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FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

ANNUAL REPORT 2014 2015

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FOREWORD

ANNUAL REPORT 2014/15

Dear partners and friends of IKTS,

It is a pleasure to present you our new annual report, again looking back on a very successful year. At our three sites, we reached an overall operating budget of over 54 million euros, thereby achieving very good external funds revenue of 76 %, which splits into respectively 50 % from industrial and public-sector revenue. This success was only possible by steadily and reliably collaboration with partners from research and especially industry, for which we would like to give our thanks. We would also like to thank the various ministries of the German federal government as well as the Free States of Saxony and Thuringia for their excellent support. Due to this support, we were able to further invest in our infrastructure and to further extend our core competencies. In the current year, we are focusing on the enhancement of "Additive Manufacturing" as technology platform and our "Bio- and Medical Technology" business division.

Completely new possibilities and perspectives emerge from the integration of the IKTS in Dresden-Klotzsche into the overall IKTS structure. By developing new test methods over the entire value-added chain of materials diagnostics up to in-line production monitoring, our core competencies and offers for industry are considerably extended. In doing so, we rely on a broad spectrum of new methods in the fields of optics (e.g. optical coherence tomography OCT), acoustics (e.g. high-frequency phased array ultrasonic analytics), electromagnetic methods (e.g. high-frequency eddy current) and X-ray methods (e.g. highly integrated X-ray line detectors). Substantial synergies arise from the areas electronics and microsystems technology through to the "smart materials". Due to the integration of the electronics and software competencies of the IKTS in Dresden-Klotzsche, we are able to complete our systems expertise. The "eneramic®" project funded by the Fraunhofer Future Foundation for the development of a fully integrated 100 W fuel cell system is a perfect example. By integrating in-house electronics and software solutions, the system costs were reduced by a factor of 2 resulting in the development of commercial prototypes. In order to link our three sites and to leverage the synergies, we adapted our divisions and fully integrated the IKTS in Dresden-Klotzsche into our organizational chart. As a result of this action, we also hope to master the still considerable business challenges at Dresden-Klotzsche more effectively.

Further highlights and development trends from our business divisions are comprised in this new annual report. I hope you enjoy browsing the articles and that numerous new project ideas arise from your reading, which we are happy to discuss with you at any time. As always, I offer you to make use of our excellent equipment and facilities, as well as our outstanding IKTS team. We are looking forward to cooperating with you.

Yours,

Alexander Michaelis

May 2015

Fraunhofer IKTS – "one stop shop" for ceramics

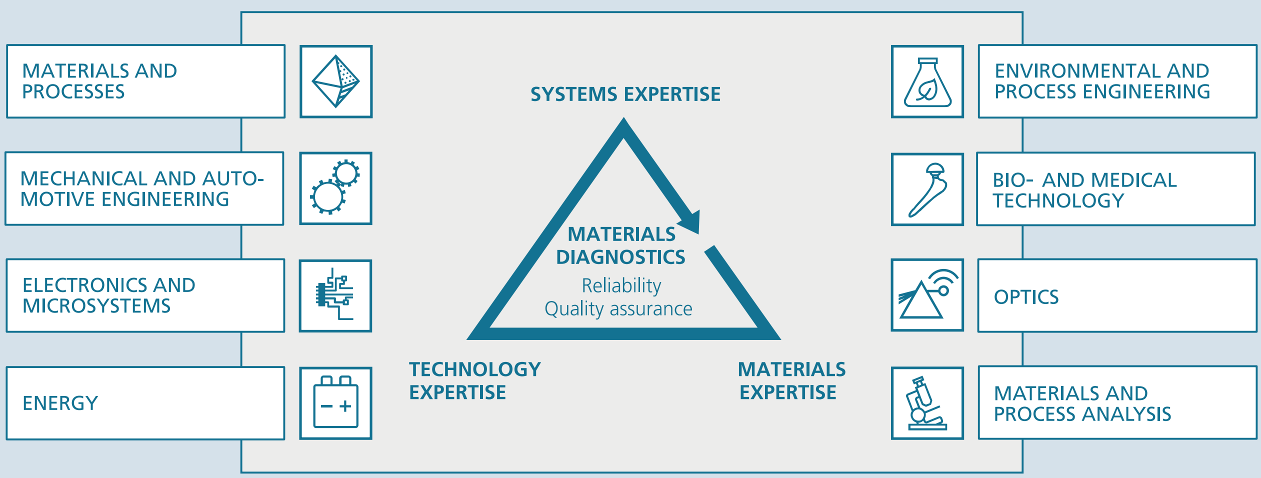
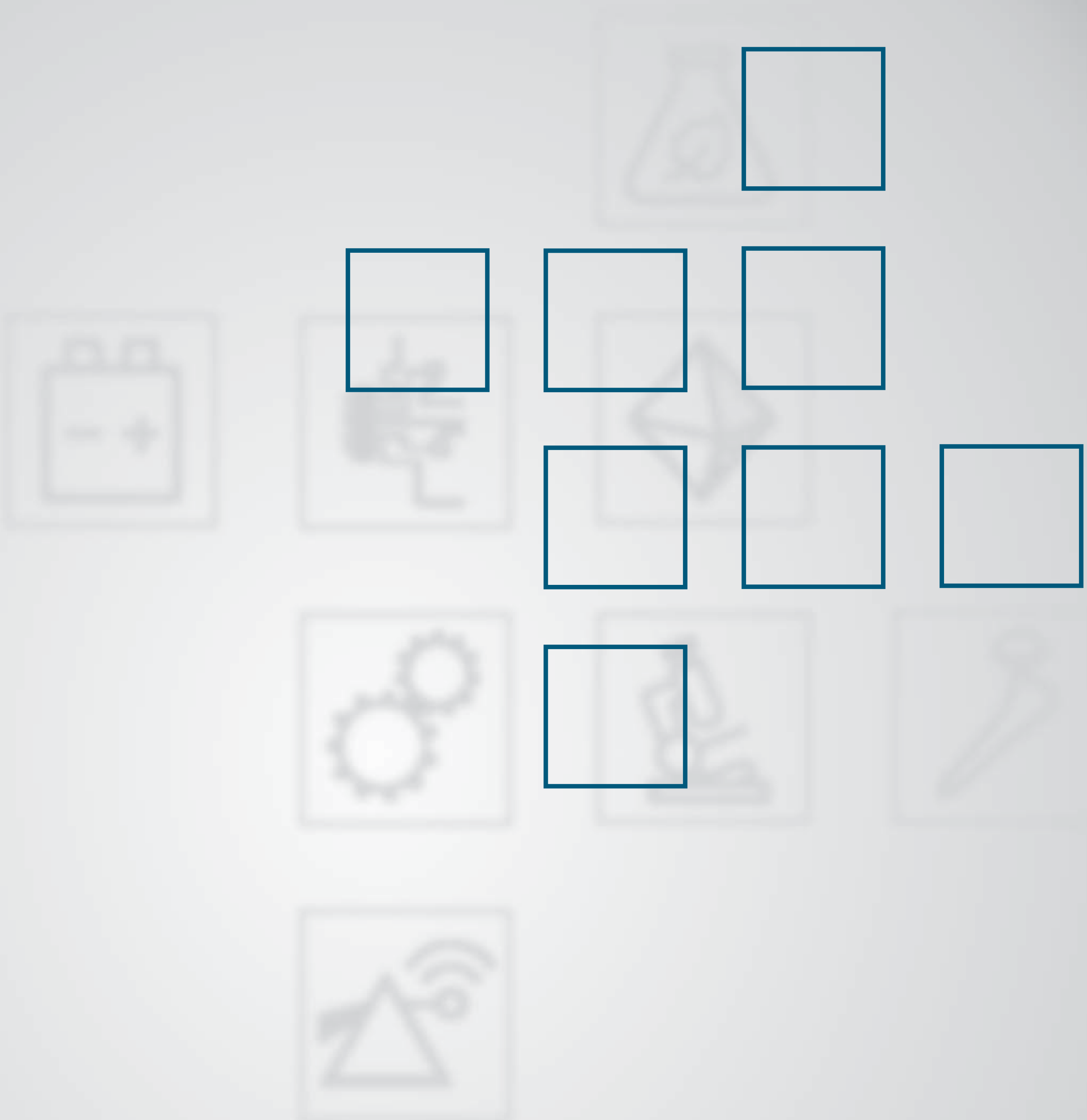


TABLE OF CONTENTS

ANNUAL REPORT 2014/15

FRAUNHOFER IKTS IN PROFILE



PORTRAIT

FRAUNHOFER IKTS IN PROFILE

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 m² of useable space have been set up for this purpose at the sites in Dresden and Hermsdorf.

Based on comprehensive materials expertise in advanced ceramic materials, the institute's development work covers the entire value creation chain, all the way to prototype production. Fraunhofer IKTS forms a triad of materials, technology and systems expertise, which is enhanced by the highest level of extensive materials diagnostics. Chemists, physicists, materials scientists and engineers work together on an interdisciplinary basis at IKTS. All tasks are supported by highly skilled technicians.

