ceramic matrix particularly influences the properties of the composite, and thus the performance of wear parts. Here, standard high-resolution scanning electron microscopes reach their limits. STEM detectors which use electron transmission for image generation are one tool to increase the resolution. However, a prerequisite is that electron transparent samples are available which are prepared in-situ by focused ion beam (FIB). The combination of FIB and STEM allows to show the microstructure in high resolution (lower nanometer range) and to gain important knowledge about the structure of the interfaces. Figures 1 and 2 show the interface between diamond and SiC at which SiC crystallites in the range from 20 to 80 nm develop by diffusion.

Local analysis of interfaces and orientation relationships

Metastable phases such as diamond change to their stable modification during heat treatment. In case of diamond, the cubic crystal lattice changes to hexagonal. This process starts at the surfaces or defects in the particles. The transformation rate depends on the crystallographic orientation of the surface. The surfaces of diamond particles (Figure 4) have low indices, for example {111} and {110} [2]. By FIB preparation, the samples can be locally cut to obtain complete information about the position of the interface in a three dimensional coordinate system (Figure 3). Based on this information and referring to the crystal orientation to the sample surface which was determined by electron backscatter diffraction (EBSD) the surface can be indexed, and thus, the behavior of the different interfaces can be exactly analyzed. The knowledge about these interfaces can be used to specifically design materials with defined structures and properties. Due to a solution-precipitation process, laterally grown SiC grains develop at these





surfaces. Here, coherent phase interfaces can develop between both adjacent phases. The prerequisite is that there are only little differences of interatomic distances of both crystal lattices. Analyzing the indices and the position of the surfaces of two adjacent phases, information about possible relationships of the adjacent phases can be obtained. Such analyses are usually only possible by means of high-resolution transmission electron microscopy.

Sources

[1] M. Herrmann, B. Matthey, S. Höhn, I. Kinski, D. Rafaja, A. Michaelis, Journal of the European Ceramic Society, 32, 2012

[2] Butenko et al., Journal of Applied Physics, Vol. 88, 1999

Acknowledgments

We gratefully acknowledge BMBF for funding the EkoDiSc (03X3583H) project, and AiF for funding the DiaSiC project (16861BR/1).

Services offered

- Manufacturing of prototypes of superhard, wear-resistant diamond-SiC ceramics
- Artefact-free preparation of microstructures of superhard ceramic materials by ion beam based methods
- High-resolution analyses of nanocrystalline microstructures and interfaces by means of FESEM, FIB/STEM, and EBSD

1 *Interface between diamond and SiC taken in the high-resolution STEM contrast (FESEM).*

2 *Nanocrystalline SiC at the interface between diamond and SiC.*

3 *FIB preparation of different interfaces of a diamond particle for determining the three dimensional position of the diamond interface.*

4 *Grown diamond crystal with octahedral habit and starting graphitization at different crystallite surfaces.*

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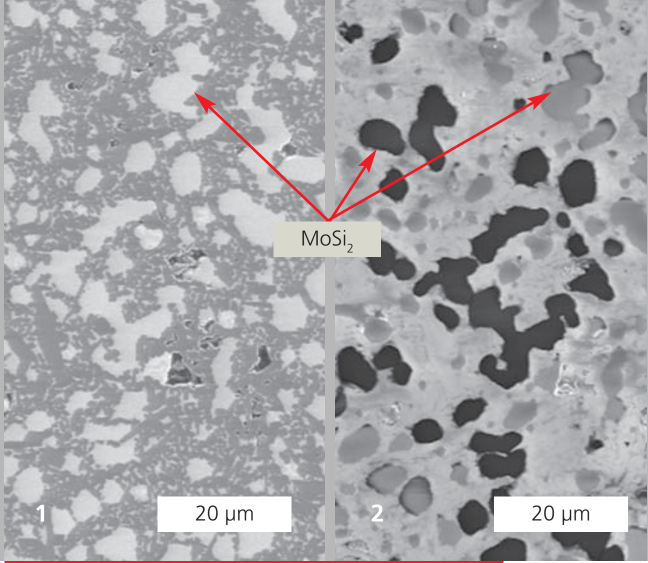
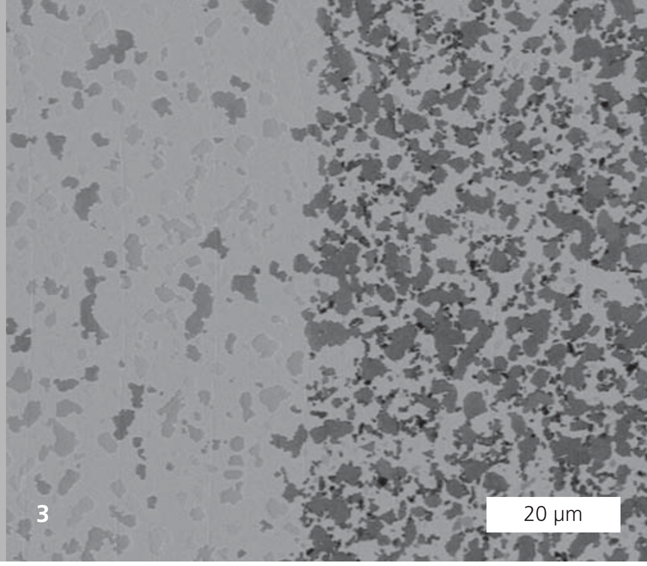




VISUALIZATION OF LOCAL ELECTRICAL CONDUCTIVITY IN CERAMICS

Dipl.-Ing. Kerstin Sempf, Dr. habil. Mathias Herrmann

The electrical conductivity of ceramics or composites plays a decisive role in a number of applications (e.g. heating elements, sensors, fuel cells, components with thick-film conductors...). In order to specifically adjust the conductivity of composites made from electrically conducting and non-conducting materials, it is necessary to have knowledge about the local embedding of the materials into the conducting paths.

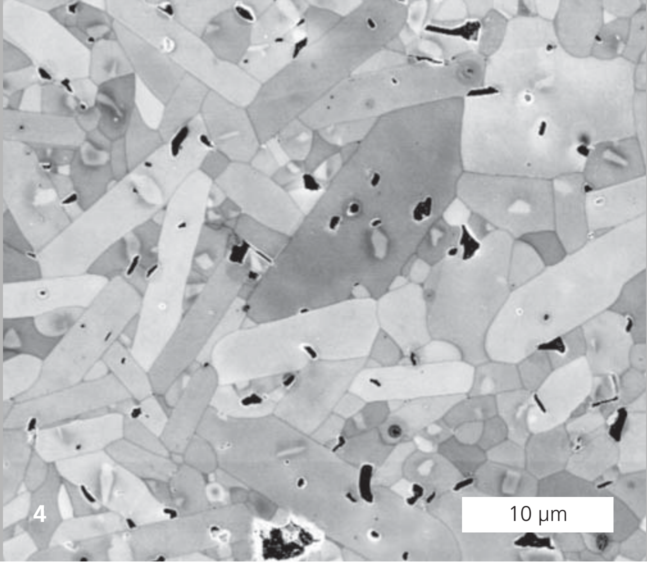
At Fraunhofer IKTS, methods were developed which allow to show conducting paths in an insulating basic matrix and local differences in conductivity in semiconductors by field-emission electron microscopy (FESEM).

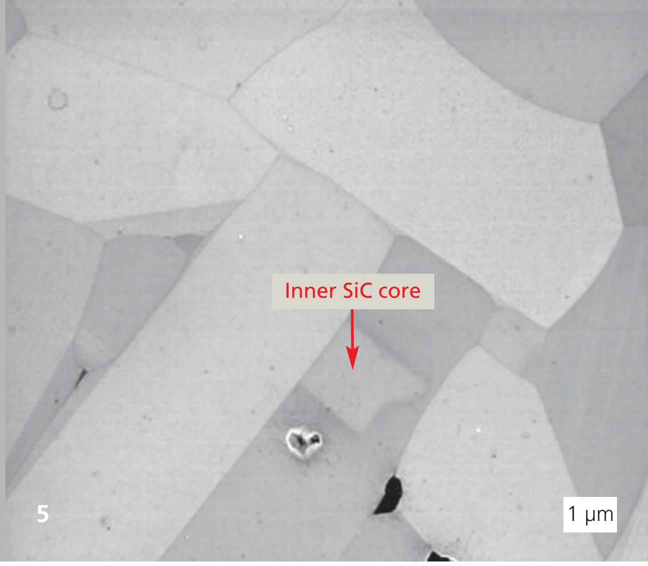
At the example of SiC materials and SiC/Si_3N_4/$MoSi_2$ composite materials which, for example, are used for glow plugs [1], Fraunhofer IKTS extensively worked on the methods [2–3].

Comparing Figures 1 and 2 it can be seen that different information can be obtained depending on the imaging mode. Whereas $MoSi_2$, Si_3N_4 and sintering additives are visible in the SE mode (Figure 1), Figure 2 shows contrasts as a function of local conductivity (dark: highest electrical conductivity). Here, it is already obvious that the $MoSi_2$ particles are not homogeneously embedded into the conducting path. FESEM allows to show the developed network of the conducting particles as there is a different dissipation of the charge induced by the electron beam. Particles in the network can dissipate the charge and, thus a charge-free imaging is possible. If the conducting particles are insulated in the matrix, the induced charge carriers are not dissipated completely, and thus, cause charges on the particles. As a result, the particles are displayed brighter. Figure 3 shows that there are different contrasts of the same phase depending of the percolation of the conducting phase. So, on the left side the non-conducting area of the component is shown, and on the right the conducting area. The interface between both areas can clearly be demonstrated. Whereas the conducting phase (SiC/$MoSi_2$) appears dark in the conducting area, it appears light in the non-conduction area.

FESEM and suitable detection mechanisms allow to show the exceeding or dropping below the percolation threshold, and particularly the interface between the conducting and non-conducting area.

The developing surface potentials can also be used for single-phase materials to show their microstructure. Figure 4 depicts the well contrasted grain structure of an SSiC material which develops due to the different embedding of the grains in the microstructure.





Additionally, the methods allow to visualize local differences in conductivity in SiC grains caused by the different defect concentrations in semiconductors. These local differences in conductivity also significantly influence the corrosion behavior of the materials [2–4]. Figure 5 shows a core of a SiC grain embedded in SSiC. It is very probable that this microstructure has developed because SiC has grown on a primary particle of the starting powder. Similar core-shell structures can be quantitatively analyzed for liquid-phase sintered SiC materials (LPS SiC) and silicon infiltrated materials (SiSiC).

These two examples give an insight into the potential of materials characterization by using state-of-the-art scanning electron microscopy.

Services offered

- Ceramographic sample preparation
- Investigation and interpretation of microstructures
- Evaluation of materials and determination of material parameters
- Failure analysis

Sources

[1] Zschippang, E., Klemm, H., Herrmann,M., Höhn, S., Matthey, B., Guth, U., Michaelis, A.: Electrical Resistivity of Si_3N_4-SiC-$MeSi_2$ (Me = Nb, Mo, W, Zr) Composite, J. Ceram. Sci. Tech. 04 [04], 2013, pp. 197–206

[2] Sempf, S., Herrmann, M., Sydow, U.: New Ways of Revealing the Microstructures of SiC materials, Prakt. Metallographie 49, 2012, pp. 64–74

[3] Herrmann, M., Sempf, K., Schneider, M., Sydow, U., Kremmer, K., Michaelis, A.: Electrochemical corrosion of silicon carbide ceramics in H_2SO_4, J. Europ. Ceram. Soc. 34, 2014, Nr.2, p. 229_DS235

[4] Sydow, U., Sempf, K., Herrmann, M., Schneider, M., Kleebe, H.-J., Michaelis, A.: Electrochemical corrosion of liquid phase sintered silicon carbide ceramics, Materials and corrosion 64, 2013, Nr.3, p. 218

1 SE micrograph of an SiC/Si_3N_4/$MoSi_2$ composite material.

2 Micrograph of the same area in the conducting mode.

3 Micrograph of the interface between non-conducting and conducting area in the SiC/Si_3N_4/$MoSi_2$ composite material.

4 Micrograph of an SSiC microstructure.

5 Micrograph of a detail of the SSiC microstructure with core-shell structure.

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MODELING OF SINTERING BY MEANS OF KINETIC METHODS

Dr. Tim Gestrich, Dipl.-Technomath. Roland Neher, Dr. Jens Klimke

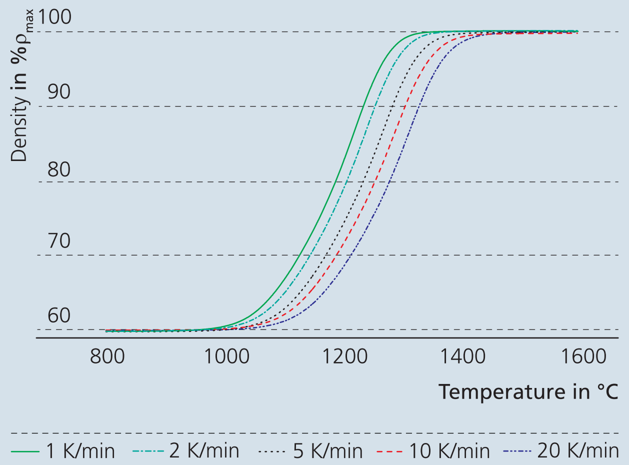
The use of thermoanalytical methods has become well established in the development of ceramic and powder metallurgy processes and materials, due to a series of successes achieved. Particularly for the process steps of debinding, outgassing and sintering these methods are of great importance, since an understanding of the processes occurring – process knowledge as a whole – is important for process control and optimization and for improvement of efficiency. Knowledge about the length and subsequently density change is of special technological and economical importance for sintering of ceramics. Exact information about the start and end of sintering defines the temperature range for sintering and allows the specification of sintering cycle for the technological process which results in energy and cost-effective production of materials. Generally, thermodilatometric investigations deliver this information.

More benefit can be achieved by controlling the shrinkage rate. Keeping the rate constant during sintering leads to a reduction of internal stress. Another approach is to control the shrinkage rate within special density regions.

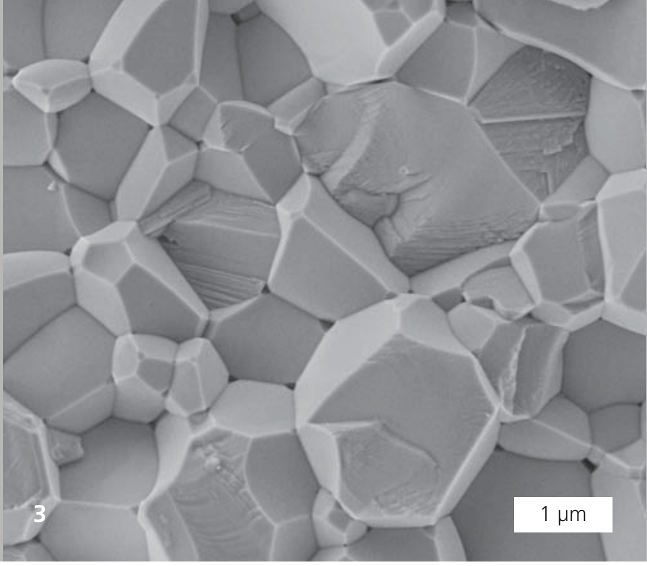
One way to control the sintering rate is to directly integrate a feedback control into the dilatometer. Another way is to use methods which describe the kinetic of sintering and allow calculating the length change for arbitrary temperature-time paths. Beside the advantage of being able to compute the length change response for any temperature-time profile in advance, also knowledge about the mechanisms governing sintering can be deduced depending on the method used.

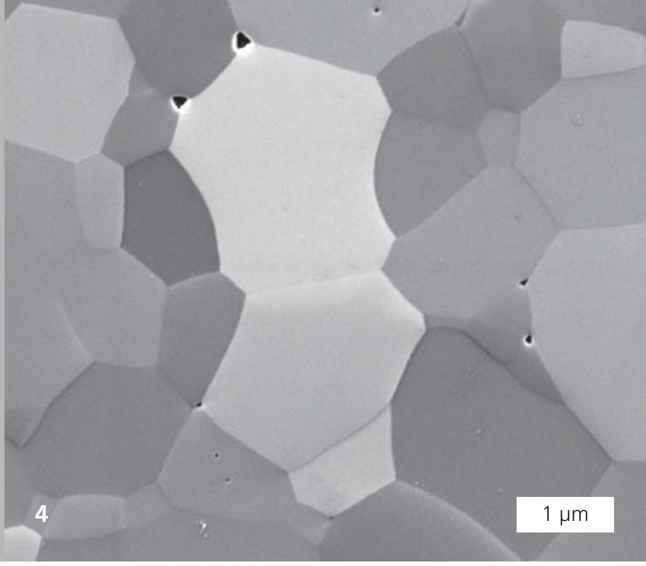
Three methods modeling thermoanalytical data directly are applied by the "Thermal Analysis and Thermal Physics" group of Fraunhofer IKTS, namely the Kinetic Field of Response developed by Palmour [1], Master Sintering Curve developed by Su and Johnson [2] and Thermokinetic developed by Opfermann [3].