The focus is placed on manufacturers and especially existing and potential users of ceramics as project partners and customers. Fraunhofer IKTS operates in eight marketoriented divisions in order to demonstrate and qualify ceramic technologies and components for new industries, new product ideas, new markets outside the traditional areas of use. 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 into the technical standard. 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 markedly added value at low cost.

Competent analysis and quality assessment

High-performance analysis and quality control are a decisive factor 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 that specialize specifically 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 site 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 AND 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 ENGINEERING

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 AND PROCESS ANALYSIS, 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

Multilayers
- HTCC, LTCC

Aersosol and inkjet printing

Thin-film technology

Electrochemical machining

Galvanics

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

Catalysis

Biomass technology
- Preparation
- Conversion

Photocatalysis

Chemical process engineering

COMPONENTS AND 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

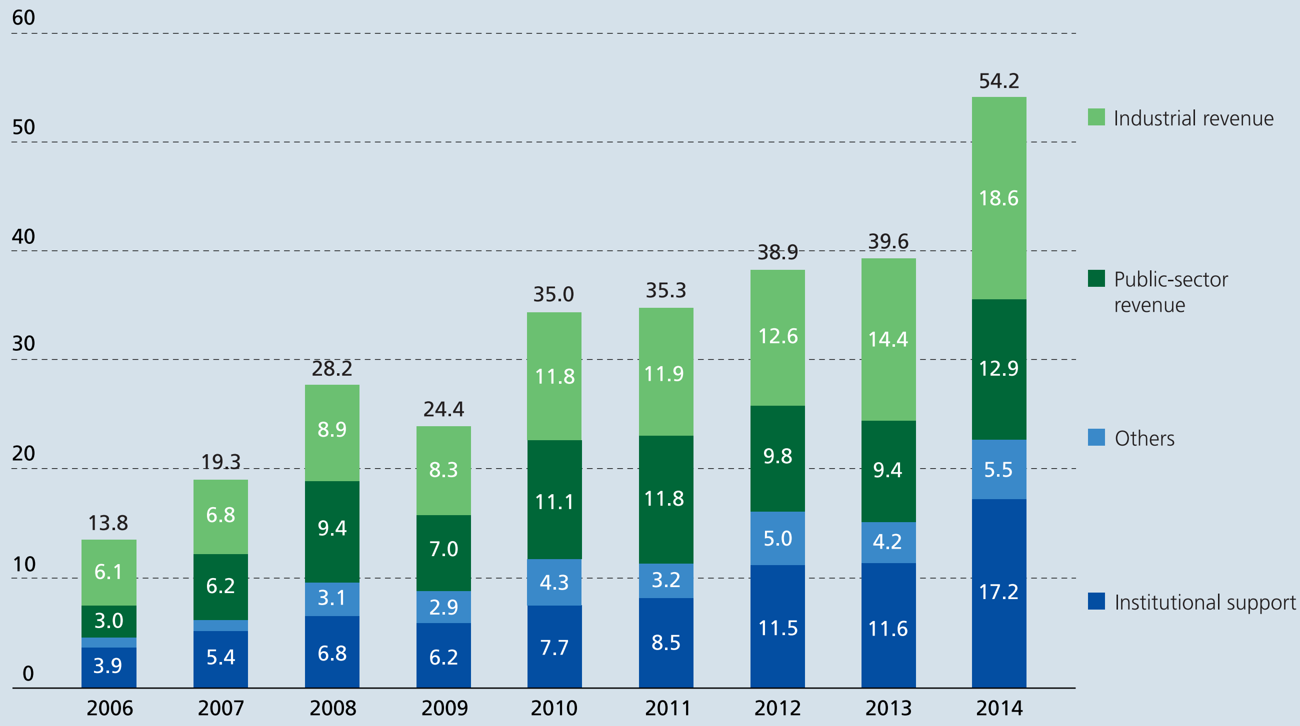
Technologies
- Micro- and nanoanalytics
- Ultrasonic testing
- High-frequency eddy current
- Optical methods
- X-ray methods

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

Revenue (in million euros) of Fraunhofer IKTS for the budget years 2006–2014



Operating budget and revenue

Due to both the organic growth of the cost centers and the integration of the former Fraunhofer IZfP Dresden, the overall operating budget of Fraunhofer IKTS has increased by 14.7 million euros to a total of 54.2 million euros.

The volume divides into 50.1 million euros for the operating budget itself and 4.1 million euros for investment budget. The largest sums are allocated to the IKTS on Winterbergstrasse with an operating budget of 26.3 million euros and an investment budget of 2.9 million euros. In the first joint budget year, the IKTS in Dresden-Klotzsche made a considerable contribution to the costs, overproportionally to its profit share, with 13 million euros operating budget and 1.1 million euros investment budget. Appropriate actions were initiated here. Regarding an independently considered, balanced budget, the IKTS in Hermsdorf contributed to the operating budget with 10.8 million euros and to the investment budget with 0.1 million euros. Further substantial resources for equipment in Hermsdorf were provided as part of the new research building and the battery pilot plant, which are not included here.

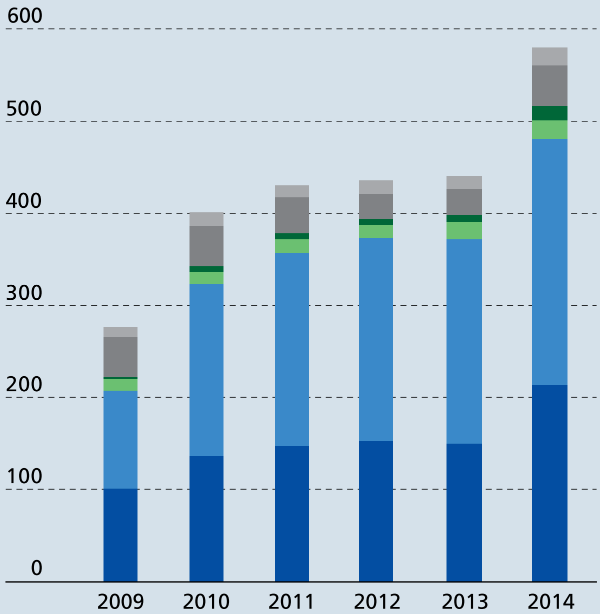
Staff development

The staff level reached a new maximum with 138 new full-time positions. Altogether 64 additional scientific employees strength-en the Fraunhofer IKTS team. Furthermore, 20 scientists currently work on the completion of their PhD theses. Hence, the amount of scientists achieved with 40 % the level, which existed before the integration of Hermsdorf. Another focus was placed on technical and administrative jobs with 19 apprentices.

Expansion of the research basis

The enhancement of the research field Materials Diagnostics due to the integration is a unique chance for ceramics research and the IKTS industry partners. The access to the system experts was prepared by integration projects. The year 2014 was represented by the premise of qualifying personnel and equipment. Further efforts are necessary here because the specific material properties cannot be sufficiently analyzed with the existing methods. New processes and their application fields as well as the testing automation in ceramic manufacturing were focal points of 2014 and are further enhanced in 2015 in the context of industry 4.0.

Personnel developments at Fraunhofer IKTS
Number of employees 2009–2014, full-time equivalents
Personnel structure on December 31 of each year



	9	15	13	16	14	19
	45	43	40	27	28	44
	2	6	6	5	8	16
	13	13	14	15	19	20
	106	187	211	221	223	267
	101	137	147	154	150	214
=	276	401	431	438	442	580

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

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

ORGANIZATIONAL CHART FRAUNHOFER IKTS

Institute Director	Prof. Dr. habil. Alexander Michaelis
Deputy Institute Director / Head of Administration	Dr. Michael Zins
Deputy Institute Director / Marketing and Strategy	Prof. Dr. Michael Stelter, Dr. Bärbel Voigtsberger
Deputy Institute Director	Dr. Ingolf Voigt
Deputy Institute Director	Dr. Christian Wunderlich

Materials

Nonoxide Ceramics
Dipl.-Krist. Jörg Adler
Nitride Ceramics and Structural Ceramics with Electrical Function
Carbide Ceramics and Filter Ceramics

Oxide Ceramics
Dr. Isabel Kinski
Materials Synthesis and Development
Pilot Manufacturing of High-Purity Ceramics
Oxide and Polymerceramic Composites

Processes and Components
Dr. Hagen Klemm
Powder Technology
Shaping
Component Development
Finishing
Process Technology and Silicate Ceramics

Sintering and Characterization / Non-Destructive Testing

Dr. habil. Mathias Herrmann
Thermal Analysis and Thermal Physics*
Heat Treatment
Ceramography and Phase Analysis

Environmental and Process Engineering

Nanoporous Membranes
Dr. Hannes Richter
Zeolite Membranes and Nano-Composites
Carbon-Based Membranes
Membrane Prototypes

High-Temperature Separation and Catalysis
Dr. Ralf Kriegel
High-Temperature Membranes and Storages
High-Temperature Separation
Catalysis and Materials Synthesis

Biomass Technologies and Membrane Process Engineering
Dr. Burkhardt Faßauer
Biomass Conversion and Water Technology
Mixing Processes and Reactor Optimization
Membrane Process Technology and Modeling
Technical Electrolysis and Geothermal Energy

Chemical Engineering and Electrochemistry
Dr. Matthias Jahn
Modeling and Simulation
Process Systems Engineering
Electrochemistry

Technische Universität Dresden

ifWW – Inorganic-Nonmetallic Materials	Prof. Dr. habil. Alexander Michaelis
IAVT – Electronic Packaging Laboratory	Prof. Dr. habil. Norbert Meyendorf
DCN – Dresden Center for Nanoanalysis	Prof. Dr. habil. Ehrenfried Zschech

Friedrich-Schiller University Jena

Technical Environmental Chemistry	Prof. Dr. Michael Stelter

Powder and Suspension Characterization*
Quality Assurance Laboratory*, Mechanics Laboratory
Chemical and Structural Analysis
Hard Metals and Cermets
Accredited Test Lab*

* accredited according to DIN EN ISO/IEC 17025

Electronics and Microsystems Engineering

Smart Materials and Systems
Dr.-Ing. Holger Neubert
Multifunctional Materials and Components
Appl. Material Mechanics & Solid-State Transducers
Systems for Condition Monitoring

Hybrid Microsystems
Dr. Uwe Partsch
Thick-Film Technology and Photovoltaics
Microsystems, LTCC and HTCC
Functional Materials for Hybrid Microsystems
Systems Integration and Electronic Packaging
Technical Center Renewable Energy HOT
Ceramic Tapes

Testing of Electronics and Optical Methods
Dr. Mike Röllig
Optical Test Methods and Nanosensors
Speckle-Based Methods
Reliability of Microsystems

Systems for Testing and Analysis
Jun.-Prof. Henning Heuer
Electronics for Testing Systems
Software for Testing Systems
Eddy Current Methods
Ultrasonic Sensors and Methods

Microelectronic Materials and Nanoanalysis
Prof. Dr. habil. Ehrenfried Zschech
Micro- and Nanoanalysis
Materials and Reliability for Microelectronics

Project Group Berlin
Prof. Dr. habil. Norbert Meyendorf

Energy Systems / Bio- and Medical Technology

Materials and Components
Dr. Mihails Kusnezoff
Joining Technology
High-Temperature Membranes and Storage Materials
Ceramic Energy Converters
Materials MCFC

System Integration and Technology Transfer
Dr. Roland Weidl
System Concepts
Validation
Mobile Energy Storage Systems
Stationary Energy Storage Systems
Thin-Film Technologies

Bio- and Nanotechnology
Dr. Jörg Opitz
Bio- and Nanosensors
Acoustical Diagnostics
Optical Coherence Tomography
Bio-Nanotechnology Application Lab

BOARD OF TRUSTEES

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

THE FRAUNHOFER-GESELLSCHAFT

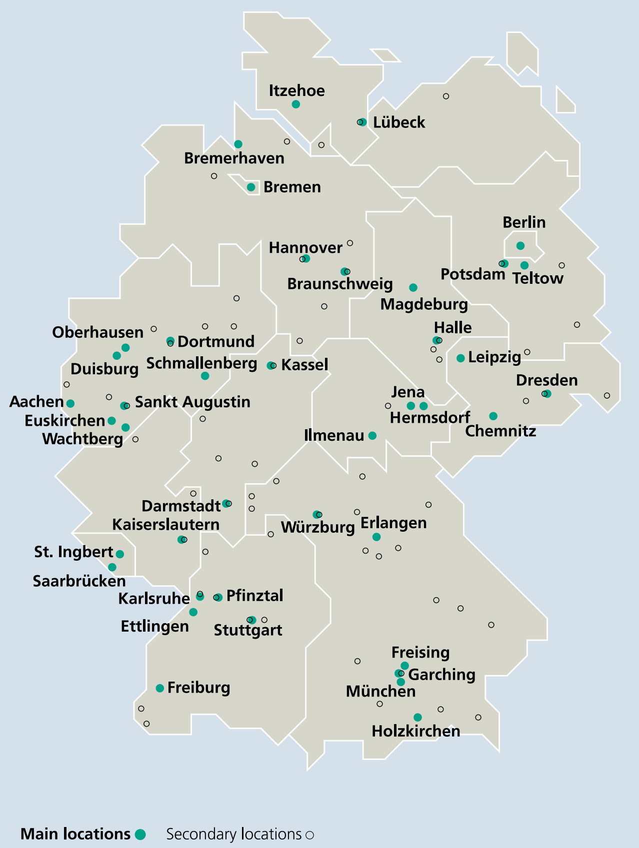
Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual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

At present, the Fraunhofer-Gesellschaft maintains 66 institutes and research units. The majority of the more than 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 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

RETROSPECTIVE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March 22, 2014
International World Water Day – exhibition and join-in experiments at Schloss Wackerbarth

Water is life. It is the essential element of the human being. On March 22 and 23, 2014, everything revolved around the topic "water and energy" at Schloss Wackerbarth. Alongside numerous research institutions, Fraunhofer IKTS presented exhibits, lectures and experiments, and thus answered current questions of the visitors in a practical way.

Even small visitors found entertainment, for example in the Aqualino creative workshop or in a flood protection vehicle of the fire department. The accompanying water photography exhibition by Dr. Gabriele Neugebauer showed water in its finest form.

March 28, 2014
Visit of South Korean President Park Geun-hye at Fraunhofer IKTS

As part of her official state visit, the president of the Republic of Korea, Park Geun-hye, was a guest at the IKTS in Dresden. The Fraunhofer President Professor Reimund Neugebauer and Professor Alexander Michaelis, Institute Director of Fraunhofer IKTS, met the distinguished guest for a brief exchange and guided the president through the IKTS. Park Geun-hye was accompanied by a delegation from politics, economy and science as well as representatives of the Korean press. On the German side, Saxon Prime Minister Stanislaw Tillich as well as the former Saxon Minister of Science Professor Sabine Freifrau von Schorlemer and the First Mayor of Dresden Dirk Hilbert attended the meeting, among others.

Subject of the meeting was the improvement of the scope for cooperation. For this purpose, the presidents of Fraunhofer and the South Korean research institute ETRI signed a Memorandum of Understanding regarding the cooperation. ETRI is considered to be the best public research institute for information and communication technology in South Korea and was listed 1st place by the patent board of the USA in 2011. The talks with the South Korean president also served the purpose of fixing the meaning of this cooperation on the highest level in order to prospectively raise funds more easily.

March 31, 2014
Aerospace workshop in São Paulo

The non-destructive testing as key element of aerospace was topic of the symposium called "NDT in aviation". More than 30 participants from economy and research assembled at the Centro de Convenções ABIMAQ in order to discuss current developments and future challenges. With this event, Fraunhofer IKTS contributed to the "German Year" in Brazil 2013/2014, which is an initiative of the Federal Foreign Office aiming at the intensification of the strategic relationship between the two countries.

April 24, 2014
Fraunhofer IKTS and Mayur REnergy Solutions Inc. (MRE) sign a Memorandum of Understanding and announce a joint venture

With the establishment of a joint venture for the development and distribution of cost-effective fuel cell devices, efficient and environmentally friendly systems are provided in the future, with which the tense power situation in India and other developing countries can be solved sustainably. The agreement to

1 Korean President Park Geun-hye visiting Fraunhofer IKTS, f.l.t.r. President Park Geun-hye, Prof. Alexander Michaelis, Prof. Reimund Neugebauer, Prof. Sabine Freifrau von Schorlemer, Saxon Prime Minister Stanislaw Tillich.
2 Tour in the IKTS showroom during the Korean state visit.
3 Exhibition opening at Schloss Wackerbarth on the occasion of the World Water Day.

1

2

establish this promising joint venture was made as part of a business trip of the former Thuringian Minister of Economy, Labour and Technology Uwe Höhn.

May 7, 2014

Inauguration of the new IKTS research building in Hermsdorf

Two years after the corner stone ceremony, the new three-storey research building of Fraunhofer IKTS in Hermsdorf, was ceremoniously inaugurated in the presence of the former Thuringian Minister of Science Christoph Matschie as well as 150 participants from politics, economy and research. The created capacities allow for an expansion of the industry-relevant research in the area of environmental technologies and promise the development of new applications for high-performance ceramics. The strategic research focuses on the leading markets of recycling and sustainable water management, raw materials efficiency, as well as environmentally friendly energies and energy storage.