Density (ρ) during sintering with 1, 2, 5, 10 and 20 K/min



The Kinetic Field of Response (KFR) allows a fast and easy overview about the kinetic behavior of the material during densification. However, generally all kinetically determined temperature activated processes which can be described by the Arrhenius equation can be converted in a KFR. The Master Sintering Curve (MSC) was developed under the assumptions of isotropic sintering and that one diffusion mechanism (volume or grain-boundary diffusion) dominates sintering and that microstructural evolution only depends on density. The software tool Thermokinetic (Netzsch GmbH) is based on the theory of kinetic analysis of chemical reactions. Thermokinetic allows deriving a kinetic model by a multivariate kinetic analy-





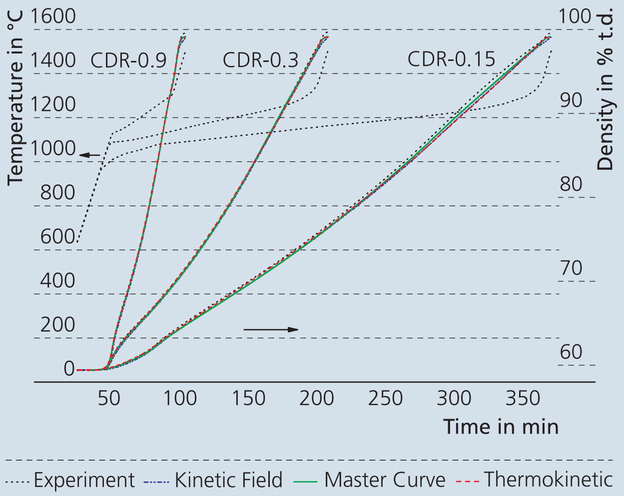
sis. For processes with multiple, parallel or competitive steps different equations are combined in a system of differential equations to describe the concentration changes of the individual reactants and products. This reactant and product concentrations are proportional to property changes and can also be applied to formally describe length changes. This method is the most complicated tool and allows to describe very complex processes.

The methods were compared among each other and with experiments in order to evaluate their abilities to predict length change during sintering for various temperature-time paths. For this purpose a high purity corundum (> 99.99 % Al_2O_3, average particle size of 0.15–0.20 µm, doped with MgO) was used as a model system for solid state sintering and SiC materials with Y_2O_3/ Al_2O_3-additives were used as model systems for sintering where the amount of liquid phase is strongly varying.

In the case of alumina Kinetic Field of Response, Master Curve and Thermokinetic concepts are able to properly describe and predict the density evolution even for complicated temperature-time profiles. For the liquid phase sintered SiC materials which show multiple steps of densification with different activation energies all methods also achieved a good agreement between experiment and calculation. With Themokinetic a slightly better fit was obtained.

Therefore, the modeling methods may be used for optimization of sintering, microstructure and properties of a wide range of materials.

Prediction of densification by KFR, MSC and TK and experimental data for three constant densification rates



Acknowledgments

The authors would like to thank the German Research Foundation for partial financial support (HE 2457/14-2).

Services offered

- Clarification and optimization of processes during sintering, outgassing and debinding
- Thermoanalytical investigations of processes in different atmospheres and in the temperature range between -160 °C and 2400 °C
- Determination of thermophysical properties (thermal conductivity, heat capacity, coefficient of thermal expansion)

Sources

[1] Palmour, H., III, Hare, T. M., in: Kuczynski, G. C., Uskoković, D. P., Palmour, H. I., Ristić, M. M. (Eds.): Sintering 85, Springer US, 1987, pp. 17–34

[2] Su, H., Johnson, D. L., Journal of the American Ceramic Society 79, 1996, pp. 3211–3217

[3] Opfermann, J., Journal of Thermal Analysis and Calorimetry 60, 2000, pp. 641–658

1 *Netzsch thermodilatometer.*

2 *Thermoanalytical lab.*

3 *Fracture surface: A_2O_3.*

4 *Microstructure: Al_2O_3.*

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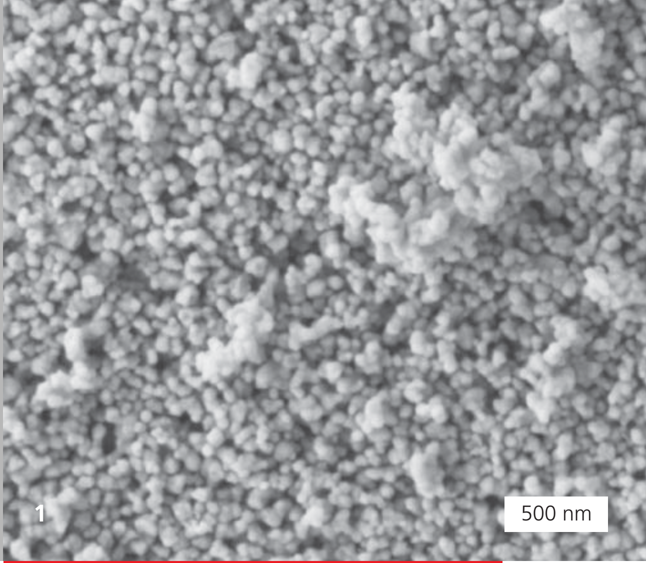
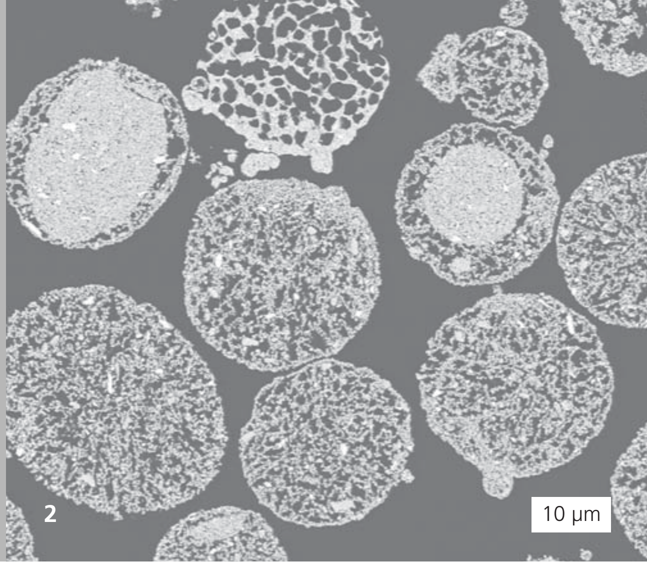




MATERIALS AND PROCESS ANALYSIS

NANOMATERIALS: RAW MATERIAL – PROCESSING – MICROSTRUCTURE

Dr. Annegret Potthoff, Dr. Anja Meyer, Kerstin Lenzner, Jan Räthel

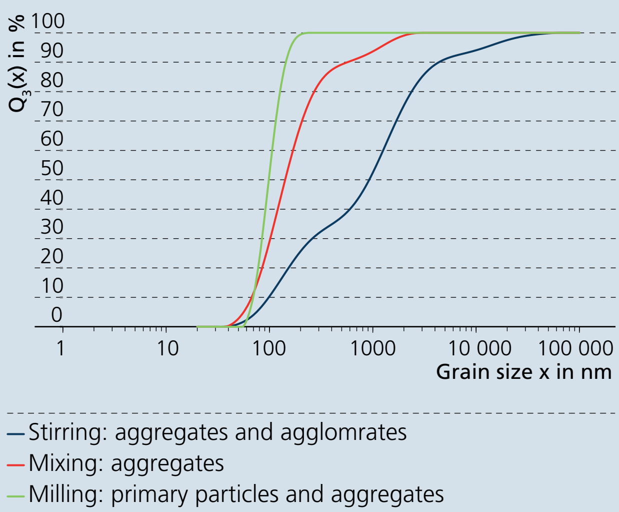
Motivation

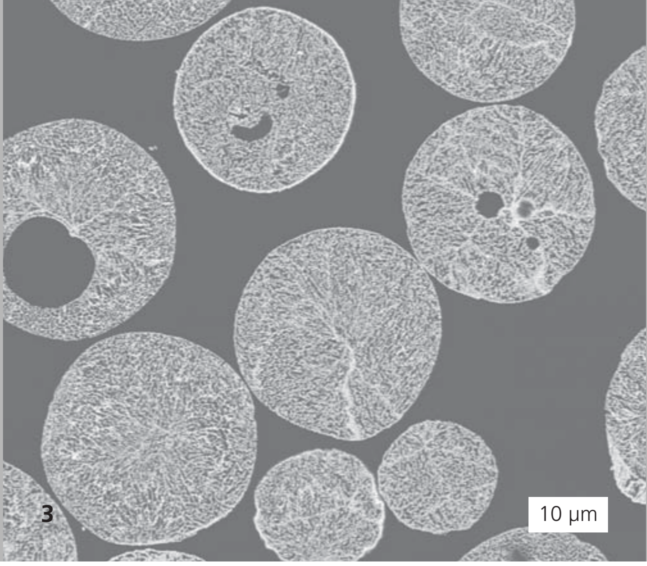
The use of nano-scaled materials for the development of high-performance ceramics may lead to an improvement of physical, mechanical and optical properties. Raw materials are usually available as aggregates and agglomerates (Figure 1).
By varying the mechanically induced energy, different processing stages have been prepared to derive correlations between the particle size distribution and its processing behavior along the ceramic processing route granulation – shaping – sintering.

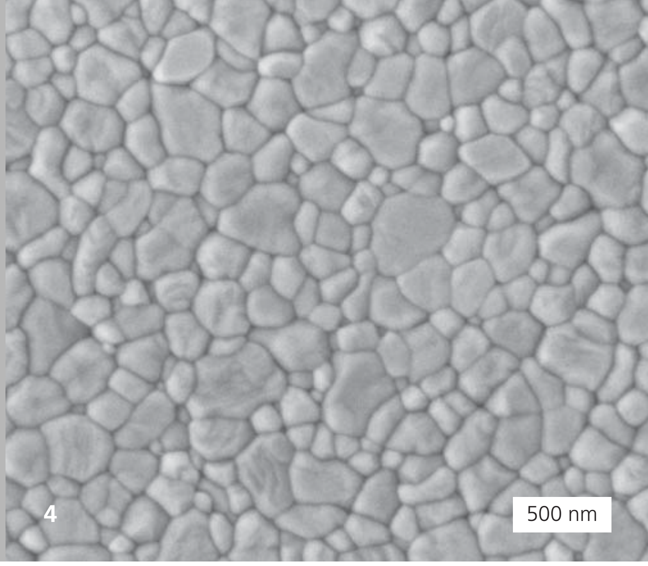
Approach and results

Partially-stabilized zirconia powder with uniform dispersion of 3 mol % yttria TZ-3Y-E (Tosoh Inc.) was chosen as a representative oxide raw material and processed in an aqueous suspension. Selected polymeric aids and organic acids were used for colloidal stabilization of the zirconia suspension. Three significantly different particle size distributions could be achieved (diagram 1) based on the boundary conditions mentioned above and by an incremental increase in energy input during the processing steps: stirring – mixing – grinding. Those differently processed materials/suspensions affect the inner structures and the strength of spray freeze dried granulates (Figure 2 and 3). Whereas the stirred suspension after spray freeze drying still showed the presence of remaining structures from the starting raw material and low strength values of green single granules, the ground raw materials exhibit homogeneous granule structure and higher strength values. Those granulates were further processed by identical parameters for uniaxial and cold isostatic pressing (CIP). Afterwards, they were sintered under the same conditions based on the parameters offered by the raw material supplier at T = 1350 °C. The influence of the amount of energy induced during processing was clearly demonstrated by the physical and mechanical properties determined by density measurements after sintering (diagram 2) as well as by 4-point bending tests and grain size distribution in the sintered microstructure (Figure 4). With increasing energy input and identical sintering conditions the density and strength of the prepared test samples were significantly increased. The influence of primary particle's processing conditions, therefore, can be proved along the entire ceramic production chain.

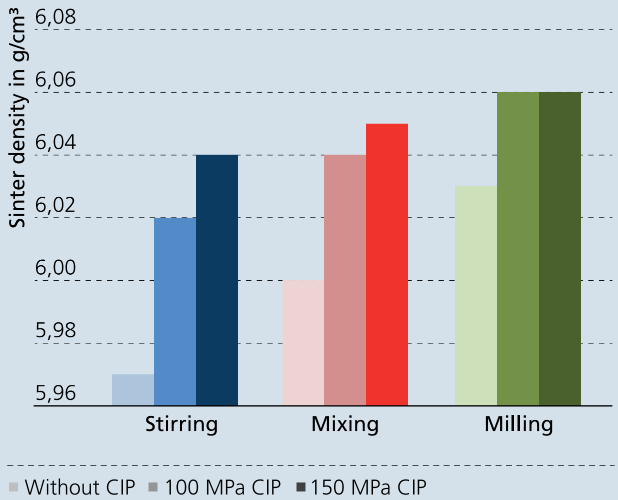
Particle size distribution of different processing stages







Sinter density as a function of processing and shaping route



Summary and Outlook

The above mentioned processing routes and results obtained can be easily transferred to the processing of other oxide and non-oxide ceramic raw materials:

- The effectiveness of processing with an identical mechanical energy input strongly correlates with the nature of the used processing aids.
- If identical particle sizes are obtained the processing characteristics are not influenced by the stabilization.
- The processing conditions influence the properties of the granulates as well as the sintered specimens.
- The raw material's potential can be fully exploited in the subsequent production processes if the nanomaterial is not only deagglomerated but also desaggregated during processing.
- Profitability calculations show that the costs for energy-intensive processing are compensated reduced processing times for heat treatment, and at lower temperatures as well as by better properties of the produced dense, nano-scaled ceramics.

Services offered

- Analysis and evaluation of existing processing, shaping, debinding and sintering processing.
- Analysis, valuation and preparation of ceramic raw materials taking into account the subsequent production route.
- Application of suitable in-process characterization methods along the entire production chain: raw material testing – processing – shaping – sintering.

1 FESEM of granulate TZ-3Y-E.
2 FESEM of spray freeze dried granulate stirring.
3 FESEM spray freeze dried granulate grinding.
4 FESEM grinding (sintered, etched).

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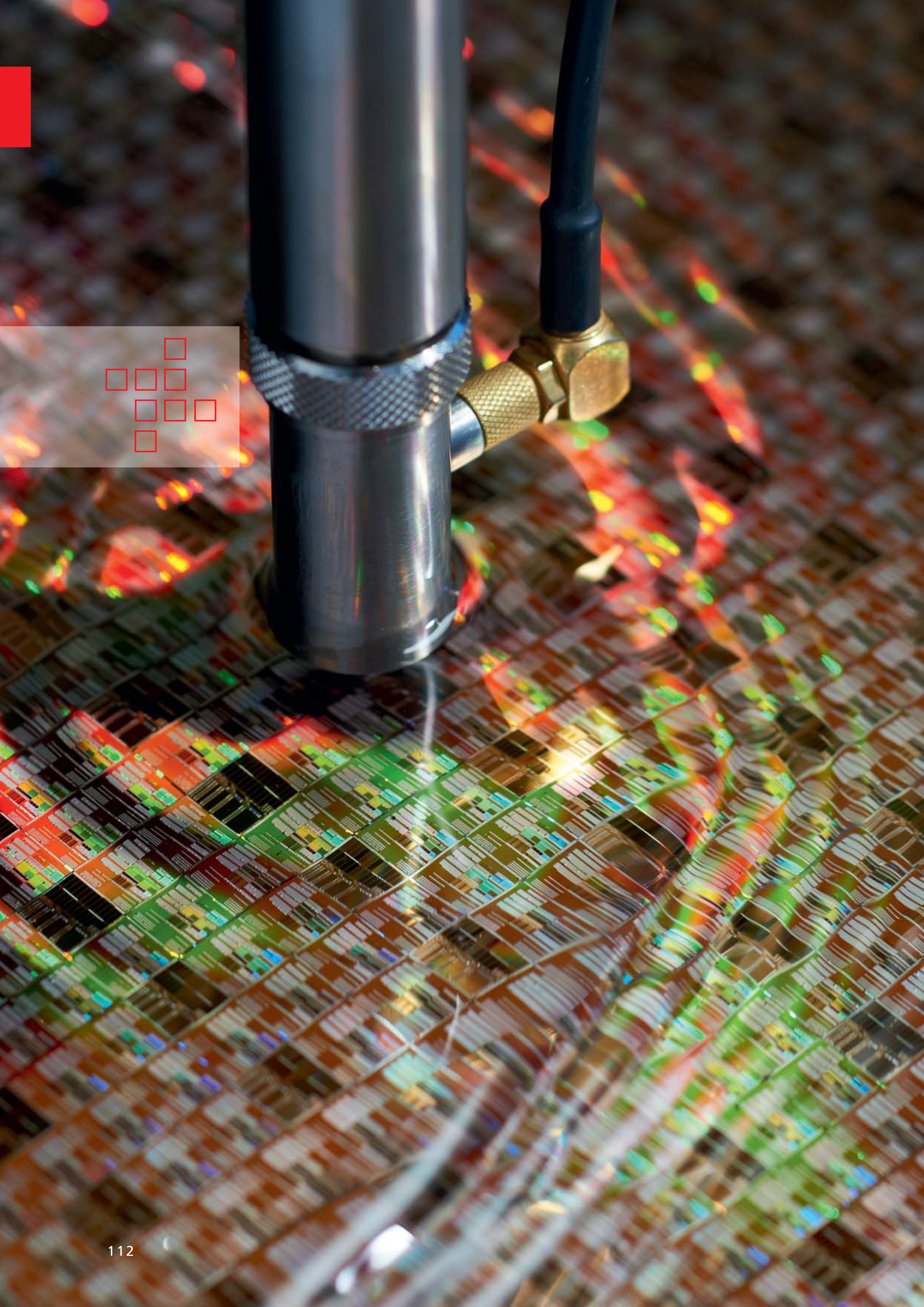


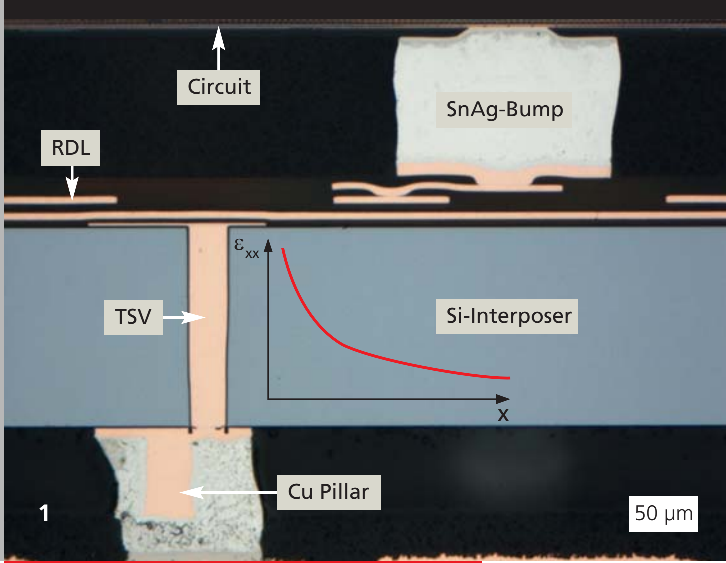
BRANCH MATERIALS DIAGNOSTICS

Project reports

In January 2014, the Dresden-based location of the Fraunhofer Institute for Non-Destructive Testing IZFP was integrated into Fraunhofer IKTS as the Institute's Materials Diagnostics Branch (IKTS-MD). Using its excellent reputation and comprehensive experience, IKTS-MD focuses on future technologies in the fields of applied microelectronics and complex sensor systems.

In almost all application fields, due to growing complexity of products and systems, R&D partners are increasingly required who are able to evaluate and ensure the reliability and long life for the range from material level to system level. Unique technical equipment at Fraunhofer IKTS-MD as well as the excellent network with industrial partners form the basis for application-specific process and system development as well as a comprehensive portfolio of services for materials, components and process diagnostics. In the fields of nanoanalytics, sensor technology and structural health monitoring, Fraunhofer IKTS-MD has unique competencies which are used in multiscale material characterization, sensor development or systems integration. For an efficient and economic development process, simulation and software expertise are available as well as many years of experiences in the development of highly precise test electronics.

For quality assurance in light-weight construction, integrated structural health monitoring of aircraft and plant structures or the fast growing field of biotechnology and environmental technology – the competencies of IKTS-MD are required in almost all fields where durable and reliable products as well as efficient production processes are important.



CHARACTERIZATION OF MULTI-SCALE MATERIALS OF MICROELECTRONIC PRODUCTS

Dr. Martin Gall, Dr. Uwe Mühle, Prof. Dr. Ehrenfried Zschech

Modern microelectronic products are characterized by the heterogeneous integration of various materials. For an evaluation of the performance and reliability of these complex systems, simulations using very accurate materials data are necessary. Furthermore, materials properties are often size-dependent, i.e. the characteristics of a macroscopic sample often differ from a microscale or nanoscale sample of the same material. The following diagram illustrates the use of physical models and accurate layout/process information for simulations aiming at multi-scale characterization of modern microelectronic products, in this particular case for the 3D integration of integrated circuits. As an input for the simulation, very accurate (thermo)mechanical materials data are needed; for the model validation, high-resolution measurements of mechanical strains inside the transistor channel are required.

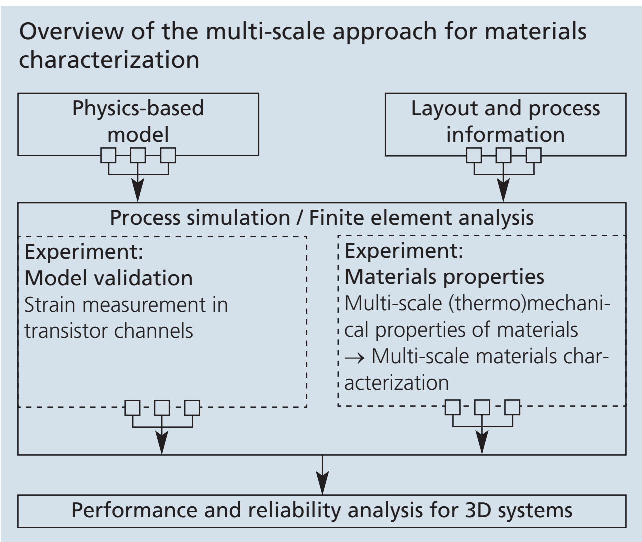
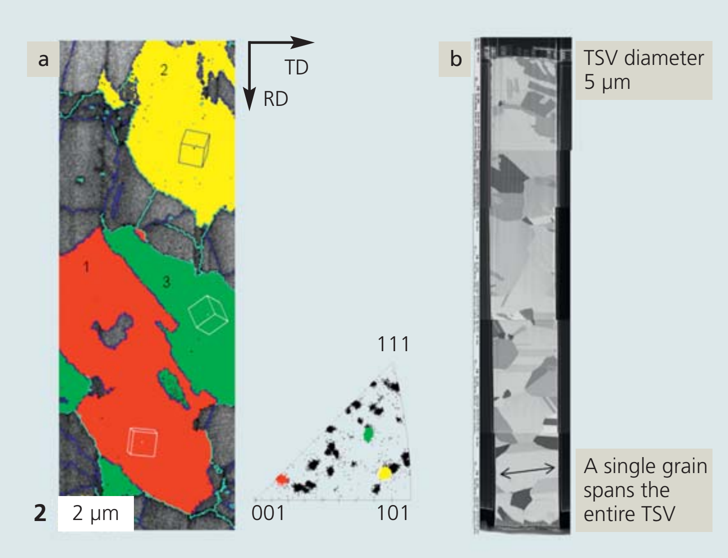
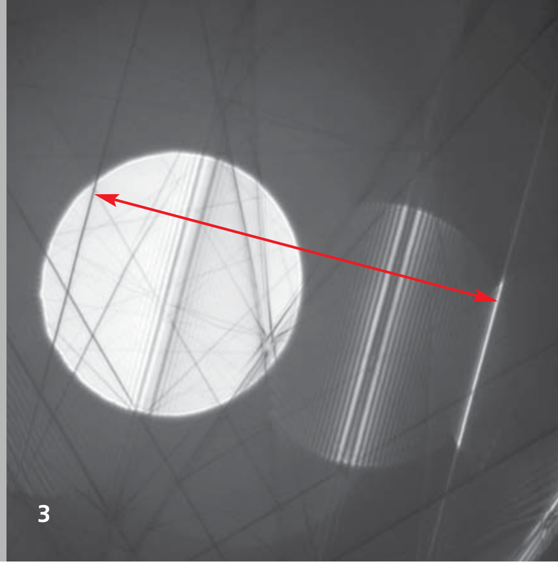


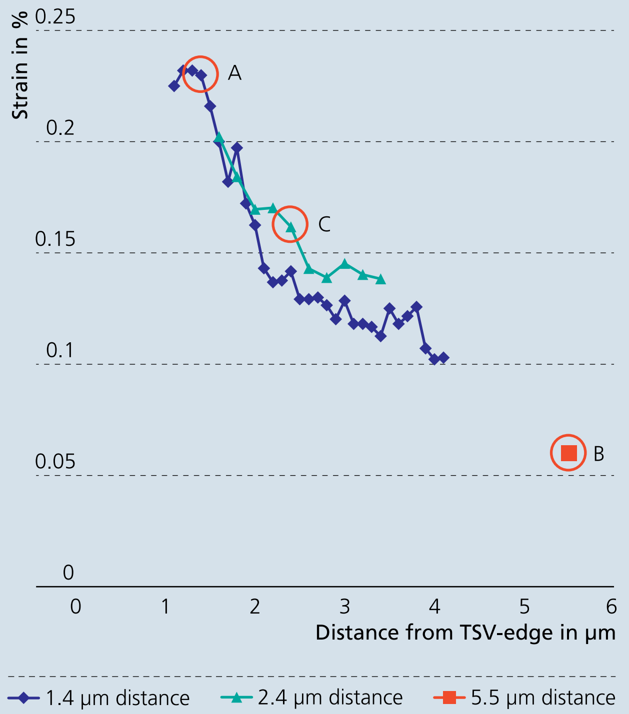
Figure 1 shows an example of a 3D integrated system (silicon interposer technology, Fraunhofer IZM-ASSID). The control of mechanical strain within the range of the active devices is essential for the reliability of such microelectronic products. The three-dimensional stacking of ICs leads to new challenges for the measurement of mechanical strains on the scale of single digit nanometers.

Particularly, the influence of the different coefficients of thermal expansion for silicon and copper contacts, the so-called Through Silicon Vias (TSVs), but also the effect of further elements of the packaging assembly such as solder joints on the performance of active devices must be measured. Figure 2 illustrates details of such TSVs. Figure 2a shows the microstructure which has an impact on the local stress state due to the highly anisotropic elastic properties of copper. Figure 2b shows a composite figure in the scanning electron microscope (SEM). In order to determine the mechanical strain close to the TSVs, a method was developed which uses the high sensitivity of electron diffraction in a transmission electron microscope (TEM) to the distortion of the crystal lattice (Figure 3). This application implies that the mechanical stress condition, resulting from the process, does not change during the preparation of the TEM sample. Therefore, the TSV and the ambient stack system must not be influenced by the preparation in the focused ion beam (FIB) tool. A low-damage TEM sample then enables the generation of electron diffraction diagrams in several distances from the TSV. The local strains in the transistor channels, as shown in Figure 4, have an important influence on the performance and reliability of the active devices.





Strain as a function of distance from the TSV for three test transistors (A, B, C) and within two TEM samples (blue and green curves)



Cooperation partner

- Fraunhofer Institute for Reliability and Microintegration IZM, All Silicon System Integration Dresden ASSID, Germany
- GLOBALFOUNDRIES Inc., Dresden, Germany
- Semiconductor Research Corporation, Albany/NY, USA
- SEMATECH, Albany/NY, USA
- Mentor Graphics Corporation, Fremont/CA, USA
- Qualcomm Inc., San Diego/CA, USA

Services offered

- Characterization of multi-scale materials
- Scanning electron microscopy and focused ion beam
- Imaging and analytical transmission electron microscopy
- Reverse engineering and sample preparation

1 *Schematic of a 3D system (Si interposer technology, Fraunhofer IZM-ASSID) and visualization of the strain as a function of distance (red curve).*

2 *Through silicon via: (a) local microstructure, (b) overview in SEM.*

3 *Image in convergent beam electron diffraction (CBED) mode: The distance between the dark and bright so-called Kikuchi lines is inversely proportional to the stress component in this direction.*

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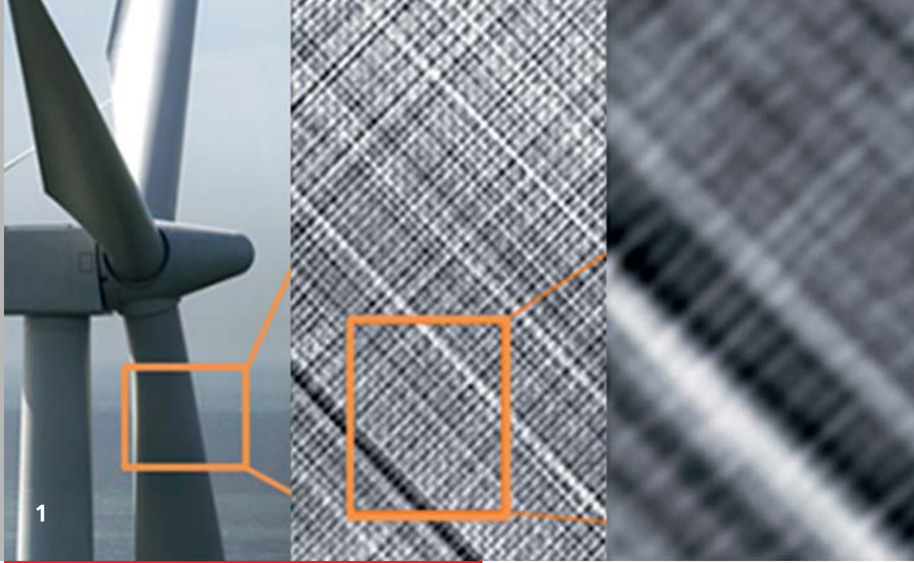

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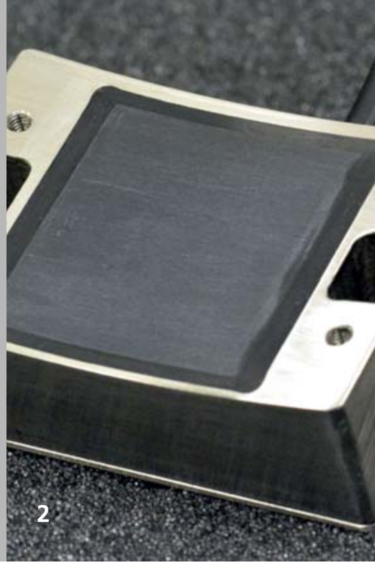


2

MATERIALS DIAGNOSTICS BRANCH

NEW SENSORS FOR MATERIALS CHARACTERIZATION

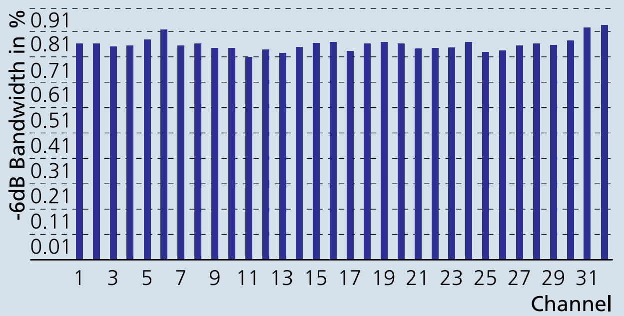
Jun.-Prof. Henning Heuer, Dr. Thomas Herzog, M.Sc. (NDT) Martin Schulze, Dipl.-Ing. Matthias Pooch, Dr. Peter Krüger, Dipl.-Ing. Thomas Lohse, Dipl.-Wirtsch.-Ing. Simone Gäbler, Ba. Eng. Jürgen Michauk

Application of new materials requires methods for their testing and quality assurance. In the world-wide competition, innovations have to be transformed into economically usable applications ever faster. New sensors for materials characterization help to reduce the risk which is connected with the use of new materials and production techniques. Hence, they are an enabler for the rapid and efficient application of new materials. Whether fiber-reinforced plastics in aerospace and automotive engineering or non-metallic materials for high-performance applications, complex materials and structures can be efficiently tested using novel concepts based on ultrasound, X-ray and eddy current sensors.

Due to the integration of the former Fraunhofer IZFP-D into Fraunhofer IKTS, our customers have access to a complete process chain ranging from the sensor material, e.g. piezoelectric ceramics, to the fabrication and certification of complex phased array sensors and system solutions including hardware, software and application from one source. Together with the "Testing Systems" department and the accredited NDT inspection center complete ultrasonic testing systems can be developed, fabricated and certified which are tailored to optimally suit customer needs.

With ultrasonic sensors but also with semifinished products such as PZT composites it is possible to flexibly respond to market needs. Actual research issues are high-channel matrix sensors in the conventional frequency range and high-frequency matrix sensors based on thin-film technology for future ultrasonic phased array microscopy. Ultrasonicsensors, especially multi-channel phased array sensors, are complex microtechnical products. Competences in microsystem engineering, available in the cluster Silicon Saxony, offer excellent conditions to realize new generations of ultrasonic sensors.

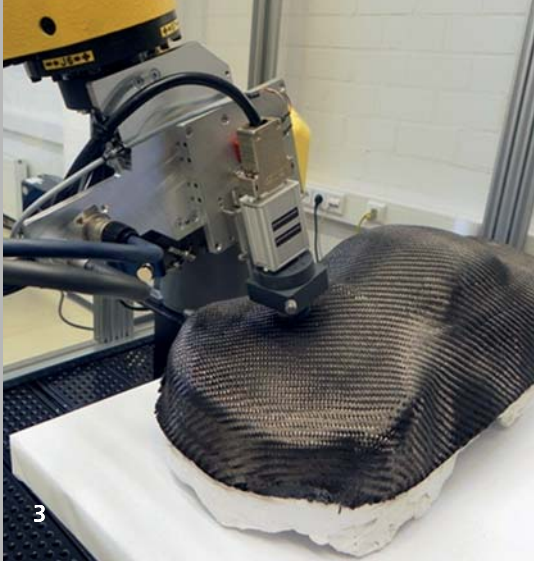
Deviation of bandwidth of 32-channel phased array sensors (2.5 MHz)



Fraunhofer IKTS-MD has a leading global position in high-frequency eddy current testing (HFEC) and possesses all necessary competences in electronics, software, sensorics and manipulation as well as the application know-how.

EddyCus® systems are applied for the testing of low conductive materials such as CFRP, semiconductors or ceramics. Our customers come from various industries, e.g. automotive, solar and ceramic industry. Besides the development and realization of sensor systems, solutions for integrating testing systems into automated processes were developed.

Based on industrial robots, flexibly applicable testing systems are developed for complex 3D structures by digitalizing unknown objects by means of light stripe projection including scan tracking and programming.