With the construction of new laboratory, office and technology facilities on 2,775 m², Fraunhofer IKTS further extends the procedural bases through to upscaling. From here, the institute contributes nationally and internationally to the promotion, development and expansion of energy- and environmentally friendly solutions.

For the construction and new scientific equipment, the European Union provided 13.5 million euros out of the "Operationelles Programm Thüringen 2007–2013". Further 4.5 million euros are funds of the Free State of Thuringia and the German Federal Ministry of Education and Research (BMBF) in equal shares. For the local industrial network, the new developments of Fraunhofer IKTS play an important role.

May 20–21, 2014

Workshop "Additive manufacturing of ceramic materials"

Additive Manufacturing is an industrially established process for plastics and metals. For ceramics, additive manufacturing methods become more important as well.

The workshop "Additive Manufacturing of Ceramics", which was organized in the name of the Fraunhofer Additive Manufacturing Alliance, presented current research activities and promising applications of different additive manufacturing methods for ceramic materials. Nearly 80 participants from industry and research made this event very successful.

In the Fraunhofer Additive Manufacturing Alliance, eleven Fraunhofer institutes joined their forces to enhance the development and application of additive manufacturing methods. Together, they represent the entire technology chain and materials diversity of additive manufacturing.

June 5–6, 2014

Industry day "Electrically conducting ceramics"

The high economic viability and efficiency of electrical heating elements, ceramic sensors or electrodes generate competitive advantages in plant and mechanical engineering, energy generation, chemical technologies, and environmental and process engineering.

The industry day "Ceramic materials for electrical applications" was concerned with current developments of Fraunhofer IKTS in the areas of ceramic conductors, component manufacturing and processing of electrically conducting ceramics as well as the simulation of the operating behavior of ceramic components. 50 participants from industry and research accepted the invitation. The successful event was topped off with an accompanying industrial exhibition regarding commercially available ceramic products for electrical applications.

July 4, 2014

Researchers' Night

For the 12th time already, the network "Dresden – Science City" organized the Researchers' Night. On the premises of the Fraunhofer Institute Center, about 1,500 visitors informed themselves about current research highlights and took part in exciting experiments and presentations regarding issues, such as energy, environment, health, nanotechnology and specialized materials, in the four Fraunhofer institutes.

At Fraunhofer IKTS, novel product developments and experiments of all three sites were presented this time. Children and research-interested adolescents, for example, visualized their fingerprints electrochemically and were able to listen to chewing grain weevils with highly sensitive measurement technology. A glassy sewage plant demonstrated the treatment of waste waters via microorganisms. Furthermore, the visitors could inform themselves about the functional principle of ceramic injection molding and learned how energy is produced from straw.

August 8, 2014

Federal Minister of Economy Sigmar Gabriel visits CEEC in Jena

"Energy research is an important strategic key for the Energy Transition. This applies in particular to system-oriented research projects, such as the development of new storage technologies", says Federal Minister of Economy Sigmar Gabriel in the context of a visit at the Center for Energy and Environmental Chemistry CEEC in Jena. Sodium nickel chloride batteries are perfectly suitable for stationary energy storage from an economical and ecological point of view. A core component of this battery is a ceramic electrolyte made of ß-alumina, which is developed at Fraunhofer IKTS with special regard to materials selection, manufacturing methods and quality assurance.

September 2014

Foundation of Bio-Nanotechnology Application Lab

Supported by the Free State of Saxony, Fraunhofer IZI and Fraunhofer IKTS founded a joint application lab regarding the research in the area of bio- and nanotechnology in Leipzig.

With its Dresden-Klotzsche site, Fraunhofer IKTS possesses extensive know-how in the areas of applied microelectronics, sensor systems, nanoanalytics and materials characterization. This know-how is combined with the biological competencies of Fraunhofer IZI in Leipzig, particularly in the fields of cellular and molecular biology. The cooperation is aimed at developing innovative, minimally invasive analysis technology and sensor concepts as well as optimizing the process and quality control in biotechnology.

1 *Signing of a term sheet with Mayur REnergy Solutions Inc. (MRE) in Pune, India, for the foundation of a joint CFY stack company. f.l.t.r. Uwe Höhn, former Thuringian Minister of Economy, Labour and Technology, Siddharth R. Mayur, Mayur REnergy Solutions Inc. (MRE), Prof. Alexander Michaelis, Fraunhofer IKTS, Dr. Narendra Jadhav, Member of Planning Commission of National Advisory Council India.*

2 *Inauguration of new Fraunhofer research building in Hermsdorf.*

3 *Researchers' Night at Fraunhofer IKTS.*

4 *Federal Minister of Economy Sigmar Gabriel at the IKTS booth while visiting the CEEC in Jena.*

RETROSPECTIVE

November 11, 2014
OptoNet cluster meeting at Hermsdorf

The IKTS in Hermsdorf, as a young member of the Photonics Network Thuringia OptoNet, invited to a cluster meeting for the first time.

This productive meeting aimed at promoting the professional exchange between the cluster members, informing about the competencies and novel research results of Fraunhofer IKTS as well as generating prospective synergy effects.

Accompanying the lecture progam, a tour through the laboratories and pilot plants offered insights into the practical research of Fraunhofer IKTS in greater depth to the approximately 50 participants.

December 4–5, 2014
Symposium "Electrochemical methods in battery research. Well done. But accurately interpreted?"

This year, the conference series, established in 2005, focused on electrochemical and complementary analytical methods for materials applied in energy storage systems. Thus, the symposium established a connection between basic and application-oriented research regarding the understanding of mechanisms und materials behavior of electrochemical storage systems.

The accompanying industrial exhibition offered device manufacturers an efficient contact platform and opportunity to learn about the latest developments.

About 80 participants from industry and research accepted the invitation of Fraunhofer IKTS and made the event very successful.

January 15, 2015
Ceramics Vision

For the 9th time, Fraunhofer IKTS invited to the symposium series "Ceramics Vision". In the high-quality program with invited lectures from industry and science, new developments and innovation in the field of high-performance ceramics were presented. This time, structural and functional ceramic materials development particularly in the areas of oxide ceramics and smart materials was focused. Since the institute's foundation, these research fields have been core competencies of Fraunhofer IKTS and were shaped by Dr. Andreas Krell und Dr. Andreas Schönecker, who both will retire in 2015. As part of the symposium, both department heads talked about prospective challenges and visions regarding their traditional fields of activity.

January 20, 2015
CIO campus with the topic "Water and materials"

For the first time, Fraunhofer IKTS in Hermsdorf organized the CIO campus regarding the topic "Water and materials", in collaboration with the Cleantech Initiative Ostdeutschland (CIO).

More than 100 participants from politics, economy and research gained an insight into novel approaches for the closure of resource cycles, practical experiences from a business' perspective and possibilities for supporting resource-efficient technologies in their own companies.

Furthermore, representatives of the Federal Ministry of Economy, the Thuringian Ministry of Economy, Science and the Digital Society as well as the Federal Environment Agency showed current political framework conditions and chances for companies in the cleantech sector.

Awards

Coating experts awarded with "Betonwerksteinpreis" in the category innovation

As part of the international ashlar days 2014, the German Federal Working Group Artificial Stone, Finished Parts, Terrazzo and Natural Stone BF BFTN awarded a prize to Dr. Thomas Hoyer and Anett Heyer, Fraunhofer IKTS, for their extraordinary engagement and their revolutionizing results in the German artificial stone sector.

Advanced surface treatment for artificial stone and natural stone was developed, with which properties like solidification, stain resistance, non-slip safety and splendor of the rock can be achieved in simultaniously in contrast to conventional coatings. These coatings are based on novel nanocomposite technology.

Fraunhofer Medal for Dr. Andreas Schönecker

Within the frame of the 9th "Ceramics Vision", Dr. Andreas Schönecker was honored with the coveted Fraunhofer Medal. This award is given to individuals who rendered outstanding services to the Fraunhofer-Gesellschaft.

For 40 years, Dr. Andreas Schönecker has worked as a physicist with PhD in the field of applied materials research. Under his guidance, the department "Functional Ceramics" of the former Central Institute for Solid Body Physics and Materials Research of the GDR Academy of Science developed into one of the main pillars of Fraunhofer IKTS. Central research fields of his scientific specialty are the synthesis, technology and component development as well as the functional verification of multifunctional materials on the basis of dielectric, ferroelectric and piezoelectric high-performance ceramics. The application spectrum of these materials is diverse and was processed in numerous R&D projects from industrial and public principals. Focal research points of the last years include developments regarding multilayer capacitors, filters, sensors, actuators, ultrasonic transducers and generators.

First worldwide energy efficiency award for scientist of Fraunhofer IKTS

On September 30, 2014, the "Cool Award" was assigned for the first time in the context of the Cool Silicon Day 2014. With this award, the top cluster Cool Silicon honors outstanding solutions for energy-efficient information and communication technologies. Altogether seven individual projects were awarded with this prize in three categories.