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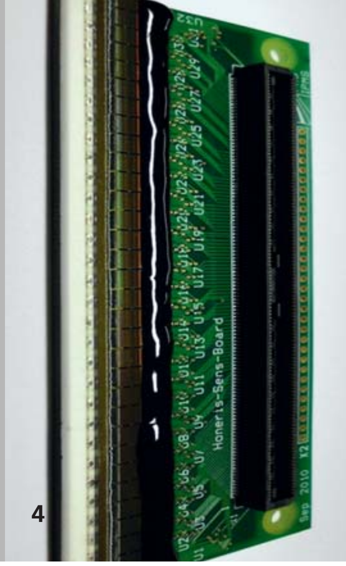

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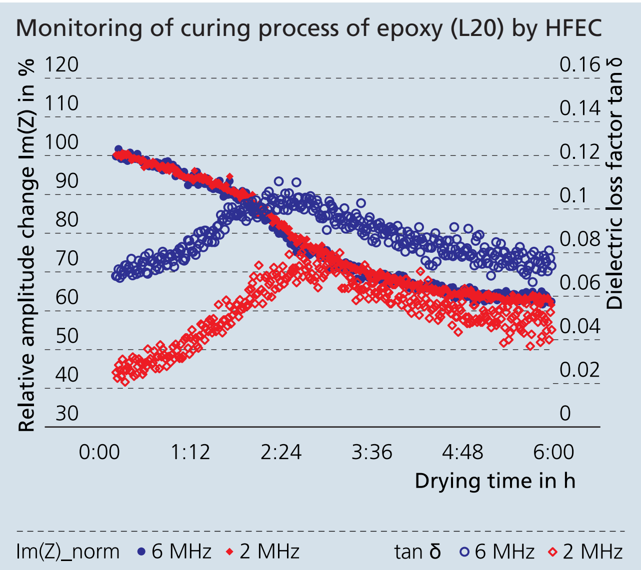
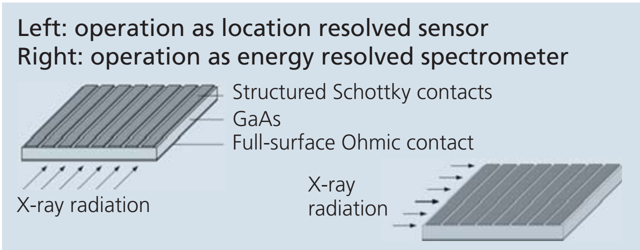
High-frequency eddy current testing systems are also used for the characterization of e. g. curing reactions of epoxide resins and for the electrical characterization of ceramics (figure 5).





In close cooperation with the Fraunhofer Institutes IPMS and IIS, a new generation of high-resolving, direct-converting X-ray detectors was developed. First prototypes are already available and are currently transferred to industrial applications. Direct-converting X-ray detectors transform, similarly to the functional principle of a solar cell, X-ray photons penetrating the absorber material (here GaAs) directly into electrical impulses. With CMOS integrated read-out electronics on a semiconductor chip, the impulses can be read out, analyzed and further processed. The advantages of direct-converting detectors in combination with monolithically integrated read-out electronics can be found in the increase of sensitivity, the possibility of an energy resolution by adjusting thresholds and a cost-efficient fabrication of very large detectors as well.
A detector line was realized with 1024 separately readable pixels of 100 µm size each. The modules are connectable so that they can be combined to meter long detectors quasi blind pixel free.

Services offered

- **Ultrasonic sensors:** technology development and small-lot production of individual ultrasonic sensors of all kinds
- **Eddy current sensors:** complete systems for characterization of low- and non-conducting materials, application development, services
- **X-ray detectors:** design, development and fabrication of X-ray detector lines, application development

1 Testing of carbon-fiber reinforced plastics with imaging eddy current techniques.

2 Ultrasonic sensor for phased array applications with 32 channels, 2.25 MHz and shaped transducer.

3 Robot-based guidance of the eddy current sensor over complexly formed surfaces.

4 Direct-converting X-ray detector line with GaAsa absorber and monolithically integrated read-out electronics.

5 Image of the electrical conductivity of SiC ceramics showing an inhomogeneity (source: Suragus GmbH).

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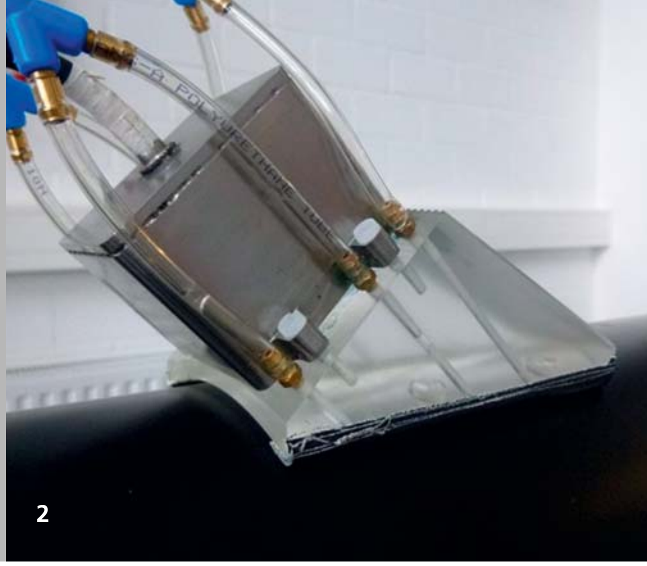
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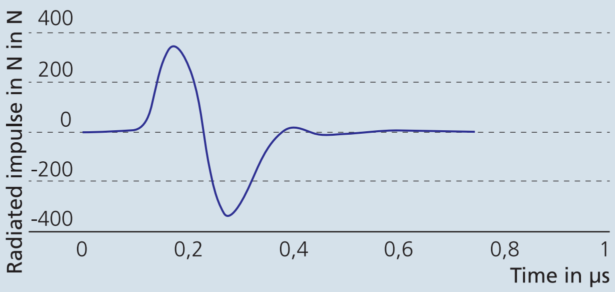
MATERIALS DIAGNOSTICS BRANCH

SIMULATION-SUPPORTED OPTIMIZATION OF PIEZOELECTRIC SENSORS

Dr. Frank Schubert, Dr. Mike Röllig, Jun.-Prof Henning Heuer, Dr. Bernd Köhler, Andreas Gommlich, Henry Scholz

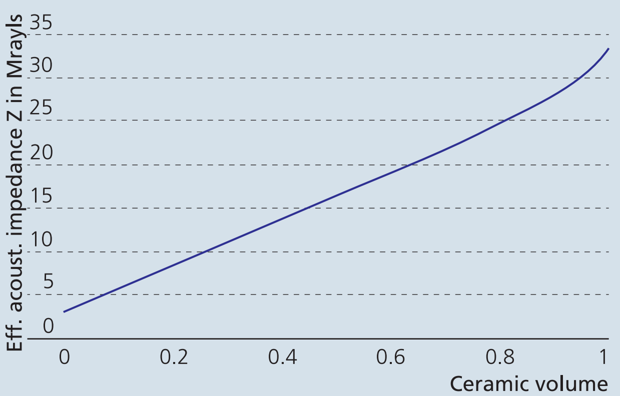
Nowadays piezoelectric sensors are used in a wide variety of technical and industrial applications. One specific field of application is materials diagnostics and condition monitoring based on ultrasonic waves. In this context individually adapted and optimized transducers as well as embedded sensors are essential. For optimization of their functionality and reliability efficient numerical modeling tools can be applied, either based on commercial FEM software or on proprietary developments of Fraunhofer IKTS-MD.

Calculated radiated impulse of a piezo transducer

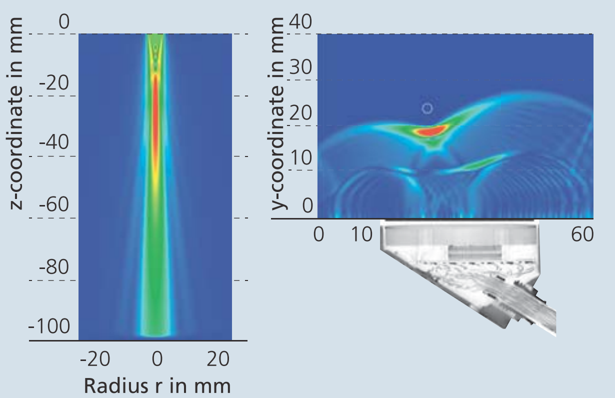


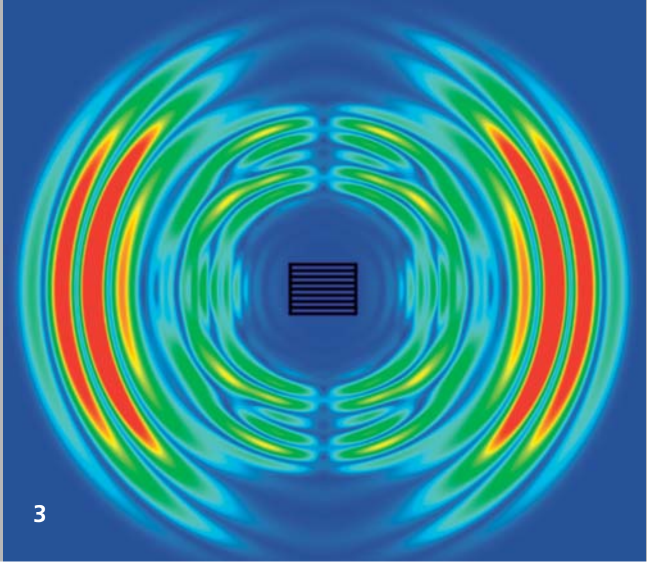
The simulation-supported optimization already starts at the material level. An example is given by the effective acoustic impedance of a piezo composite material that can be adapted to the specific application by variation of the volume fraction of the piezoceramic rods in the polymer matrix. If the piezo material is specified an optimized pulse form with adequate frequency spectrum for excitation can be obtained by systematically adapting backing and adaptation layers. For this purpose, self-developed simulation tools are used that include the coupling of piezoelectric and acoustic field quantities. With the time history of the emitting pulse the resulting wave field inside the specimen under test can also be calculated. In this context intensity plots and time-resolved wave front snapshots can be extracted. Nearly arbitrary single element transducers and phased array configurations can be considered.

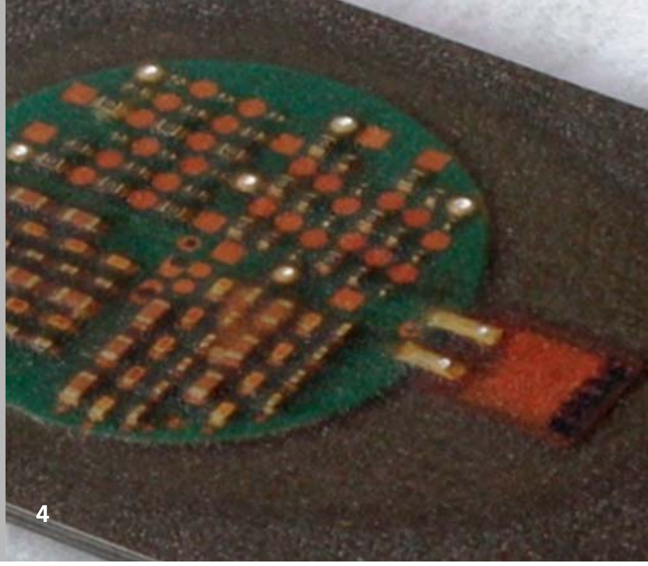
Effective acoustic impedance of a piezocomposite as function of the ceramic volume



Simulated wave fields of ultrasonic transducers





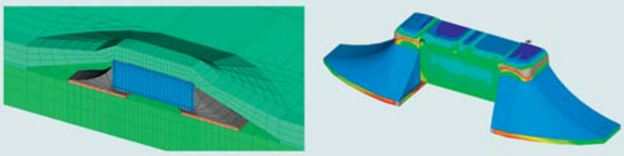


For the calculations an effective hybrid simulation technique is used that combines specific numerical methods with the concept of transient point source synthesis. With this approach also three-dimensional time-resolved wave fields ("4D simulation") can be calculated efficiently on a standard PC. If necessary the interaction between the propagating waves and the defects inside the material can be incorporated as well. In addition, the geometry of transducer wedges used for angle-beam excitation through curved surfaces can also be optimized so that the typical defocusing effects in the medium can be compensated or even overcompensated (focusing instead of defocusing).

Structural health monitoring (SHM) of buildings, constructions, vehicles and components is another field of application for piezoelectric sensors with steadily growing interest. Here, the permanent and reliable integration of sensors is essential in order to monitor with high sensitivity e.g. stresses, strains and material degradation over time. One possible SHM approach is based on guided ultrasonic waves in which the interaction of the waves with the material is used to identify macroscopic cracks and delaminations but also mesoscopic fatigue and deformation phenomena. In this context the integrated sensor needs to be optimized with respect to functionality and reliability over its whole lifetime. Moreover, it has to be guaranteed that sensor and corresponding sensor-near electronics do not cause structural changes or damage of the host structure.

The directivity pattern of an integrated ultrasonic transducer depends on the specific electrode configuration and in particular on its size and shape. Therefore, the resulting wave field can be optimized in a wide range according to the specific application. For this purpose, special acoustic simulation tools for embedded piezo sensors are used. Another important aspect is related to the embedding technology. It needs to be optimized with respect to the geometry and the materials of sensors and electronics in order to keep the thermomechanical load peaks small and thus, to increase the remaining lifetime of the measuring system. For this purpose, specific FEM-based models have been developed that enable the simulation of realistic thermomechanical load szenarios.

FEM-based stress simulation



Finally the results of simulation-supported optimization can be verified experimentally by using laser vibrometry, electrical impedance measurements and cyclic load tests for instance.

Services offered

- Simulation-supported sensor design
- Selection of materials and geometries
- Optimization of embedding technologies, sensor functionality and reliability
- Experimental verification and validation in our accredited testing laboratory

1 *Curved phased array transducer for solid shaft testing.*
2 *Phased array transducer with wedge for angle-beam testing and with water coupling.*
3 *Calculated sound field of a piezo fibre transducers coupled to an Aluminum plate.*
4 *CFRP integrated piezo sensor with electronics for SHM based on guided waves.*

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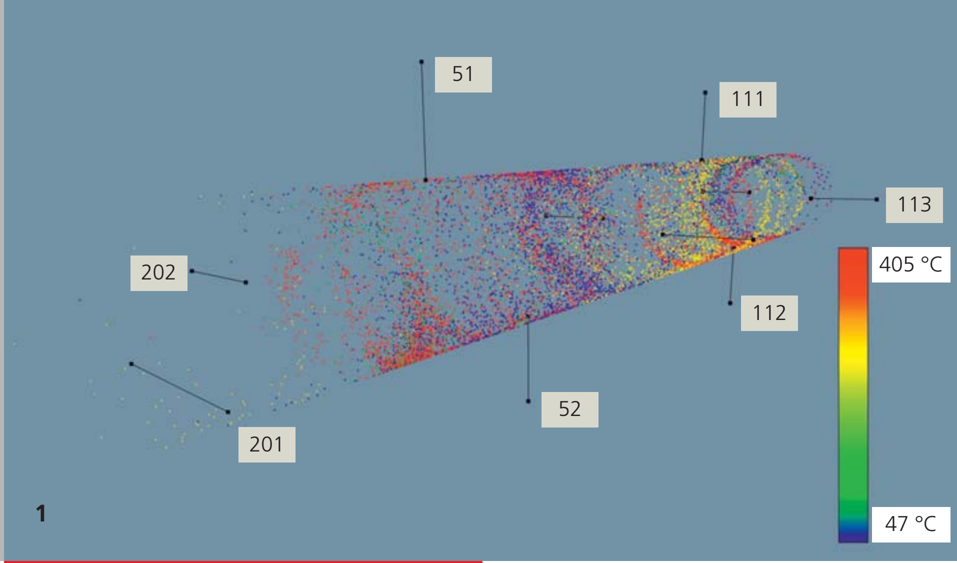


MATERIALS DIAGNOSTICS BRANCH

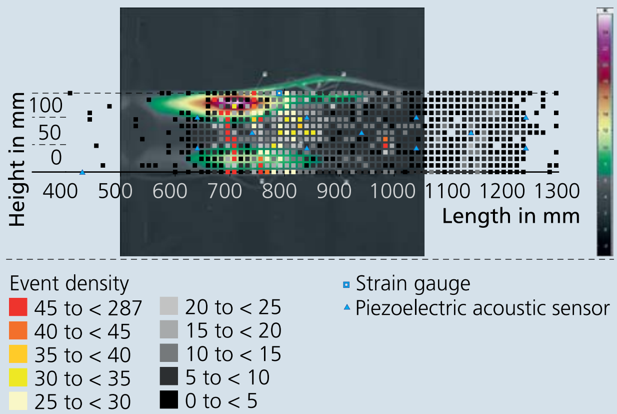
SHM FOR THE ENERGY TURNAROUND – FROM HOT PIPES TO OFFSHORE FOUNDATIONS

Dipl.-Ing. Bernd Frankenstein, M.Sc. Thomas Klesse, Dr. Lars Schubert, Dipl.-Geophys. Eberhard Schulze, Dr. Bianca Weihnacht

The energy turnaround is on everyone's lips – and also in the focus of current research projects. The transition to renewable energies is connected with special challenges for the existing primary energy power plants (coal, oil, gas) as well as for the energy production from renewable sources (onshore and offshore wind turbines). In order to cover the basic energy demand, conventional coal and nuclear power plants were operated at a constant power level in the past. The energy of the varying energy peaks was provided by gas power plants due to the fact that they can be switched on and off fairly easily. Since the renewable energy plants increase constantly, the existing regulation mechanisms are not sufficient for the resulting peaks during days with a lot of sun and wind. Basic power plants have also to be run in a dynamic setting. This is connected with constant thermal cyclic stresses of the pipe systems caused by temperature changes, as the operating temperatures may rise up to 500 °C. Creep resistant steels fatigue faster if they undergo constant cyclic stresses. Methods of permanent condition monitoring (SHM – structural health monitoring) help to detect damages at an early stage.

Particularly offshore constructions are exposed to high dynamic cyclic stresses (due to wind, waves and vibrations caused by rotor dynamics). Furthermore, they are often difficult to reach in the case of damage due to the current weather situation. In the worst case, the plant is not available for a longer period. SHM methods help to detect damages on rotor blades, drive chains, gear boxes and foundation in time. Hot pipes can be monitored by acoustic emission techniques and permanently installed ultrasonic transducers. In the case of damage, dislocations in the pipe material cause acoustic emissions which are localized by the applied transducers. Figure 1 shows localized acoustic emission events at a test mockup in the power plant Neurath (Germany) and assigns the temperature using color codes. It is clearly seen that specific pipe areas show a higher acoustic emission rate during temperature changes. Besides the temperature induced acoustic emission events, flow induced emissions can be observed at operating temperatures of 400 °C.

Acoustic emissions during a fatigue test of a composite beam
(red: high event density, black: low event density; in the back a thermography image of the beam after structural failure)



Active and passive SHM methods can also be used for damage detection in fiber composite structures. These methods are based on guided waves as specific ultrasonic measurements. The diagram above is based on a dynamic fatigue test of a glass fiber composite beam, as used in nearly any rotor blade for stabilization of the half shells. In the background, a ther-

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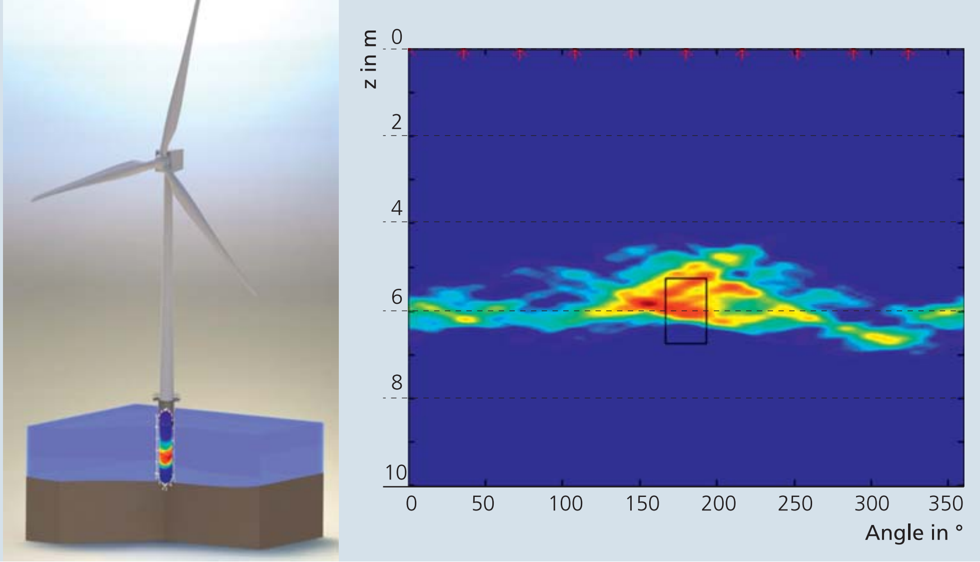

mography image is visible which indicates higher temperatures in the damaged area of the bonded seams caused by friction than in the intact area. In the foreground, areas of higher acoustic emission rates are marked by yellow-red colors. The location of the acoustically detected damages correlates well with the thermography results.

For the construction of offshore turbines, different kinds of foundation structures exist. On the left side of Figure 2, a common type of a wind turbine, the monopile type, is shown. Within the monopile, bonding structures between steel and concrete exist on a length of up to 8 m which are called grouted joints. These joints are exposed to high alternating stresses also caused by the rotor placed at a height of 100 m. In case of failure, pittings develop which cause a weakening of the joints and therefore a lower quality that might result in a settlement of the tower. These kinds of joints shall be monitored by active ultrasonic techniques. Figure 2 shows the result of a synthetic aperture focusing technique (SAFT) reconstruction method where a damage was located on the circumference of the grouted joint.

Services offered

- Problem-adapted layout, design and production of SHM systems for condition monitoring
- Simulation of elastic wave propagation process and damage interaction with ANSYS, EFIT and Wave3000
- Measurement supervision of fatigue tests on industrial structures
- Instrumentation of power plant components, onshore and offshore wind turbines (certificates available)

1 *Located acoustic emissions events on a hot pipe at different temperatures (red: 400 °C, blue: 50 °C).*

2 *Monopile offshore wind turbine (left) and material damages visualized by an imaging ultrasonic method (right).*

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MATERIALS DIAGNOSTICS BRANCH

CERAMIC PHOSPHORS FOR QUALITY ASSURANCE AND PROCESS CONTROL

M. Sc. Manuela Reitzig, Dr. Olaf Röder, Dr. Jörg Opitz, Dr. Thomas Härtling

Background

Ceramic phosphors show a pronounced luminescence emission in response to optical excitation, e.g., laser irradiation. So-called upconversion phosphors are of particular interest. In this class of materials the interplay between a host crystal lattice and several doping elements enables the subsequent absorption of two low-energy light quanta (photons) and results in the emission of one high-energy photon. Hence, these phosphors have the capability to convert infrared radiation into visible light. Figure 1 shows the emission of upconversion phosphors applied in form of a dot code on a metal part.

Material properties

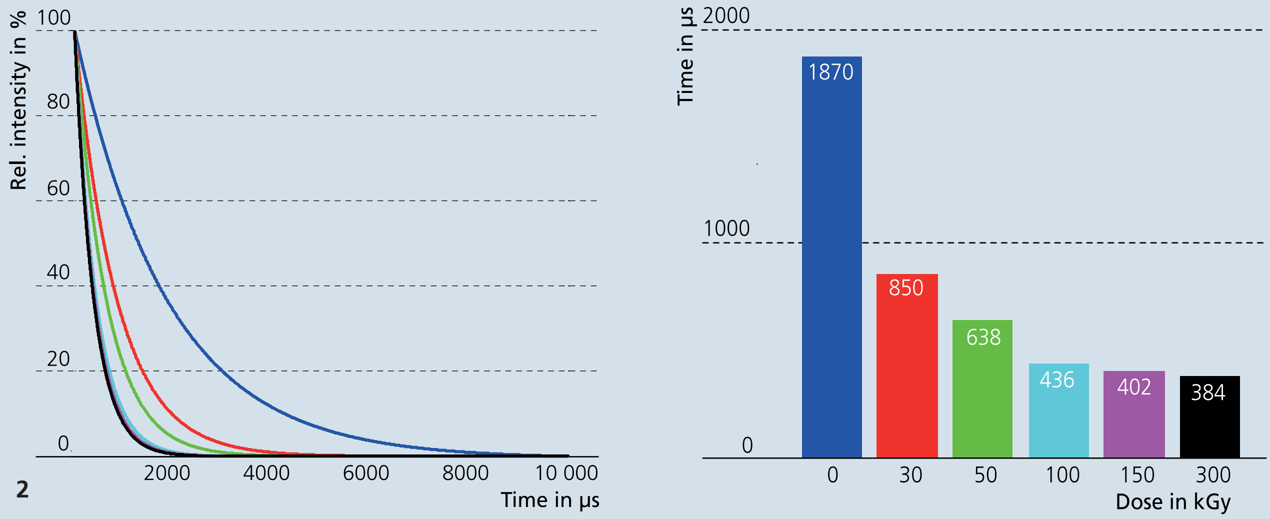
Besides their intensive light emission the materials show an extraordinary robustness. Most of them are oxides, oxysulfides, or fluorides and are thus inert at high temperatures, insensitive to humidity, and compatible with numerous matrix materials such as inks and pastes. Typically, pigments of a size of 1–10 µm are applied so that thin surface coatings or thin interlayers with integrated pigments can be fabricated. Furthermore, the sensitivity of their emission decay time to energy exposure plays an important role for process control applications. For example, certain subgroups of the upconversions phosphors drastically alter their emission decay time after exposure to high-energy radiation, e.g. electron or gamma radiation.

The concept of micro- and nanosensors

The material properties mentioned above were intensively investigated by the "Optical Nanosensorics" group (Fraunhofer internal program ATTRACT) during the last years. Upconversion phosphors are an excellent example for non-destructive testing. The group pursues the approach to apply optically active micro- and nanoscale materials as sensors for quality assurance and process control. These pigments are applied at the surface or are incorporated into the component which is to be tested. By changing their optical properties they provide information on material states in a technical component or on the process history, or they serve as secure markers for batch tracing and as protection against forgery. Besides metal nanoparticles and nanodiamonds, ceramic phosphors are mainly applied for such tasks at Fraunhofer IKTS-MD. In this context, commercially available particles and pigments were usually used in the past. With the integration of Fraunhofer IZFP-D into IKTS it is now possible to expand the value chain by specifically designing the optical material properties during synthesis of ceramic phosphors. Hence, it will become possible to provide our customers and partners with even more comprehensive solutions, and to achieve even higher value creation.

Product labeling

Product labeling is a first interesting application field for ceramic phosphors. The materials are of advantage wherever classical concepts such as barcodes or RFID labels fail due to



extreme environmental conditions or where forgery-proof labels are required. In these situations their resistivity to high temperatures, humidity, or strong electromagnetic fields can be used. Figure 1 shows an example from the automotive sector. Here, a car body component was labelled which subsequently passed a forming process at more than 900 °C. The label in form of a dot code was applied before heating and is still readable with high contrast after the process. Figure 1 shows the light emission after laser excitation. Such kind of labels allow batch tracing even for components which go through extreme process conditions. If several different phosphors with specifically designed optical properties are used these labels even work as protection against product forgery.

Process control

Another example for the application of ceramic phosphors is depicted in Figure 2. Here, the luminescence decay time after short laser pulse excitation is shown. In the investigation, materials were exposed to different doses of electron irradiation. The graphs excellently demonstrate the correlation between luminescence decay time and electron dose: The luminescence significantly decreases with increasing energy dose. This distinct material property can, for example, be applied for determining the irradiation dose during electron beam sterilization on arbitrarily formed surfaces which are difficult to be accessed, e.g. medical products and their packages, or food packaging. The use of commercially available dosimeter stripes is often not possible in these cases. In 2013, dosimetrically active packages and packaging elements were developed at Fraunhofer IZFP-D by physically incorporating upconversion phosphors into polymer foils. These works were carried out within a Fraunhofer-funded research program ("The Markets Beyond Tomorrow"). With the developed packages, the successful sterilization can directly be proved on the package itself. Furthermore, the validation and revalidation of electron beam systems can be carried out fast and reliably.

To assure the quality of the entire electron beam irradiation process, suitable read-out electronics and systems were developed which allow evaluating the optical response of the upconversion pigments in use. Starting from this basis, the integration of both the labelling and the dosimeter application into production processes will be pursued in the future.

Services offered

- Individual labeling solutions
- Materials integration into product or package
- Process integration of testing procedure

1 Dot code based on ceramic phosphors for batch tracing of hot forming components.

2 Reduction of emission decay time due to electron beam exposure of a suitable upconversion material with different energy doses.

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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 and Networks

AMA Association for Sensors and Measurement

Association Competence Center for Aerospace and Space Technology Saxony/Thuringia (LRT)

Association for Manufacturing Technology and Development (GFE)

Association of Electrochemical Research Institutes (AGEF)

Association of German Engineers (VDI)

Association of the Thuringian Economy, Committee of Research and Innovation

Association of Thermal Spraying (GTS)

BioMeT Dresden Network

Carbon Composites (CCeV)

Ceramics Meeting Point Dresden

Competence Center for Nano Evaluation nanoeva®

Competence Network on Optical Technologies (Optonet)

Cool Silicon

DECHEMA – Society for Chemical Engineering and Biotechnology

DKG/DGM Community Committee

DRESDEN-concept

Dresden Fraunhofer Cluster Nanoanalysis

Energy Saxony

Ernst Abbe University of Applied Sciences Jena, university council

European Powder Metallurgy Association (EPMA)

European Rail Innovation Center

European Research Association for Sheet Metal Working (EFB)

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

Expert Group on High-Temperature Sensing Technology in the German Society for Materials Science

Fraunhofer Adaptronics Alliance

Fraunhofer Additive Manufacturing Alliance

Fraunhofer AdvanCer Alliance

Fraunhofer Battery Alliance

Fraunhofer Energy Alliance

Fraunhofer Group for Materials and Components – MATERIALS

Fraunhofer Group for Microelectronics

Fraunhofer Nanotechnology Alliance

Fraunhofer Numerical Simulation of Products, Processes Alliance

Fraunhofer Sensor Network

Fraunhofer Vision Alliance

Fraunhofer Water Systems Alliance (SysWasser)

German Acoustical Society (DEGA)

German Ceramic Society (DKG)

German Energy Storage Association (BVES)

German Engineering Association (VDMA)

German Society for Materials Research (DGM)

German Society for Non-Destructive Testing (DGZfP)

International Energy Agency (IEA) Implementing Agreement on Advanced Fuel Cells

International Zeolite Association

Materials Research Network Dresden (MFD)

Meeting of Refractory Experts Freiberg (MORE)

Micro-Nanotechnology Thuringia (MNT)

NanoMat – Supraregional Network for Materials Used in Nanotechnology

Nanotechnology Center of Excellence for "Ultrathin Functional Layers"

ProcessNet – an Initiative of DECHEMA and VDI-GVC

Research Association for Diesel Emission Control Technologies (FAD)

Research Association for Measurement Technology, Sensors and Medical Technology Dresden (fms)

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

Silicon Saxony

Society for Knowledge and Technology Transfer of TU Dresden mbH (GWT)

TransNanoPowder Information and Consulting Center

WindEnergy Network Rostock

THE FRAUNHOFER GROUP FOR MATERIALS AND COMPONENTS – MATERIALS

Fraunhofer research in the field of materials science and engineering 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 and in all dimensions, on molecular scale as well as on component scale and with respect to processes. 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 mainly 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. With strategic forecasts the group supports the development of future materials and technologies.

Key objectives of the Group are:

- To increase safety and comfort and to reduce the consumption of resources in transport, mechanical engineering, plant construction and building industry
- To raise the efficiency of systems for generating, converting, storing energy and distributing
- 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
- Recycling concepts

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
- Integrated Circuits IIS

Chairman of the Group:

Prof. Dr.-Ing. Peter Elsner | Fraunhofer ICT
www.materials.fraunhofer.de

FRAUNHOFER ADVANCER ALLIANCE

Systems development with high-performance ceramics

The usage of high-performance ceramics allows for new applications in energy technology, mechanical and plant engineering, and medical technology. Well-known examples are highly efficient tools and coatings, new matrial and manufacturing technologies for medical-technical products as well as creative solutions for energy and resource saving industrial processes. This innovative area has become an established field of expertise of the Fraunhofer-Gesellschaft.

Four Fraunhofer Institutes (IKTS, IPK, ISC/HTL and IWM) have joined together to form the Fraunhofer AdvanCer Alliance. It is the aim of AdvanCer to develop individual systems solutions with advanced ceramics for inustry. The research activities of the Fraunhofer 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. Development work is conducted and supported by modeling and simulation methods.

Furthermore, AdvanCer has established a comprehensive range of presentation, training and consultancy services to support small and medium companies in solving complex tasks ranging from prototype development to technology transfer. Since 2005, the Fraunhofer AdvanCer Alliance 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.

Fields of cooperation

- Materials development for structural and functional ceramics, fiber-reinforced ceramics, cermets and ceramic composites
- Component design and development of 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
- Defect analysis, failure analysis, quality management
- Analysis of energy demand for thermal processes, development of temperature cycles with improved energy efficiency
- Increase of efficiency using ceramic components

Services offered

- Development, testing and evaluation of materials
- Prototype and small series production
- Method and technology development, technology transfer
- Process analysis and design
- Consulting, feasibility studies, training programs

Spokesperson of the Alliance

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Fraunhofer-Institut für Keramische Technologien und Systeme IKTS
www.advancer.fraunhofer.de

1 *Tests on NC free-form grinding of Si_3N_4 micro gas turbine rotors (source: Fraunhofer IPK).*

CERAMICS MEETING POINT DRESDEN

Ceramics Meeting Point is an integral part of the public relations activities of Fraunhofer IKTS. The industry partners use the fast access to the research infrastructure of the Fraunhofer-Gesellschaft. The cooperation of Fraunhofer IKTS, TASK GmbH and its various members forms the basis for various industry projects, ranging from characterization of materials to the exclusive development project for large-scale production. The opportunity to see the latest research topics in one room and to get in contact with possible suppliers is advantageous for the institute. The Fraunhofer AdvanCer Alliance comprising seven Fraunhofer Institutes also benefits from this infrastructure.

To strengthen the visibility of the ceramic industry sector the cooperation with Goeller Verlag was enhanced. The newly developed magazine "Ceramic Applications" is a key element to inform potential users of advanced ceramics. The presence will be further improved through the planned trade fair activities. Particularly, the international interest in associations is increasing. One highlight was when South Korea's President Park Geun-hye visited Ceramics Meeting Point informing about the importance of advanced ceramics from industrial to life science applications.