In the category "Scientific work", the prize was awarded to Uwe Lieske, André Dietrich, Dr. Lars Schubert and Bernd Frankenstein of Fraunhofer IKTS for their contribution "Wireless System for Structural Health Monitoring Based on Lamb Waves", which was developed within the project CoolSensorNet. The IKTS scientists Bernd Frankenstein and Dr. Andreas Schönecker belong to the award winners in the category "Energy-efficient solutions". They were honored for their contribution "Structure monitoring with wireless sensors" made in the project CoolMaintenance.

The award is assigned to realized projects in the Cool Silicon research association, which have made a globally unique contribution to the resource-conserving efficiency increase of information and communication technologies (ICT).

1 Glimpse of the lecture room during the symposium "Electrochemical methods in battery research. Well done. But accurately interpreted?".
2 Dr. Andreas Krell in discussion with participants of the "Ceramics Vision".
3 Dr. Andreas Schönecker received the Fraunhofer Medal by Prof. Alexander Michaelis during the "Ceramics Vision".
4 Uwe Lieske (l.) is one of the IKTS award winners of the Cool Awards 2014 in the category "Scientific work".

SCIENCE MEETS MARKET – TRADE FAIR REVIEW 2014

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The institute showed its broad topic and application spectrum with numerous technology and product-news at many national and international trade fairs and exhibitions. The expansion of the research portfolio with competencies from materials diagnostics and testing extended the presence of IKTS.

Selected highlights

As an animalistic symbol for highest flexibility, the "Pastemäleon" found its way into the exhibition under the motto "Customized functional films" at the beginning of the year. On the occasion of the institute's 5th appearance at the International Nanotechnology Exhibition and Conference in Tokyo, a modern REACH- and RoHS-compliant paste portfolio, which can be individually customized, was presented to partners for the first time. In the simultaneously offered and well-attended seminar, the focus was placed on thick-film pastes for the application on silicon – an excellent substrate material in the manufacturing of prospective power electronics. These activities were promoted by the Fraunhofer Representative Office in Tokyo as experienced mediator between German research and Japanese market.

In February, the FC Expo, also in Tokyo, attracted likewise numerous international visitors. The first-time demonstration of the fuel cell system eneramic® ranked as the highlight of the appearance. In the course of the year, prospective customers throughout Germany but also in Korea and Brazil had the opportunity to learn about Fraunhofer IKTS and development results regarding mobile, off-grid and reliable power supply.

At the globally significant industrial gathering Hannover Messe International (HMI) in April, the IKTS demonstrated novel solution concepts for the fields energy and environmental engineering as well as mechanical and plant engineering. The ceramic high-temperature battery cerenergy®, presented for the first time in Hall 27, showed how a cost-efficient stationary energy supply is secured in the future. Furthermore, our scientists showcased the application of the eneramic® fuel cell system as energy source for traffic control systems. During the trade fair, a set of traffic lights was fed by the system, which guided the visitors luminously to the IKTS booth from far away. Another premiere in the area of ceramic shaping technologies approached prospective customers from the chemical industry and instrumental analytics at the structural ceramics area in Hall 6. The novel process of glass powder injection molding allows for a new variety of forms for glass components.

The International Trade Fair for Life Science Process Technologies Technopharm as well as the Trade Fair for Processing, Analysis, and Handling of Powder and Bulk Solids Powtech took place simultaneously at the end of September in Nuremberg, where the IKTS experts introduced innovative solutions for the areas process control and quality assurance, as well as modern methods and developments in the fields of powder technology and mechanical process engineering. For the efficient processing of granulates and powdery particles in industrial products, an infrastructure for the simulation of air-granulate flows in characterized materials, developed in collaboration with Fraunhofer ITWM, was presented. Great attention was attracted by the novel product labeling process, which enables the reliable sterilization control of product and packaging surfaces via electron radiation by using powdery ceramic materials.

The newest generation of an optical cancer diagnosis device was introduced at the leading trade fair for the medical supplier industry and product development CompaMed in November in Düsseldorf. The prototype for cell diagnostics was

1 *Lutz Kiesel explains the ceramic membranes developed in Hermsdorf at HMI.*
2 *Dr. Nataliia Beshchasna in an interview at the CompaMed in Düsseldorf regaring the optical cancer diagnosis device.*
3 *By means of visualized operating data, Thomas Pfeifer describes the mobile electricity generation via the eneramic® system.*


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developed at the IKTS in Dresden-Klotzsche and allows physicians to directly and automatically evaluate the obtained biopsies of the patient with the help of the autofluorescence of human tissue and a threshold algorithm, specifically created for the respective tissue region, within minutes. The presentation received wide international press coverage.

Overview

nano tech
13th International Nanotechnology Exhibition and Conference
Tokyo, January 29–31, 2014
IKTS booth at German pavilion

Battery Japan
5th International Rechargeable Battery Expo
Tokyo, February 26–28, 2014
Joint booth Fraunhofer Battery Alliance

Fuel Cell Expo
10th International Hydrogen and Fuel Cell Expo
Tokyo, February 26–28, 2014
IKTS booth at German pavilion

Intertraffic
International trade fair for infrastructure, traffic management safety and parking
Amsterdam, March 25–28, 2014
Joint booth FABEMA

Printed Electronics
Berlin, April 1–2, 2014

International Green Energy Expo
Daegu, April 2–4, 2014

Hannover Messe
Hannover, April 7–11, 2014
IKTS booth (Hall 6)
IKTS booth (Hall 27)
Joint booth Fraunhofer Adaptronics Alliance (Hall 2)
Joint booth LEG Thuringia (Hall 4)
Joint booth Fraunhofer Energy Alliance (Hall 13)
Joint booth Energy Saxony (Hall 27)

IFAT
Trade Fair for Water, Sewage, Waste and Raw Materials Management
Munich, May 5–9, 2014
Joint booth Fraunhofer Water Systems Alliance

RapidTech
Trade Fair and User's Conference for Rapid Technology
Erfurt, May 14–15, 2014
Joint booth Fraunhofer Additive Manufacturing Alliance

Optatec
International trade fair for optical technologies, components and systems
Frankfurt, May 20–22, 2014
Joint Fraunhofer booth

ILA Berlin Air Show
International Aerospace Exhibition
Berlin, May 20–25, 2014
Joint booth Fraunhofer Innovation Cluster LCE
Joint booth Saxony Economic Development Corporation

Innovationstag Mittelstand
Berlin, May 22, 2014

Sensor + Test
21st International Measurement Fair
Nuremberg, June 3–5, 2014
Joint booth "Forschung für die Zukunft"

Actuator
14th International Conference on New Actuators
8th International Exhibition on Smart Actuators and Drive Systems
Bremen, June 23–25, 2014
Joint booth Fraunhofer Adaptronics Alliance

CFK-Valley Stade Convention
Stade, June 24–25, 2014
Joint booth with Fraunhofer IFAM

European SOFC Forum
Lucerne, July 1–4, 2014
Joint booth Energy Saxony

Green Energy and Biogas Brazil
São Paulo, July 16–18, 2014

Euro PM
European Powder Metallurgy Congress and Exhibition
Salzburg, September 21–24, 2014

WindEnergy Hamburg
Hamburg, September 23–26, 2014
Joint booth Wind Energy Network

Powtech
Trade Fair for Processing, Analysis, and Handling of Powder and Bulk Solids
Nuremberg, September 30–October 2, 2014

TechnoPharm
International Trade Fair for Life Science Process Technologies
Nuremberg, September 30–October 2, 2014

World of Energy Solutions
Stuttgart, October 6–8, 2014
Joint booth Energy Saxony

Composites
9th European Trade Fair & Forum for Composites, Technology and Applications
Düsseldorf, October 7–9, 2014
Joint Fraunhofer booth

Semicon Europe
Trade fair for the European Semiconductor Industry
Grenoble, October 7–9, 2014
Joint booth Fraunhofer Group for Microelectronics