In the workshops and training courses of the Fraunhofer AdvanCer Alliance, Ceramics Meeting Point is used to present the state of the art as desired by the participants. Thus, a project forum for small and medium-sized companies has developed, facilitating contacts to project initiators and research institutes. By visiting the Ceramics Meeting Point within the framework of numerous events taking place at Fraunhofer IKTS, once again more than 1800 visitors informed about ceramic product innovations and manufacturers in 2013.

www.task.info

Members of Ceramics Meeting Point

1 *Presentation of Ceramics Meeting Point at Fraunhofer IKTS workshop »Additive Manufacturing of Ceramics«.*

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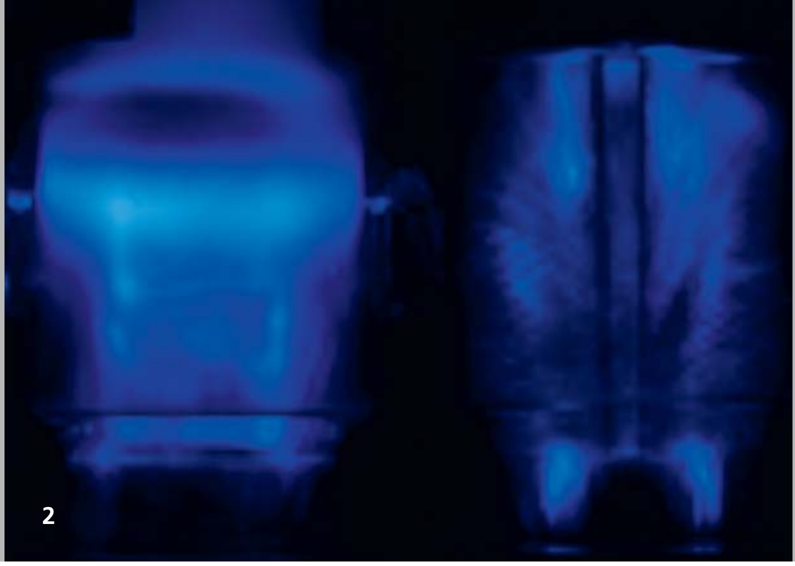

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ENVIRONMENTAL ENGINEERING AT THE FRIEDRICH SCHILLER UNIVERSITY JENA

Since Prof. Dr. Michael Stelter took the chair of environmental engineering at the Friedrich Schiller University Jena, Institute for Technical and Environmental Chemistry (ITUC), a new working group was formed under the guidance of Dr. Patrick Bräutigam. Since his dissertation in 2011, Dr. Bräutigam has been working on the investigation and optimization of cavitation-based methods in water treatment. Currently, the group, besides its leader, consists of one PhD, one PhD student and four Master students.

Cavitation in reaction technology

Cavitation phenomena are at the center of the group's activities, which investigates classic generation of cavitation bubbles through ultrasound waves as well as alternative hydrodynamic methods and combinations thereof. Reactors are developed, tested and optimized for various applications, respectively, from laboratory up to industrial scale. A large potential for cavitation reactors has been identified in the field of water treatment. Hydroxyl radicals that form in situ during the collapse of cavitation bubbles are suitable to oxidatively decompose "micro pollutants", such as pharmaceutical traces, hormones, antibiotics, industrial chemicals and also ingredients of cosmetics like triclosan in wastewater treatment plants.

Cavitation can also be used in sludge or biomass disintegration, which is also developed together with industrial equipment manufacturers and users. A third use for cavitation is chemical processing and separation technology. The group has developed a method for continuous transesterification of plant oils to bio diesel in a very compact plant assisted by means of hydrodynamic-acoustic cavitation.

In the future, the group will explore the broad range of possible applications for cavitation-based together with Fraunhofer IKTS. Some first projects that are conducted in cooperation have already been started.

Contact

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2 Use of luminol to visualize the cavitation fields in the reactors.

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Schneider, J.; Johannes, M.
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5th International Conference on Shaping of Advanced Ceramics – Shaping 5, Mons (29.-31.1.2013), Presentation

Schneider, J.; Johannes, M.; Sandkuhl, O.
Feinstdisperse Y-TZP-Keramiken für Implantate und dentale Restauration
8. Jahrestagung der Deutschen Gesellschaft für Biomechanik, Ulm (15.-17.5.2013), Poster

Schneider, M.; Schubert, N.; Michaelis, A.
ECM on SiC-based ceramics – A first approach
9th International Symposium on Electrochemical Machining Technology – INSECT 2013, Chemnitz (12./13.11.2013), p.125-130, Presentation

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Electrochemical Machining – Eine alternative Werkstoffbearbeitung
Workshop Elektrochemie – Verfahrenstechnologie für vielfältige Anwendungen, Hanau (24.1.2013), Presentation

Schneider, M.; Langklotz, U.; Michaelis, A.
Electrolyte / Separator combinations and the internal resistance of LIBs
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Schönecker, A.
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Schönecker, A.; Rödig, T.; Eßlinger, S.
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Schönecker, A.; Eßlinger, S.; Rupitsch, S.J.
Activation and characterization of electro-mechanical coupling of piezoceramic components with regard to optimized use in smart structure applications
4th Scientific Symposium »Lightweight Design by Integrating Functions« des SFB/Transregio 39 »PT-PIESA«, Nürnberg (26./27.3.2013), p.75-79, Presentation

Schöne, J.; Körnig, A.; Beckert, W.; Michaelis, A.
Thermal modeling of a honeycomb reformer including radiative heat transfer
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Schöne, J.; Beckert, W.; Ganzer, G.; Pönicke, A.; Michaelis, A.
Two-dimensional modeling of a SOFC stack repeating unit
5th European Fuel Cell Piero Lunghi Conference – EFC13, Rome, Italy (11.-13.12.2013), p.155-156, Presentation

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19. Symposium Verbundwerkstoffe und Werkstoffverbunde, Karlsruhe (3.-5.7.2013), Presentation

Schubert, N.; Schneider, M.; Michaelis, A.
ECM of cemented carbides with various microstructure
9th International Symposium on Electrochemical Machining Technology – INSECT 2013, Chemnitz (12./13.11.2013), p.145-150, Presentation

Schulz, M.
Keramische Festelektrolyten für Hochtemperaturbatterien
2. Sächsisches Forum für Brennstoffzellen und Energiespeicher, Leipzig (5.11.2013), Presentation

Schwankl, M.; Flössel, M.; Körner, C.; Gebhardt, S.; Singer, R.F.; Michaelis, A.
Integration of piezoceramic components in aluminum high pressure die castings
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Schwarz, B.
EFFIGEST – Entwicklung einer energetisch hocheffizienten Prozesskette zur EFFIzienzsteigerung bei der Vergärung von GEflügelmist unter Nutzung modifizierter STrohfraktionen und mit prozessintegrierter Gewinnung marktfähiger Dünger - Erstvorstellung
5. Statuskonferenz des BMU-Förderprogrammes »Energetische Biomassenutzung«, Leipzig (14./15.11.2013), Presentation

Schwarz, B.
PROKOSYS – Prozesse, Komponenten und Systeme für den flexibilisierten Betrieb von Biogasanlagen unter Nutzung biogener Rest- und Abfallstoffe
5. Statuskonferenz des BMU-Förderprogrammes »Energetische Biomassenutzung«, Leipzig (14./15.11.2013), Presentation

Sempf, K.; Pönicke, A.; Triebert, A.; Gestrich, T.; Schilm, J.; Martin, H.-P.; Böhm, G.; Schnee, D.
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keramik für die Leistungselektronik
4th User Meeting Ultraschallmikroskopie, Westhausen (12./13.6.2013), Presentation

Sempf, K.
Einsatz der Ultraschallmikroskopie zur Prozesskontrolle beim Aktivlöten von Kupfer-Keramik-Verbunden
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Sempf, K.
Lokale elektrische Leitfähigkeit in SiC-Keramik
14. Wissenschaftliches Seminar des Dresdner Fraunhofer Clusters Nanoanalytik und des Dresden Center for Nanoanalysis der TU Dresden, Dresden (25.10.2013), Presentation

Seuthe, T.; Grehn, M.; Mermillod-Blondin, A.; Bonse, J.; Eberstein, M.
Compositional dependent response of silica-based glasses after femtosecond laser pulse irradiation
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Seuthe, T.; Grehn, M.; Bonse, J.; Mermillod-Blondin, A.; Eichler, H.; Eberstein, M.
Femtosecond laser induced structural modifications in binary and ternary silicate glasses probed by micro raman spectroscopy
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Seuthe, T.; Grehn, M.; Mermillod-Blondin, A.; Bonse, J.; Eberstein, M.
µ-Raman Spektroskopie an fs-Laser modifizierten Gläsern
Fachausschuss I der DGG »Chemie und Physik des Glases«, Würzburg (8.10.2013), Presentation

Simon, A.; Kinski, I.; Schulz, M.; Richter, H.; Voigt, I.
CNT auf porösen Keramikträgern für die Energie- und Umwelttechnik
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Simon, A.; Kinski, I.; Schulz, M.; Richter, H.; Voigt, I.; Ritter, U.
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Growing of carbon nanotubes on asymmetric porous ceramic substrates by catalytic chemical vapor deposition (CCVD)
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Application of coating technologies for the production of functional material composites
26. PTS Streicherei Symposium, München (17./18.9.2013), Presentation

Slawik, T.; Moritz, T.; Scholl, R.; Michaelis, A.
Multilayered metal-ceramic composites made by coating technologies
8th Pacific Rim International Conference on Advanced Materials and Processing – PRICM8, Waikoloa, Hawaii (4.-9.8.2013), Presentation

Stahn, M.; Weyd, M.; Richter, H.; Voigt, I.
Development of ceramic membranes with the help of fluid flow simulation
3rd Dissemination Workshop of the nano4water cluster, Dresden, (17./18.4.2013), Poster

Stahn, M.; Richter, H.; Puhlfürß, P.; Reichel, U.
Erhöhung der Festigkeit oxidkeramischer Bauteile durch Einbringen eines Material- und Gefügegradienten
DKG-Jahrestagung 2013, Weimar (18.-20.3.2013), Presentation

Standke, G.
Development and testing of carbon and zirconia infiltrated silicon carbide materials as high temperature refractories in coal ash gasification reactors
13th International Conference of the European Ceramic Society – ECerS XIII, Limoges (23.-27.6.2013), Presentation

Stein, J.; Potthoff, A.; Meyer, A.
Aufbereitung und Charakterisierung von Suspensionen
DKG-Fortbildungsseminar – Sprühtrocknung keramischer Suspensionen – Technologie und statistische Versuchsplanung, Dresden (6./7.11.2013), Presentation

Stockmann, J.; Beckert, W.
Keramische Federelemente von der Auslegung bis zum Prototyp
Ilmenauer Federntag 2013, Ilmenau (26.9.2013), Presentation

Stockmann, J.
Trockenpressen – Technologische Aspekte
DKG-Fortbildungsseminar – Technologische Grundlagen der Granulierung und Granulatverarbeitung, Dresden (4./5.11.2013), Presentation

Stockmann, J.
Verbindungstechnik
Advancer-Schulungsprogramm Hochleistungskeramik Teil III: Konstruktion, Prüfung, Freiburg (14./15.11.2013), Presentation

Suffner, J.; Rost, A.
Glaskeramische Werkstoffe zum Fügen von hoch-chromhaltigen Metallen
SOFC-Workshop »Technologieroadmapping D A CH – III«, Reutte (25.–27.6.2013), Presentation

Svoboda, H.
Charakterisierung des Pressverhaltens
DKG-Fortbildungsseminar – Sprühtrocknung keramischer Suspensionen – Technologie und statistische Versuchsplanung, Dresden (6./7.11.2013), Presentation

Svoboda, H.
Charakterisierung des Pressverhaltens
DKG-Fortbildungsseminar – Technologische Grundlagen der Granulierung und Granulatverarbeitung, Dresden (4./5.11.2013), Presentation

Swiecinski, K.; Ihle, M.; Jurk, R.; Dietzen, E.; Partsch, U.; Eberstein, M.
Aerosol jet printing of two component thick film resistors on LTCC
9th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies – CICMT 2013 – IMAPS/ACerS, Orlando (23.-25.4.2013), Presentation

Tillmann, W.; Sievers, N.; Pfeiffer, J.; Wojarski, L.; Zielke, R.; Pönicke, A.;

Schilm, J.
Examination of the porosity in reactive air brazed joints by ultrasonic testing
10th International Conference Brazing, High Temperature Brazing and Diffusion Bonding – LÖT 2013, Aachen (18.-20.6.2013), p.46-49, Presentation

Trümper, S.; Schneider, M.
Elektrophoretische CNT-Beschichtungen
18. Seminar des Arbeitskreises Elektrochemie in Sachsen – AKES, Freiberg (11.1.2013), Presentation

Vinnichenko, M.; Hauschild, D.; Heinig, K.-H.; Krause, M.; Cornelius, S.; Lissotschenko, V.; Sauchuk, V.; Kusnezoff, M.
Modification of transparent conductive materials by millisecond laser processing
Workshop »Laser RTP« – Kompetenznetz INPLAS, Berlin (12./13.9.2013), Presentation

Voigt, I.; Michaelis, A.
Ceramic membranes and systems for energy and environmental technology
8th International Conference on High-Performance Ceramics – CICC-8, Chongqing (4.-7.11.2013), Presentation

Voigt, I.; Richter, H.; Weyd, M.
Ceramic membranes for water purification, product cleaning and solvent recovery
7th International Workshop on Crystallization, Filtration, Drying & Milling, Mumbai (21.-23.2.2013), Presentation

Voigt, I.
Ceramic membranes: From macropores to nanopores for efficient energy conversion
GIGA 2013 Academic Workshops der Universität Köln, New Delhi (16.-19.9.2013), Presentation

Voigt, I.; Richter, H.; Weyd, M.; Prehn, V.
Ceramic nanofiltration membranes – Examples of application and new developments
10. Aachener Tagung Wasser und Membranen, Aachen (29./30.10.2013), Presentation

Voigt, I.; Richter, H.; Weyd, M.
Inorganic membranes for dewatering of organic solvents including bioethanol
7th International Workshop on Crystallization, Filtration, Drying & Milling, Mumbai (21.-23.2.2013), Presentation

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Keramische Nanofiltrationsmembranen mit einer Trenngrenze von 200 Da
Fachkolloquium »Neue Möglichkeiten in der Trenntechnik durch Einsatz stabiler keramischer Membranen«, Hermsdorf (13.6.2013), Presentation

Voigt, I.; Puhlfürß, P.; Richter, H.; Zeidler, S.; Kätzel, U.
Low cut-off ceramic NF-membranes for organic solvents
4th International Conference on Organic Solvent Nanofiltration, Aachen (12.-14.3.2013), Presentation

Voigt, I.; Richter, H.; Weyd, M.; Tusel, E.; Brüschke, H.E.A.
Membrane enhanced biofuel production
3rd International Conference on Energy Process Engineering – ICEPE, Frankfurt (4.-6.6.2013), Presentation

Voigt, I.; Prehn, V.
Poröse keramische Membranen zur Effizienzsteigerung der Biomassekonversion
11. Thüringer Werkstofftag, Ilmenau (21.3.2013), Presentation

Voigt, I.; Richter, H.; Kriegel, R.; Weyd, M.
Stand der Entwicklung keramischer Membranen für die Gastrennung
DECHEMA Fachgruppen-Sitzung »Membrantechnik«, Frankfurt (24.1.2013), Presentation

Wabnitz, C.; Weiser, M.; Schneider, M.
Entwicklung einer Membranelektrodeneinheit auf Basis gerichteter Kohlenstoffnanoröhren
18. Seminar des Arbeitskreises Elektrochemie in Sachsen – AKES, Freiberg (11.1.2013), Presentation

Walter, M.; Weil, M.; Meißner, T.; Springer, A.; Duis, K.
Acute and chronic effects of magnetite-based nanocomposites on invertebrates (Hyalella Azteca and Chironomus riparius) and zebrafish embryos (Danio rerio)
3rd Young Environmental Scientists meeting – YES 2013, Krakau (11.-13.2.2013), Presentation

Weil, M.; Meißner, T.; Kühnel, D.; Duis, K.
Erste Schritte zu einer einheitlichen ökotoxikologischen Bewertung von Fe-basierten Nano- partikeln und Nanokompositen
18. Jahrestagung der SETAC GLB, Essen (23.-26.9.2013), Poster

Weil, M.; Meißner, T.; Kühnel, D.
Erste Schritte zur ökotoxikologischen Bewertung von Eisen-basierten Nanopartikeln und Nanokompositen
3. Clustertreffen NanoCare / NanoNature, Frankfurt (14./15.1.2013), Poster

Weiser, M.; Schrötke, C.; Schneider, M.; Meißner, F.; Michaelis, A.
Abscheidung von Manganoxid auf gerichteten Kohlenstoff-nanoröhren
18. Seminar des Arbeitskreises Elektrochemie in Sachsen – AKES, Freiberg (11.1.2013), Presentation

Wenzel, M.; Schmidt, R.; Partsch, U.; Eberstein, M.
Thick film pastes for nitride ceramics for high power applications
46th International Symposium on Microelectronics – IMAPS 2013, Orlando (29.9.-3.10.2013), Presentation

Wenzel, M.; Schmidt, R.; Partsch, U.; Eberstein, M.
Thick film pastes for silicon nitride ceramics
9th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies, CICMT 2013, IMAPS/ACerS, Orlando (23.-25.4.2013), Presentation

Weyd, M.; Richter, H.; Voigt, I.
Nanoporous ceramic membranes for separation processes in liquid and gaseous media
Membranes-2013, Vladimir (1.-4.10.2013), Presentation