CellMAT
3rd Conference for Cellular Materials
Dresden, October 22–24, 2014

ASNT Fall Conference
Charleston, October 27–30, 2014
Joint booth Quality Network

12th FAD Conference and Exhibition
Dresden, November 5–6, 2014

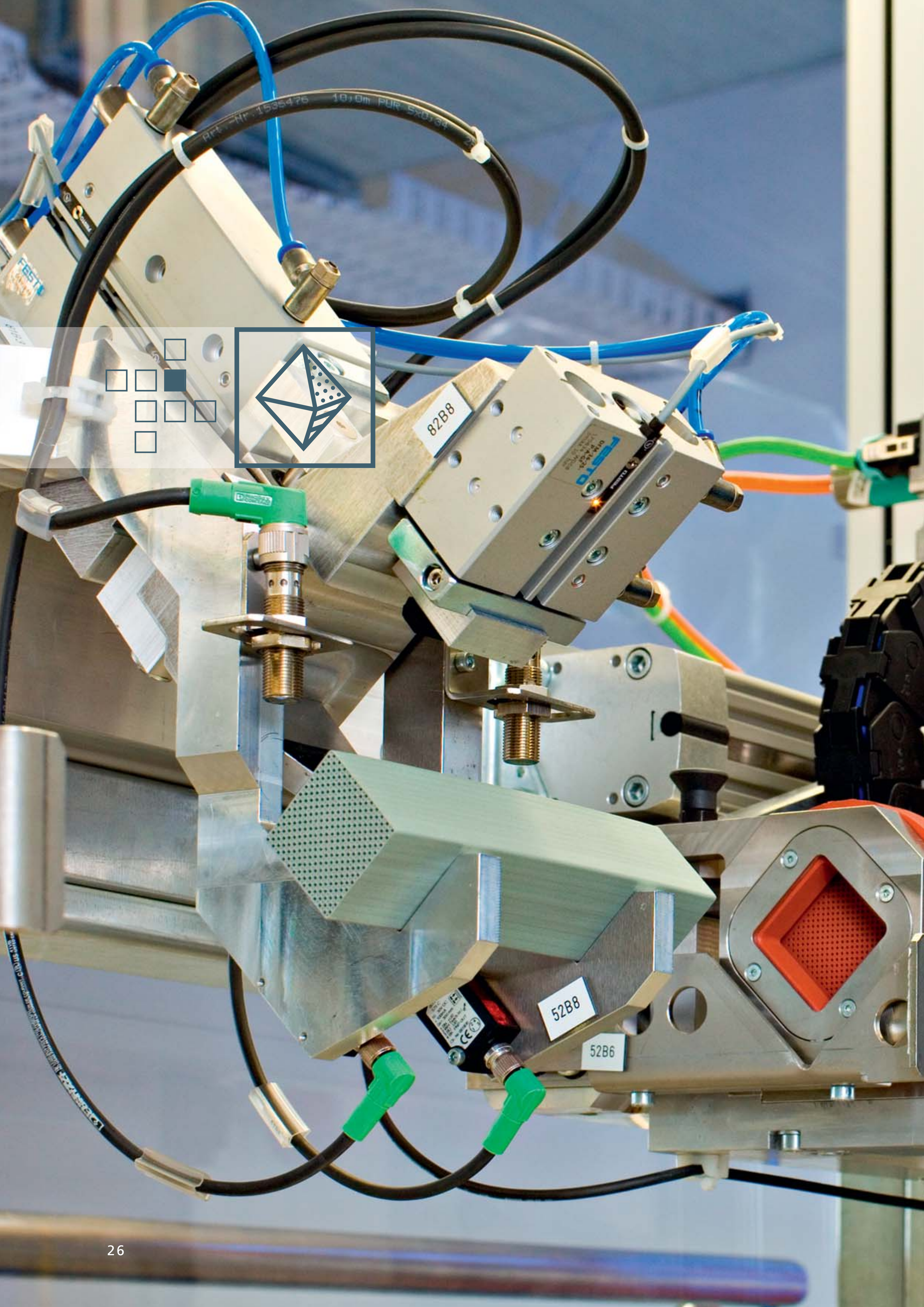
electronica
26th International Trade Fair for Electronic Components, Systems and Applications
Munich, November 11–14, 2014
Joint Fraunhofer booth

CompaMed
Trade fair for the medical supplier industry and product development
Düsseldorf, November 12–15, 2014
Joint Fraunhofer booth

Hagener Symposium
Conference and Exhibition for Powder Metallurgy
Hagen, November 27–28, 2014

EuroMold
World Fair for Mold- and Patternmaking, Tooling, Design, Additive Manufacturing and Product Development
Frankfurt am Main, November 25–28, 2014
Joint booth Fraunhofer Additive Manufacturing Alliance

1 *Martin Grund explains the functionality of the ceramic high-temperature battery cerenergy® at HMI.*
2 *IKTS booth at Powtech: great visitor interest in Nuremberg.*
3 *Dr. Markus Eberstein, Miho Sakai from the Fraunhofer Representative Office Japan and Dr. Nikolai Trofimenko at nano tech in Tokyo.*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BUSINESS DIVISION

MATERIALS AND PROCESSES

Project reports

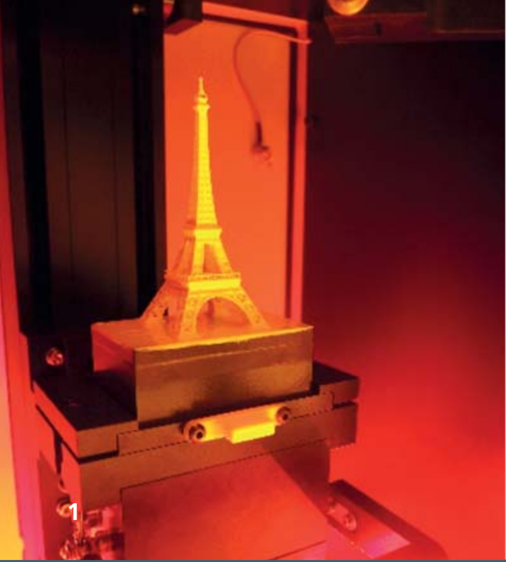
Fraunhofer IKTS's "Materials and Processes" business division offers oxide, non-oxide and silicate materials as well as composite materials, glasses, hard metals and cermets. Depending on commercially available raw materials and pre-ceramic preliminary stages, these materials are qualified for use in actual applications. They are the prerequisites to manufacturing prototypes and small-scale series (with ceramics custom-fit to the application), which are based on sustainable process developments.

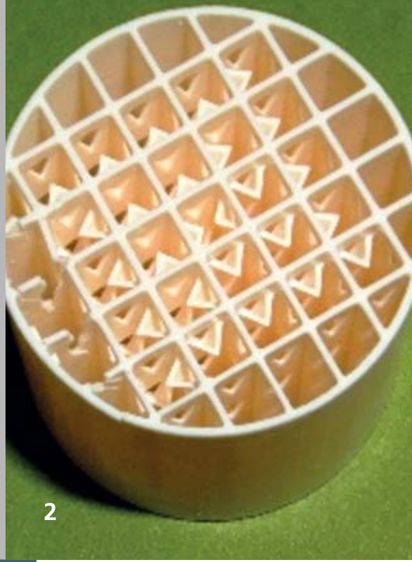
New fields of application are unlocked by systematically linking structural features with the functional properties of ceramic materials and ceramic-metal composites. Concepts like these can be found in temperature-resistant materials, conductive ceramics, luminescent materials, transparent ceramics, polycrystalline abrasives and functional coatings, among other materials.

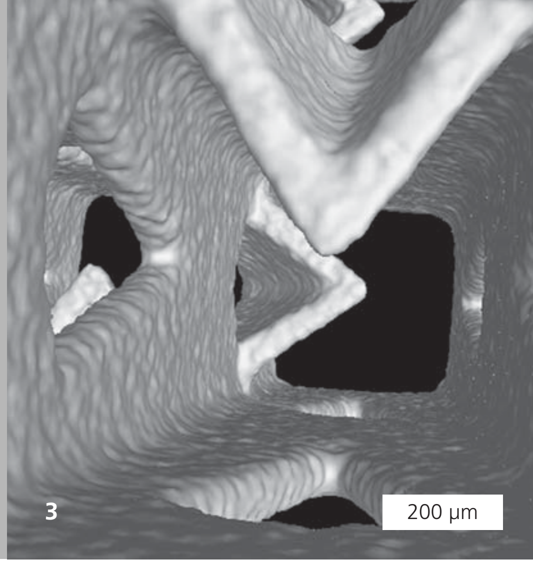
Fraunhofer IKTS sets the standard and continuously optimizes its powder technological manufacturing processes to keep them on the cutting edge in every respect – from the utmost purity to the maximum cost efficiency. This enables IKTS to establish the basis for materials and process engineering that parallels today's industries. It produces components and parts in multiple lines of technology. It is possible to upscale these products to small- and medium-scale series in-house on equipment and machinery suited for industry.

This broad spectrum of shaping services ranges from pressing, casting and plastic molding to additive manufacturing as well as multilayer technologies and direct printing processes. A large quantity of heat treatment methods, as well as the high-performance green machining and finishing, reflects the comprehensive range of expertise and services covered by the Fraunhofer IKTS portfolio. With its expertise in coating processes – including chemical vapor deposition for example, or thermal spraying, surface level properties can be modified and components customized to individual specifications. Here as well, our customers benefit from the closed technology chains, which make it possible for IKTS to take a laboratory development to pilot-plant scale.

IKTS employees additionally possess the expertise honed by decades of experience in production-tailored and customer-specific component design, and in characterizing material and production processes. This also includes failure and defect analyses of parts and components, and consulting services on how to utilize ceramic components. In addition, the scope of services also includes creating production concepts and evaluating production processes while considering cost, quality assurance and energy efficiency. When introducing innovative technologies and realizing new products, Fraunhofer IKTS can support its partners until the transition to production is launched.