Weyd, M.
Permporosimetrie zur Qualitätskontrolle meso- und mikroporöser Membranen
Arbeitskreis Keramische Membranen, Frankfurt (7.5.2013), Presentation

Weyd, M.; Richter, H.; Voigt, I.
Separation processes using nanoporous membranes
Engineering with membranes, Saint-Pierre d'Oleron (3.-7.9.2013), Presentation

Winkin, N.; Mokwa, W.; Gierth, U.; Rabbow, T.; Michaelis, A.
A flexible micro-electrode array with an embedded flexible CMOS-chip for medical applications
7th International Conference and Exhibition on Integration Issues of Miniaturized Systems, Amsterdam (13./14.3.2013), Presentation

Winkin, N.; Gierth, U.; Michaelis, A.; Mokwa, W.; Rabbow, T.
Nano-modifiziertes flexibles Mikroelektroden-Array mit integriertem CMOS-Chip für medizinische Anwendungen
MikroSystemTechnik-Kongress 2013: Von Bauelementen zu Systemen, Aachen (14.-16.10.2013), Presentation

Wolter, M.; Börner, S.; Fritsch, M.; Fauser, G.; Wunderlich, C.
Development of lithium battery electrodes – Effect of manufacturing parameters and electrode design on performance and lifetime of electrodes
Advanced Automotive Battery Conference – AABC Europe 2013, Strasbourg (24.-28.6.2013), Poster

Wunderlich, C.
Brennstoffzellen für stationäre Energieversorgung
7. Expertentreffen Energiemetropole Leipzig, Leipzig (2.12.2013), Presentation

Wunderlich, C.; Goldberg, A.; Partsch, U.; Ziesche, S.
Ceramic multilayer technology as enabling technology for robust micro fuel cell systems
Fuel Cell Seminar & Energy Exposition 2013, Columbus (21.-24.10.2013), Presentation

Wunderlich, C.
Joint Ventures zur Stärkung des technologiebezogenen Ökosystems
Fraunhofer Marketing Tag 2013 – Akquisition in Schlüsselbranchen, München (8.11.2013), Presentation

Ziesche, S.; Mosch, S.; Ihle, M.; Partsch, U.
Hochauflösendes Direktschreiben sensorischer Strukturen unter Anwendung des Aerosoldruckverfahrens
11. Dresdner Sensor-Symposium – DSS 2013, Dresden (9.-11.12.2013), p.325-329, Poster

Zins, M.
Keramische Komponenten als Schlüsselfunktion für Innovationen bei Design und Interieur
InnoMateria Award – Expertentreff der innovativen Werkstoffbranche, Kölnmesse, Köln (14./15.5.2013), Presentation

Zins, M.
Fraunhofer's success case of technology transfer to SMEs
Global R&D Conference, Coex, Seoul (6.12.2013), Presentation

Zins, M.
Herstellung, Anwendung und Einkauf von Technischer Keramik
Workshop, VW AutoUni, Wolfsburg (31.5.2013), Presentation

Zins, M.
Anwendungen und Lieferanten keramischer Hochleistungskomponenten
Advancer-Schulungsprogramm Hochleistungskeramik Teil I: Werkstoffe, Verfahren, Dresden (6./7.3.2013), Presentation

Zins, M.
Keramische Hochleistungswerkstoffe: Einsatzbereiche und Entwicklungstrends
DKG-Fortbildungsseminar – Entbinderung keramischer Formteile, Dresden (10./11.10.2013), Presentation

Zins, M.
Keramische Werkstoffe und Anwendungen: Entwicklungstrends und -angebote
DKG-Fortbildungsseminar – Thermoplastische Formgebung von Technischer Keramik – Technologie und Training, Dresden (9./10.10.2013), Presentation

Zschippang, E.
Ceramic heaters made of silicon nitride composites
2nd International Conference on Materials for Energy – EnMat II, Karlsruhe (12.-16.5.2013), Poster

Teaching activities of IKTS employees

Dr. Barth, S.
Lecture
»Keramische Verfahrenstechnik«
Ernst-Abbe-Fachhochschule Jena, Fachbereich Scitec (WS 13/14)

Dr. Eberstein, M.
Lecture
»Dickschichttechnik«
TU Bergakademie Freiberg, Institut für Keramik, Glas- und Baustofftechnik (SS 13)

Dr. Fries, M.
Lecture
»Granulationsverfahren und Granulatcharakterisierung in der keramischen Industrie«
TU Bergakademie Freiberg, Freiberg (15.05.2013)

Dr. habil. Herrmann, M.
Lecture and student affairs
»Technische Keramische Werkstoffe«
University of Witwatersrand, Johannesburg, Südafrika (03/2013 und 09/2013)

Dipl.-Ing. Höhn, S.
Lecture
»Keramografie«, im Rahmen der Lehrveranstaltung »Metallografie«
TU Dresden, Institut für Werkstoffwissenschaft (28.1.2013)

Dr. Jahn, M.
Lecture and practice
»Technische Chemie II/Reaktionstechnik«
HTW Dresden, Chemieingenieurwesen (SS 13)

Dr. Jahn, M.
Presentation
»Synthesegaserzeugung aus Biogas Reaktordesign und Integration in ein Festoxidbrennstoffzellensystem«
Friedrich-Schiller-Universität Jena, Institut für Technische Chemie (14.11.2013)

Dr. Jahn, M.
Presentation at faculty colloquium
»Verfahrenstechnische Entwicklung von Festoxidbrennstoffzellen-(SOFC)-Systemen«
TU Hamburg-Harburg (5.12.2013)

Dr. Kriegel, R.
Lecture
»Keramische Verfahrenstechnik«
Ernst-Abbe-Fachhochschule Jena, Fachbereich Scitec (WS 13/14)

Prof. Dr. Michaelis, A.; Dr. Kusnezoff, M.; Dr. Jahn, M.; Dr. Heddrich, M.; Dr. Rebenklau, L.
Lecture
»Keramische Funktionswerkstoffe«
TU Dresden, Institut für Werkstoffwissenschaft (SS 13)

Prof. Dr. Michaelis, A.
Lecture and practical training
»Keramische Werkstoffe«
TU Dresden, Institut für Werkstoffwissenschaft (WS 12/13; WS 13/14)

Prof. Dr. Michaelis, A.;
Dr. Rebenklau, L.;
Dr. Schönecker, A.
Chapter: »Technologien der Dickschichttechnik« in der Vorlesungsreihe »Hybridtechnik«
TU Dresden, Fakultät Elektrotechnik und Informationstechnik (WS 13/14)

Dr. Moritz, T.
Lecture
»Keramikspritzgießen«
Ernst-Abbe-Fachhochschule Jena, Fachbereich Scitec (18.11.2013)

Dr. Moritz, T.
Lecture
»Keramikspritzgießen«
TU Bergakademie Freiberg (19.6.2013)

Dr. Moritz, T.
Lecture
»Grundlagen der Technischen Keramik«
Kunsthochschule Halle, Burg Giebichenstein (WS 12/13)

Dr. Neumeister, P.
Lecture
»Bruchkriterien und Bruchmechanik«
TU Dresden, Institut für Festkörpermechanik (SS 13)

Dr. Potthoff, A.
Lecture
»Nanopartikelcharakterisierung«, im Rahmen der Lehrveranstaltung »Advanced Characterization Techniques«
TU Dresden, Institut für Werkstoffwissenschaft (28.1.2013)

Dr. Rebenklau, L.
Lecture
»Dickschichttechnik« und »Multilayerkeramik«
in the course of Prof. Michaelis »Funktionskeramik«
TU Dresden, Institut für Werkstoffwissenschaft (SS 13)

Prof. Dr. Stelter, M.
Lecture
»Technische Chemie I / II«
Friedrich-Schiller-Universität Jena (SS 13; WS 13/14)

Prof. Dr. Stelter, M.
Lecture
»Technische Umweltchemie«
Friedrich-Schiller-Universität Jena (SS 13; WS 13/14)

Prof. Dr. Stelter, M.
Lecture
»Technische Chemie II Vertiefungsfach«
Friedrich-Schiller-Universität Jena (WS 13/14)

Dr. Voigt, I.
Lecture
»Keramische Verfahrenstechnik«
Ernst-Abbe-Fachhochschule Jena, Fachbereich Scitec (WS 13/14)

Dr. Zins, M.
Lecture
»Metalle, Kunststoffe, Keramiken – Technische Keramik als Leichtbaustoff«
TU Dresden, Institut für Werkstoffwissenschaft (WS 12/13; WS 13/14)

Participation in bodies and technical committees

Bodies

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

Dr. Kusnezoff, M.
- Fraunhofer Energy Alliance, Representative
- SOFC Symposium of ICACC Conference series organized by American Ceramic Society in Daytona Beach, Organizer
- VDMA Working Group High Temperature Fuel Cells, Coordinator
- Scientific committee of European Fuel Cell Forum, Member

Prof. Dr. Michaelis, A.
- Editorial Board of "Journal of Ceramic Science and Technology"
- Editorial Board of "International Journal of Materials Research"
- Publication series "Kompetenzen in Keramik", Michaelis, A. (Hrsg.), Stuttgart: Fraunhofer IRB Verlag, Start 2006
- Publication series "Kompetenzen in Keramik und Umweltverfahrenstechnik", Michaelis, A. (Hrsg.), Stuttgart: Fraunhofer IRB Verlag, Start 2008

AGEF e.V. Institut at Heinrich-Heine-Universität, Arbeitsgemeinschaft Elektrochemischer Forschungsinstitutionen e.V., Member
- Forschungszentrum Dresden Rossendorf, Member
- DECHEMA Gesellschaft für Chemie Technik und Biotechnologie e.V., Member
- DGM Deutsche Gesellschaft für Materialkunde, Member
- "World Academy of Ceramics" WAC, Member
- WAC Forum Committee (2010-2014), Cooperation
- DKG Member of Excecutive Board and chairman of Forschungsgemeinschaft der Deutschen Keramischen Gesellschaft
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Koordinierung"
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Funktionskeramik", Director
- DECHEMA working committee "Angewandte Anorganische Chemie"
- DPG-Deutsche Physikalische Gesellschaft
- Institute Council of IfWW, TU Dresden
- Company Roth & Rau, Member of Supervisory Board
- AiF Wissenschaftlicher Rat
- Solarvalley Mitteldeutschland e.V., Executive Board
- Scientific Advisory Board "Photovoltaik Silicon Saxony", Member
- FH Council of Westsächsische Hochschule Zwickau, Member
- Dresdner Gesprächskreis der Wirtschaft und Wissenschaft e.V.
- NanoChem, BMBF, consultant
- Evaluation team "Interne Programme" of Fraunhofer Gesellschaft, Member
- Steering committee of Innovationszentrum Energieeffizienz, TU Dresden
- Advisory Board of eZelleron GmbH
- Executive Board of Materialforschungsverbund Dresden e.V. MFD, Member
- Energiebeirat des Wirtschaftsministeriums Sachsen
- Advisory Board of Industrielles Netzwerk Erneuerbare Energien Sachsen EESA
- Dresden concept e.V.
- Clean Tech Media Award, Member of the jury
- Evaluation team "Märkte von Übermorgen" of Fraunhofer-Gesellschaft, consultant
- NOW GmbH, Member of advisory board
- Fraunhofer USA, Board of Directors

Dr. Schneider, M.
- DGO-Bezirksgruppe Sachsen der Deutschen Gesellschaft für Gal

vano- und Oberflächentechnik, Chair
- Fachbeirat der Gesellschaft für Korrosionsschutz, GfKORR, Member

Prof. Dr. Stelter, M.
- MNT Mikro-Nano-Technologie Thüringen e.V., Member of executive board

Dr. Richter, H.
- International Zeolite Association

Dr. Voigt, I.
- BVMW-Bundesverband für mittelständige Wirtschaft

Dr. Voigtsberger, B.
- DKG Member of Presidential Council and Executive Board
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Koordinierung", chairman
- FH Council of Fachhochschule Jena
- IHK Ostthüringen zu Gera, Ausschuss für Industrie und Forschung

Dr. Wunderlich, C.
- Energy Saxony e.V., Executive Board and Deputy Chairman
- Fuel Cell Energy Solutions GmbH, Member of Advisory Board
- European Fuel Cell Forum, International Bord of Advisors

Dr. Zins, M.
- Fraunhofer AdvanCer Alliance, Spokesperson
- Editorial Board "Ceramic Applications", Göller Verlag, Chairman

Technical committees

Dipl.-Krist. Adler, J.
- DGM technical committee "Zellulare Werkstoffe"
- FAD-Förderkreis "Abgasnachbehandlungstechnologien für Dieselmotoren e.V."

Dr. Beckert, W.
- Fraunhofer Alliance "Numerische Simulation von Produkten und Prozessen" NUSIM

Dipl.-Math. Brand, M.
- Technical committee "Schallemissionsprüfung (SEP)" of Deutsche Gesellschaft für zerstörungsfreie Prüfung DGZfP

Dr. Faßauer, B.
- Fraunhofer SysWasser Alliance
- Wasserwirtschaftliches Energiezentrum Dresden – e.qua impuls e.V.
- Fachverband "Biogas"

Freund, Susanne
- Fraunhofer AdvanCer Alliancer, central office

Dr. Fries, M.
- DGM/DKG Working Group "Verarbeitungseigenschaften synthetischer keramischer Rohstoffe", Director
- DKG technical committee FA III "Verfahrenstechnik"
- ProcessNet technical group "Agglomerations- und Schüttguttechnik", Member of Advisory Board
- ProcessNet technical group "Trocknungstechnik", Member of Advisory Group

Dr. Gestrich, T.
- Joint committee "Pulvermetallurgie", expert group "Sintern"
- GEFTA Working Group "Thermophysik"

Dipl.-Ing. Gronde, B.
- Gemeinschaft "Thermisches Spritzen e.V."
- DVS Working Group "Thermisches Spritzen"

Dr. Herrmann, M.
- DGM technical committee "Thermodynamik, Kinetik und Konstruktion der Werkstoffe"
- DGM technical committee "Field Assisted Sintering Technique/Spark Plasma Sintering"

Dr. Kaiser, Arno
- GEFTA Working Group "Thermophysik"

Dr. Klemm, H.
- DKG Working Group "Verstärkung keramischer Stoffe"
- DIN Committee for Standardization "Materialprüfung NMP 291"
- DIN Committee for Standardization "Materialprüfung NMP 294"
- Carbon Composites e.V., Working Group "Ceramic Composites"

Kunath, R.
- Working Group "Spezialbibliotheken"

Dr. Kusnezoff, M.
- DIN/VDE, Referat K 141, DKE Deutsche Kommission, "Elektrotechnik Elektronik Informationstechnik"
- Working Group "Aufbau- und Verbindungstechnik für Hochtemperatursensoren"

Dr. Lausch, H.
- VDE/VDI Gesellschaft Mikroelektronik, Mikro- und Feinwerktechnik, GMM technical committee 4.7 Mikro-Nano-Integration
- VDE/DGMT/BMBF Begleitforschung Intelligente Implantate, external member
- Fraunhofer-Gesellschaft e.V., Forschungsplanung, Fraunhofer Discover Markets 2030

Dipl.-Ing. Lincke, Marc
- ANS e.V. technical committee "Biokohle"

Dipl.-Ing. Ludwig, H.
- DGM technical committee "Biomaterialien"

Dr. Moritz, T.
- ENMAT "European Network of Materials Research Centres", Vice President
- Management Committee of COST action MP0701 "Nanocomposite Materials"
- DECHEMA technical committee "Nanotechnologie"
- DKG expert group "Keramikspritzguss", Chairman of Executive Board
- Editorial Board of cfi/Ber. DKG, chairman

Dipl.-Phys. Mürbe, J.
- VDI-Bezirksverein Dresden, Working Group "Granulometrie"

Nake, K.
- DGM Working Group "Härteprüfung und AWT", technical committee "FA-12"

Dr. Petasch, U.
- FAD-Förderkreis "Abgasnachbehandlungstechnologien für Dieselmotoren e.V."

Dipl.-Ing. Pönicke, A.
- DVS-Ausschuss für Technik, Working Group W3 "Fügen von Metall, Keramik und Glas"

Dr. Potthoff, A.
- DGM/DKG Working Group "Prozessbegleitende Prüfverfahren"
- DECHEMA/VCI Working Group "Responsible Production and Use of Nanomaterials"
- Fraunhofer Nanotechnology Alliance

Dipl.-Ing Räthel, J.
- DGM technical committee "Field

Assisted Sintering Technique / Spark Plasma Sintering"

Dr. Rebenklau, L.

- VDI/VDE-GMM technical committee 5.5 "Aufbau- und Verbindungstechnik"
- VDE/VDI-Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik
- Working Group "Aufbau- und Verbindungstechnik für Hochtemperatursensoren"

Dr. Reichel, U.

- DKG technical committee "Werkstoffanwendungen"
- DKG Working Group "Verarbeitungseigenschaften synthetischer keramischer Rohstoffe"
- DGM technical committee "Field Assisted Sintering Technique/ Spark Plasma Sintering"

Dr. Richter, H.-J.

- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Keramische Membranen"
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Biokeramik"
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Generative Fertigung keramischer Komponenten"

Dr. Richter, V.