ADDITIVE MANUFACTURING OF CERAMIC COMPONENTS

Dr. Tassilo Moritz, Dr. Uwe Partsch, Dr. Steffen Ziesche, Dipl.-Ing. Uwe Scheithauer,
M. Sc. Matthias Ahlhelm, Dipl.-Ing. Eric Schwarzer, Dr. Hans-Jürgen Richter

In the field of polymers and metals, additive manufacturing methods are already established and used for manifold applications. For ceramic materials, additive manufacturing, i.e. layer-wise assembling of components from CAD data, is gaining more and more importance, especially as resource-efficient manufacturing method. Nevertheless, additive manufacturing methods for ceramics are right at the beginning of technological development. The present design of ceramic parts is limited by the opportunities of the conventional shaping techniques so far. In contrast, additive manufacturing offers the possibility to produce components of extremely complex geometries, which cannot be obtained by conventional shaping routes. A main advantage of additive manufacturing techniques can be seen in the tool-free shaping methodology. This means that either single components or small series of parts can be produced efficiently without high tooling expenses. Beside the geometrical variety, components with a high position-resoluted property profile can also be manufactured by changing the material composition at each freely chosen point of the component. This will provide novel functionalized and individualized ceramic components as single parts or small series for many technical and medical applications in the near future.

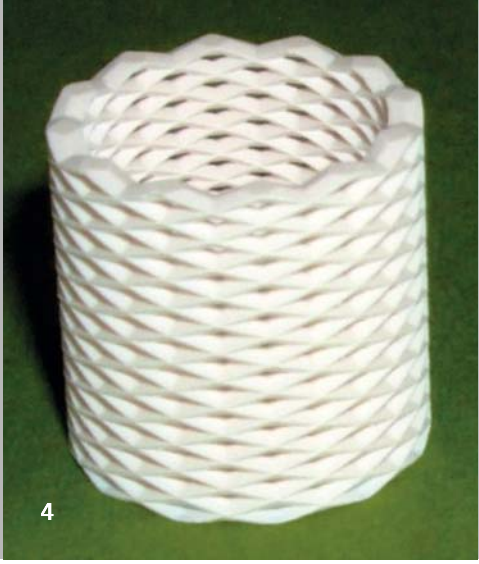
Suspension-based additive methods

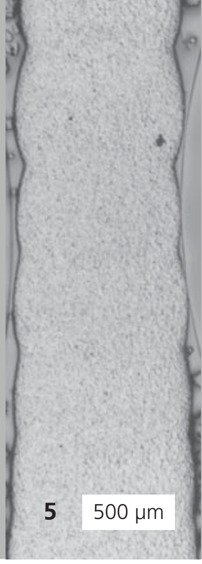
For producing dense materials structures with a high level in mechanical properties, additive manufacturing methods have to be used based on suspensions and pastes allowing a very homogeneous distribution of ceramic particles and a possibly high volume content of powder in the suspension media. A very promising method for attaining dense ceramic components with properties which can be compared to conventionally dry-pressed parts is the digital light processing (DLP). Initially, the ceramic powder is homogeneously dispersed in a photo-curable organic binder system. Via selective exposure of this suspension by means of a micromirror, a ceramic green body according to the CAD model is built.

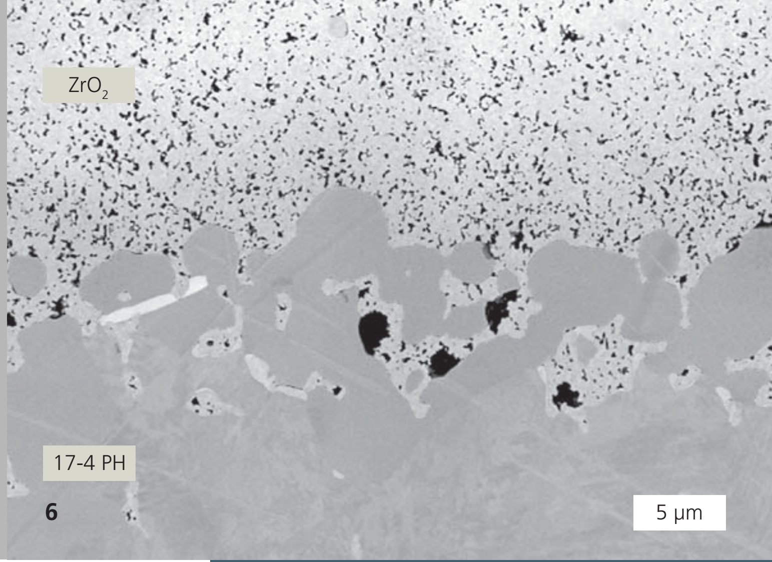
Lithography-based ceramic manufacturing (LCM)

The DLP principle described above is adapted by a device (CeraFab 7500, Lithoz GmbH, Vienna), which is used at Fraunhofer IKTS. This method, which has especially been developed for additive manufacturing of ceramic components, is called lithography-based ceramic manufacturing (LCM). In the device, the layer thickness of the suspension can be varied between 25 µm and 100 µm, the lateral resolution is 40 µm. As known from stereolithography, a radical polymerization of the binder system is initiated by selective exposure with blue light by means of the DLP modulus. All regions of a layer necessary for constructing the desired component are cured simultaneously by this method. In this way, the productivity of this technique can be increased in comparison to the dot-wise exposure by means of a UV laser beam in stereolithography.

The suspensions used for LCM show relatively high solid contents allowing green densities of the components up to 55 %. Since the components are made upside down in hanging position in the LCM method, the suspension volume necessary for the production process is relatively low, which is important for resource-efficient processing. After curing the bottommost layer close to the bottom of the glass vessel containing the suspension, the component is raised by a distance corresponding to the thickness of the next layer. A novel suspension layer is now applied by a doctor blade, which is exposed in the next processing step. At present, three different ceramic materials can be processed using the LCM machine: alumina, zirconia and tricalciumphospate. Densities achieved after sintering of the debindered green bodies are 99.4 % theoretical density in the case of alumina and 99.0 % theoretical density for zirconia. For efficient curing of the binder polymer by exposure to blue light, the ceramic particles dispersed in the binder must not absorb the radiation. For that reason, dark ceramic powders are strongly limited for use in the LCM process.

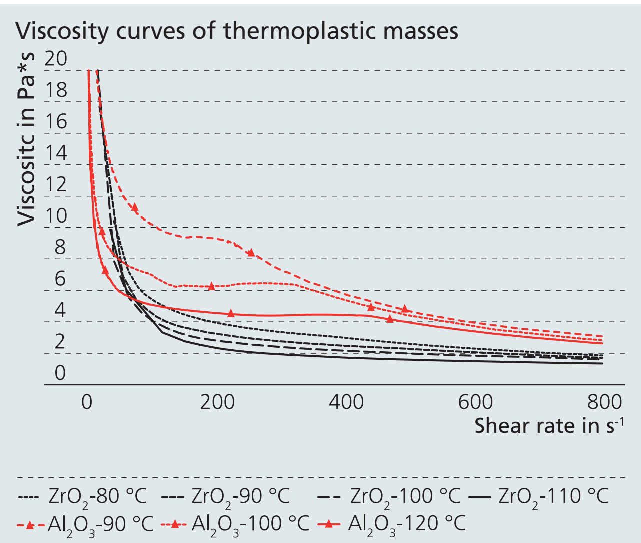






Thermoplastic 3D printing (T3DP)

Thermoplastic 3D printing is a new approach Fraunhofer IKTS follows, which excludes the limitations of the above-mentioned method. This approach bases on highly particle-filled thermoplastic suspensions with relatively low melting temperatures (80 – 100 °C). The viscosity of these suspensions should be relatively low compared to thermoplastic feedstocks used for conventional fused deposition modeling (FDM) as shown for a zirconia feedstock (Figure 4). In T3DP, the material is only applied to these positions where it is needed for construction. A heatable dispensing unit assessable in three axis is moving over a fixed platform carrying a metallic or glassy plate as carrier for the ceramic part. The thermoplastic suspension is molten in the dispensing unit for attaining a sufficient flowability and solidifies immediately when cooling down. For that reason, the solidification of the feedstock takes place almost independently from the physical properties of the ceramic powders. Binding between the single layers applied in this way is excellent (Figure 5). Thermoplastic feedstocks developed for this purpose show a solid content of 67 vol.-% in the case of alumina powder (d_{50} = 1.5 µm) and 45 vol.-% in the case of zirconia powder (d_{50} = 0.3 µm), respectively. For both materials, samples have been made by T3DP, debindered and sintered showing densities of 97.3 % theoretical density (alumina) and 98 % theoretical density (zirconia). By using two or more containers for the suspension and two or more dispensing units, different materials can be applied by this method for attaining multi-material components. Furthermore, also functionally graded materials can be manufactured in this way. Differences in the shrinking behavior of the materials can be adjusted by the solid content of the different feedstocks or by adjusting the particle size distribution and the particle shape, if necessary. First positive results could be attained for components consisting of a material combination of zirconia and stainless steel 17-4PH (Figure 6) showing the potential of T3DP for manufacturing multi-component parts with multifunctional properties.