- VDI technical committee "Schneidstoffanwendung"
- DECHEMA/VCI Working Group "Responsible Production and Use of Nanomaterials"
- DGM Working Group "Materialkundliche Aspekte der Tribologie und der Endbearbeitung"
- DIN Committee for Standardization "Werkstofftechnologie" (NWT), AA "Probenahme und Prüfverfahren für Hartmetalle"
- DIN Committee for Standardization "Materialprüfung" (NMP), AA "Nanotechnologien"
- DGM/DKG joint committee "Pulvermetallurgie", expert group "Sintern"
- Fraunhofer Nanotechnology Alliance
- EPMA Working Group "European Hard Materials Group"

Dr. Rost, Axel

- DVS-Ausschuss für Technik, Working Group W3 "Fügen von Metall, Keramik und Glas"

Dr. Schilm, J.

- DGG technical committee "Physik und Chemie des Glases"
- DKG/DGG Working Group "Glasigkristalline Multifunktionswerkstoffe"
- DVS-Ausschuss für Technik, Working Group W3 "Fügen von Metall, Keramik und Glas"

Dr. Schönecker, A.

- Advisory Board of Smart Material GmbH Dresden

Dipl.-Chem. Schubert, R.

- DKG expert group "Keramikspritzguss"

Standke, Gisela

- DGM technical committee "Zellulare Werkstoffe"

Dipl.-Ing. Stahn, M.

- VDI-Entwicklung, Konstruktion, Vertrieb

Dr. Stelter, M.

- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Energie"
- DGM technical committee "Werkstoffe der Energietechnik"

Dipl.-Min. Thiele, S.

- GTS-Gemeinschaft Thermisches Spritzen e.V.

Dr. Voigt, I.

- GVC technical committee "Produktionsintegrierte Wasser- und Abwassertechnik"
- ProcessNet working committee "Membrantechnik"
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Keramische Membranen", Director
- DGM/DKG joint committee "Hochleistungskeramik", Working Group "Koordinierung"

Dr. Wunderlich, C.

- VDI technical committee "Brennstoffzellen"

Dr. Zins, M.

- DKG coordination group "Strukturwerkstoffe Fachausschüsse"
- Technical committee "Pulvermetallurgie"
- DKG technical committee "Keramikanwendungen"
- Deutsche Messe AG, Advisory Board "Industrial Supply"
- Messe Munich, Advisory Board "Ceramitec"
- Institut für Prozess- und Anwendungstechnik Keramik, RWTH Aachen, Executive Board

Advisory boards for symposia and conferences

Prof. Dr. Michaelis, A.

- Vision Keramik 2014, IKTS Dresden (16./17.1.2014)
- DKG-Jahrestagung 2014 / Symposium Hochleistungskeramik DKG/DGM 2014, Clausthal-Zellerfeld (24.-26.3.2014)
- 13th International Ceramics Congress – CIMTEC 2014, Montecatini Terme, Italy (8.-13.6.2014), Member of the international advisory board
- 5th International Congress on Ceramics – ICC5, China, Peking (17.-21.8.2014), Member of the board of the international advisory committee
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Vancouver, Canada (14.-19.6.2015), Organizing committee
- 4. Dresdner Werkstoffsymposium »Verbundwerkstoffe und Werkstoffverbunde«, Dresden, TU Dresden IfWW (18./19.11.2013)

Dr. Fries, M.

- 18. DKG-Fortbildungsseminar – Technologische Grundlagen der Granulierung und Granulatverarbeitung, IKTS Dresden/TU Dresden (4./5.11.2013), Program organizer
- 6. DKG-Fortbildungsseminar – Sprühtrocknung: Technologie – Statistische Versuchsplanung – Produkt- und Prozessoptimierung, IKTS Dresden/TU Dresden (6./7.11.2013), Program organizer
- 6. DKG/DGM-Arbeitskreissitzung »Verarbeitungseigenschaften synthetischer Rohstoffe«, Hosokawa Alpine AG (18.4.2013), Program organizer
- DKG-Symposium »Verfahren zur Herstellung keramischer Schichten«, Erlangen (3./4.12.2013), Member program committee

Dr. Gestrich, T.

- 32. Hagener Symposium Pulvermetallurgie »Moderne Fertigungsprozesse - Qualität und Produktivität in der Pulvermetallurgie«, Hagen (28./29.11.2013), Program committee

Dr. Schneider, M.

- 6th International Workshop on Impedance Spectroscopy – IWIS 2013, Chemnitz (25.-27.9.2013), Program committee
- 9th International Symposium on Electrochemical Machining Technology – INSECT 2013, Chemnitz (12./13.11.2013), Advisory board

Dr. Schönecker, A.

- International Symposium on Piezocomposite Applications – ISPA 2013, Dresden (19./20.9.2013), Conference organizer

Dr. Vinnichenko, M.

- 537. WE-Heraeus-Seminar »Physics of Ionized- and Ion-Assisted PVD: Principles and Current Trends«, Dresden (26.-28.6.2013), Coorganizer

Zins, M.

- AdvanCer-Schulungsprogramm Hochleistungskeramik Teil I: Werkstoffe, Verfahren, IKTS Dresden (6./7.3.2012)
- InnoMateria Award – Expertentreff der innovativen Werkstoffbranche, Kölnmesse, Köln (14./15.5.2013), Jury
- Innovationsforum Interieur & Design, InnoMateria (14./15.5.2013), Program committee

Dissertations

Böttge, Daniela
Werkstoffliche und keramtechnologische Aspekte von funktionalen Beschichtungen auf hochporösen Keramikträgern
Dissertation 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Breite, Manuela
Bioethanol in der Hochtemperaturbrennstoffzelle – Partielle Oxidation von Ethanol
Dissertation 2013
Fraunhofer IKTS – TU Bergakademie Freiberg, Fakultät für Chemie und Physik

Höhn, Sören
Beitrag zur quantitativen Charakterisierung keramischer Granulate, Grünkörper und Werkstoffe im angesinterten Zustand
Dissertation 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Langklotz, Ulrike
(Mikro-)elektrochemische Untersuchungen zur Schichtdicke und den dielektrischen Eigenschaften dünner anodischer Oxidfilme auf Titan und TiAlV6-4
Dissertation 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Pönicke, Andreas
Löten von Keramik-Metall-Verbunden mit Reaktivloten an Luft und deren Alterungsverhalten bei hohen Temperaturen
Dissertation 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Energietechnik

Schroth, Stephan
Optische In-situ-Beobachtung des anodischen Auflösungsverhaltens von Kupfer unter ECM-nahen Bedingungen
Dissertation 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Tröber, Oliver
Synthese, Modifizierung und Verarbeitung von porösen, anorganischen Silicaten für die Anwendung in Polymermembranen und fotochrom schaltenden Schichten
Dissertation 2013
Fraunhofer IKTS – Friedrich-Schiller-Universität Jena, Chemisch-Geowissenschaftliche Fakultät

Diploma theses

Bartsch, Katja Alexandra
Herstellung von zweifarbigen, cogesinterten Bauteilen im Inmould-Labelling-Verfahren
Diploma thesis 2013
Fraunhofer IKTS – Hochschule Koblenz WesterWald, Campus Höhr-Grenzhausen

Bernhardt, Matthias
Aufbau eines Messplatzes zur Leitfähigkeitsuntersuchung an mischleitenden Oxidkeramiken bei hohen Temperaturen und unterschiedlichen Sauerstoff-Partialdrücken
Diploma thesis 2013
Fraunhofer IKTS – Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec

Böcker, Aletta
Degradationsverhalten von Siliciumcarbid Schaumkeramik
Diploma thesis 2013
Fraunhofer IKTS – TU Darmstadt, Material- und Geowissenschaften

Erdmann, André
Untersuchung der Hochtemperatur-Sauerstoffpermeation aus thermisch gespaltenem Wasser mittels Ce-substituierten YSZ
Master thesis 2013
Fraunhofer IKTS – Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec

Esche, Manuel
Leitfähigkeitsuntersuchung an mischleitenden Oxidkeramiken bei hohen Temperaturen und unterschiedlichen Sauerstoffpartialdrücken
Bachelor thesis, 2013
Fraunhofer IKTS – Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec

Freytag, Axel
Synthese und Charakterisierung p-leitender thermoelektrischer Keramiken
Master thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Mathematik und Naturwissenschaften, Fachrichtung Chemie und Lebensmittelchemie

Glier, Philipp
Untersuchungen zum Alterungsverhalten von Fe_2O_3-dotierten Katalysatorsystemen bei der Hochtemperaturoxidation von Kohlenmonoxid
Bachelor thesis 2013
Fraunhofer IKTS – TU Bergakademie Freiberg, Fakultät Maschinenbau, Verfahrens- und Energietechnik

Gottschlich, Benjamin
Spritzversuche von Nitriden mittels Plasmaspritzen
Diploma thesis 2013
Fraunhofer IKTS – Hochschule Mittweida, Fakultät für Maschinenbau

Greß, Carolin
Untersuchungen zum Betriebsverhalten eines SOFC-Systems mit realem Biogas und zur Integration einer Anodenabgasrezirkulation
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Hielscher, Sebastian
Zerstörungsfreie Bewertung und Nachweis von Fehlerursachen an Hochtemperatur-Brennstoffzellen aus CFY-Interkonnektoren
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden,

Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Hölzel, Martin
Darstellung der Nickelbasislegierung MAR-M 247 nach dem Masterlegierungsprinzip über galvanische Nickelabscheidung in definiert porösen Strukturen
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Hubmann, Jonas
Untersuchungen an Pt/Mn dotierten Katalysatoren auf Basis beschichteter Schaumkeramik zur CO Hochtemperaturoxidation
Bachelor thesis 2013
Fraunhofer IKTS – TU Bergakademie Freiberg, Fakultät Maschinenbau, Verfahrens- und Energietechnik

Jähnert, Kevin
Grundlegende Untersuchungen zu UV- härtenden Schlickersystemen für das Gießen von Folien nach dem Doctor-Blade-Verfahren und deren thermischer Nachbehandlung
Master thesis 2013
Fraunhofer IKTS – Friedrich-Schiller-Universität Jena, Physikalisch-Astronomische Fakultät, Institut für Materialwirtschaft und Werkstofftechnologie

Kasibhatla, Raghavendra Rohith
Thermo-fluidic modeling of a fuel cell stack using OpenFOAM
Master thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Strömungsmechanik

Kluge, Eric
Korrosionsverhalten von SiC-Diamantkomposit-Werkstoffen in wässrigen Lösungen
Diploma thesis 2013
Fraunhofer IKTS – Hochschule Zittau/Görlitz, Fachbereich Mathematik, Naturwissenschaften

Meyer, Robert
Weiterentwicklung und Charakterisierung zeolithgefüllter Kompositmembranen
Master thesis 2013
Fraunhofer IKTS – Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec

Reitzig, Sven
Entwicklung niedertemperaturaktivierter Metall-Precursortinten für den Aerosoldruck
Master thesis 2013
Fraunhofer IKTS – Hochschule Zittau/Görlitz

Rhein, Sebastian
Herstellung und Charakterisierung von dotierten Yttrium-Aluminium-Granat (YAG)-Pulvern
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Rosenberg, Markus
Katalysatortests an Kathoden für Zink-Luft-Batterien
Bachelor thesis 2013
Fraunhofer IKTS – Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec

Schmidt, Ulrike
Korrelation der elektrischen Kenndaten von Silberkontaktschichten auf Silizium mit der Mikrostruktur
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Schrötke, Carl
Untersuchung der Vorgänge an der Phasengrenze Metall/Oxid/Elektrolyt unter dem Aspekt der Feldstärke beim Pulsanodisieren von Aluminium
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Schwarzer, Eric
Wasserbasierender keramischer Schlicker – Theoretische und experimentelle Untersuchung des Trocknungsverhaltens zur Reduzierung von Trocknungsdauer und Defektentstehung
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Verfahrenstechnik und Umwelttechnik

Speer, Kerstin
Auswahl von alternativen elektronenleitenden Materialien und deren Eigenschaften zur Herstellung von dichten, asymmetrischen, sauerstoffpermeablen Komposit-Membranen
Master thesis 2013
Fraunhofer IKTS – Friedrich-Schiller-Universität Jena, Physikalisch-Astronomische Fakultät, Institut für Materialwirtschaft und Werkstofftechnologie

Svidler, Rostislav
Konstruktion, Aufbau und Inbetriebnahme eines Prüfstandes zur Untersuchung des ferroelektromechanischen Materialverhaltens an piezokeramischen Probekörpern unter Mehrfeldbelastung
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Leichtbau und Kunststofftechnik

Utikal, Jan
Untersuchung des Betriebsverhaltens einer Differentialkreislaufapparatur für den Einsatz neuartiger Katalysatorträger
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Voigt, Karsten
Charakterisierung und Vergleich der Suspensionseigenschaften von pyrogener und gefällter Kieselsäure
Bachelor thesis 2013
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Wabnitz, Christian
Platinfunktionalisierung von Kohlenstoff basierenden Elektroden mittels Pulsstromabscheidung für die Anwendung in der Polymer-Elektrolytmembran-Brennstoffzelle
Bachelor thesis 2013
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Wolfrum, Anne-Kathrin
cBN verstärkte Siliciumnitrid- und SiAlON-Werkstoffe
Diploma thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Zähr, Linnart
Untersuchungen zur Leitfähigkeit an B-dotierten ZnO-Schichten erzeugt mittels PECVD
Bachelor thesis 2013
Fraunhofer IKTS – TU Dresden, Fakultät Mathematik und Naturwissenschaften

EVENTS AND TRADE FAIRS PROSPECTS

Conferences and events

2nd Dresden Nanoanalysis Symposium (DNS)
July 2, 2014, Dresden, Fraunhofer IKTS-MD

Long Night of Sciences
July 4, 2014, Dresden, Fraunhofer IKTS

Symposium »Applied electrochemistry in materials science«
December 4–5, 2014, Dresden, Fraunhofer IKTS

Symposium »Optical Coherence Tomography for Non-Destructive Testing – OCT4NDT«
March 23–24, 2015, Dresden, Fraunhofer IKTS-MD

International Conference and Exhibition on Ceramic Interconnect & Ceramic Microsystems Technologies – CICMT 2015
April 20–23, 2015, Dresden, Fraunhofer IKTS

International Symposium on Piezocomposite Applications ISPA
September 2015, Dresden,
Transparent Factory and Fraunhofer IKTS

Please find further information at
www.ikts.fraunhofer.de/en/Events.html

Seminars and workshops

DKG seminars

Spray drying
November 12–13, 2014, Fraunhofer IKTS

Technological fundamentals of granulation and granule processing
April 2015, Fraunhofer IKTS

Please find further information at
www.dkg.de

AdvanCer training program:
Introduction into advanced ceramics

Part III: Design, testing
November 13–14, 2014, Freiburg

Part I: Materials, technologies, applications
March 4–5, 2015, Dresden

Part II: Machining
May 6–7, 2015, Berlin

Part III: Design, testing
November 12–13, 2015, Freiburg

Please find further information at
www.advancer.fraunhofer.de/en.html

Participation in trade fairs

European SOFC Forum
Lucerne, July 1–4, 2014
Joint booth Energy Saxony e.V.

Green Energy and Biogas Brazil
São Paolo, July 16–18, 2014

Euro PM
Salzburg, September 21–24, 2014

WindEnergy Hamburg
Hamburg, September 23–26, 2014
Joint booth Wind Energy Network

POWTECH
Nuremberg, September 30–October 2, 2014

TechnoPharm
Nuremberg, September 30–October 2, 2014

World of Energy Solutions (Battery & Storage, f-cell)
Stuttgart, October 6–8, 2014
Joint booth Energy Saxony e.V.

Composites
Düsseldorf, October 7–9, 2014
Joint Fraunhofer booth

Semicon Europe
Grenoble, October 7–9, 2014
Joint booth of Fraunhofer Microelectronics Alliance

ASNT Fall Conference
Charleston, October 27–30, 2014
Joint booth of Quality Network

electronica
Munich, November 11–14, 2014
Joint Fraunhofer booth

CompaMed
Düsseldorf, November 12–15, 2014
Joint Fraunhofer booth

Hagener Symposium
Hagen, November 27–28, 2014

EuroMold
Frankfurt am Main, November 25–28, 2014
Joint booth of Fraunhofer Additive Manufacturing Alliance

Please find further information at
www.ikts.fraunhofer.de/en/tradefairs.html

ANFAHRT ZUM FRAUNHOFER IKTS

Please find further information at
www.ikts.fraunhofer.de/de/kontakt.html

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/Nickern“ (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 along the An der Rennbahn to Winterbergstrasse
- Fraunhofer IKTS is on the left side of the road

By train

- From Dresden main station take tram 9 (direction Prohlis) to stop “Wasaplatz“
- 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 at

By car

- Highway A4: exit "Dresden-Flughafen" in direction Hoyerswerda along H.-Reichelt-Straße to Grenzstraße
- Maria-Reiche-Straße is the first road to the right after Dörnichtweg

- From Dresden city: B97 in direction Hoyerswerda
- Grenzstraße branches off to the left 400 m after the tram rails change from the middle of the street to the right side
- Maria-Reiche-Straße branches off to the left after approximately 500 m

By train

- Take tram 7 from Dresden city to stop "Arkonastraße"
- Turn left and cross the residential area diagonally to Grenzstraße
- Follow this road for about 10 min to the left and you will reach Maria-Reiche-Straße

- Take suburban train S2 to "Dresden-Grenzstraße"
- Reverse for ca. 400 m
- Maria-Reiche-Straße branches off to the right

By plane

- After arriving at airport Dresden use either bus 80 to bus stop "Grenzstraße Mitte" at the beginning of Dörnichtweg and follow Grenzstraße for 150 m
- Or take suburban train S2 to "Dresden-Grenzstraße" and walk about 400 m further along Grenzstraße

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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