Powder-based additive manufacturing

3D printing

In this manufacturing method, a thin powder layer is applied by a doctor blade. Afterwards, the powder particles are glued by a binder solution added to the powder bed by a printing head. Densification of the powder particles during this 3D printing process is relatively low, i.e. completely densified ceramic components cannot be obtained by this method. 3D printing is, for instance, used for manufacturing porous bioactive ceramic structures made of hydroxyapatite. Furthermore, the production of components for filtration applications, as catalyst support and for complex shaped ceramic cores or molds for investment casting is possible. Fraunhofer IKTS uses a commercially available 3D powder bed printer with a construction area of 350 x 250 x 200 mm^3 and a minimum layer thickness of 87 µm.

1 *LCM method: Demonstration part processing.*

2 *LCM method: Al_2O_3 honey comb structure.*

3 *CT reconstruction (detailed) of the mixing structure from figure 2.*

4 *LCM method: Open-cell structure Al_2O_3.*

5 *Thermoplastic 3D printing: Al_2O_3 layers.*

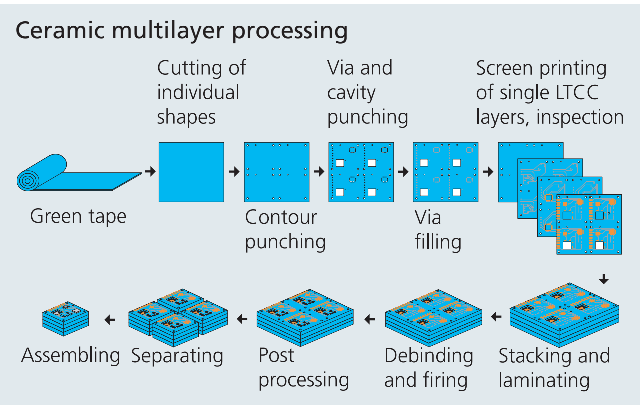
6 *Thermoplastic 3D printing: Interface ZrO_2 steel.*

Selective laser sintering (SLS)

For selective laser sintering, a powder bed is applied by a doctor blade, too. The selective solidification by means of a laser beam results in a dense material structure for ceramic powders, which contain a liquid phase forming additive, e.g. mixtures of Al_2O_3/SiO_2. Moreover, the laser sintering process can be used for simply attaining ceramic green bodies. For example, complex shaped SiC components were made by means of a CO_2 laser. The porous structure was infiltrated with liquid silicon forming SiSiC. The properties of these components are comparable to SiSiC parts made by conventional shaping techniques like dry pressing, green machining and finishing.

Laminated object manufacturing (LOM)

LOM or multilayer technology has been applied at Fraunhofer IKTS for more than 15 years. Beside the opportunity to obtain 3D-structured components, this methods offers a layer-wise integration of further materials and an opportunity for embedding different functionalities, like conducting paths, passive components (R, L, C), heaters and sensors. For LOM, ceramic single or multilayer tapes are produced initially, structured layer by layer subsequently and provided with the necessary functional structures by sieve and mask printing. By stacking and laminating the single layers, the desired 3D component is generated. Fields of application of LOM are, for instance, ceramic and glass-ceramic multilayer wiring supports for high-frequency and power applications, multilayer capacitors and chokes, piezo electrical stack actors, microfluidic components for medicine and biotechnology, such as various physical and chemical sensors. The spectra of materials for LOM technology is very wide both for the ceramic tapes (LTCC – low-temperature cofired ceramis, HTCC – high-temperature cofired ceramics) and functional pastes.



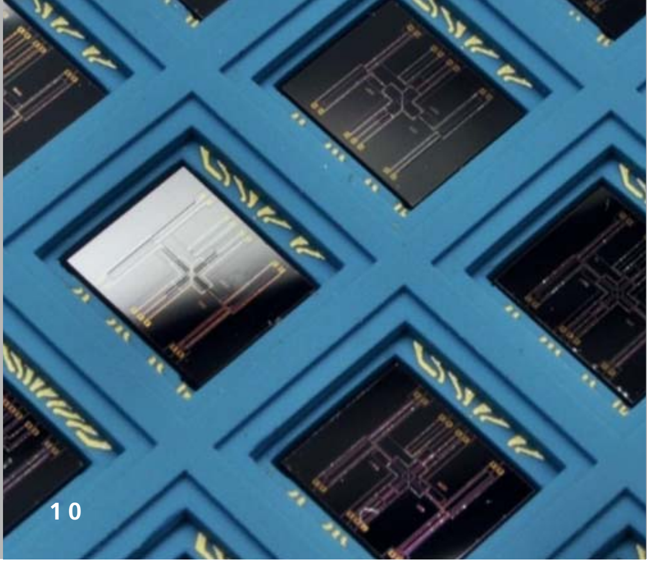
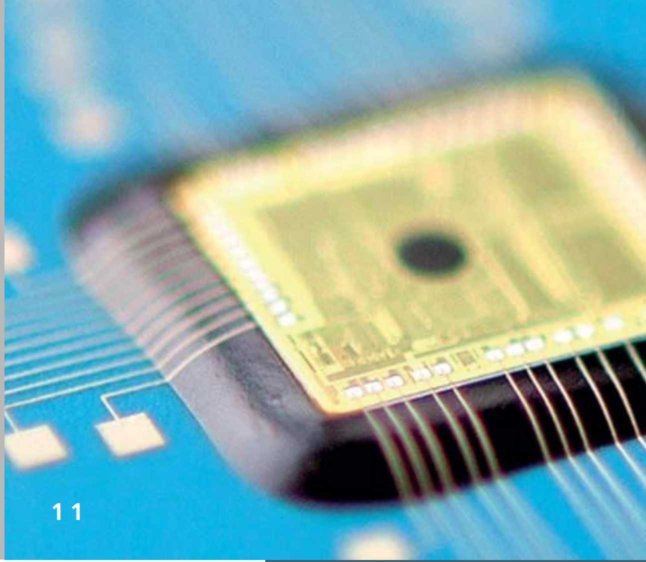
Fraunhofer IKTS covers the complete process chain starting with the initial material over simulation-based component design and manufacturing technology to functional testing and system integration. Present focal points in LOM technology are further miniaturization of components, e.g. for MEMS packages on wafer level (see Figure 10), which demands an increase in the structural resolution of the used manufacturing technologies, a forced integration, such as 3D printing of passive components, and integration of non-electrical functions in multilayered assemblies, like chambers, channels and membranes by using sacrificial materials.

Combining laminated object manufacturing with other shaping techniques established at Fraunhofer IKTS (for instance ceramic injection molding) offers additional chances for production of complex shaped, multifunctional, miniaturized and customized ceramic 3D components.

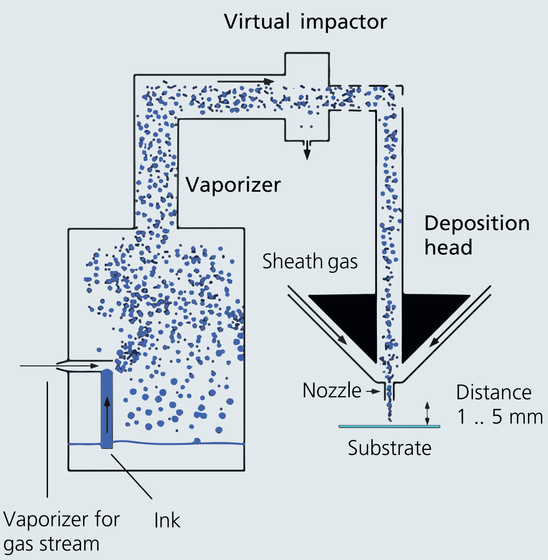
Key technologies for functionalization of above-mentioned 3D components are digital printing methods, which allow providing free-formed surfaces with desired functional structures in high resolution. For that purpose at Fraunhofer IKTS, different microextruction and dispenser methods, such as ink-jet and aerosol-jet technologies, are available. Especially the aerosol-jet technology is suited for coating of 3D and free-formed surfaces with functional structures, e.g. conducting paths, R, L, C, sensors, etc.. This method bases on atomizing particle-containing and particle-free inks in microscale. The droplet flow generated in this way is focused in the printer head (diameter < 10 µm). Due to the comparatively high waist length of 1–3 mm, geometrical steps can be overprinted, functional structures can be written and fibers can be coated.

Conclusion and outline

Additive manufacturing methods open new horizons in design and construction of ceramic components. Due to the tool-free shaping technology and the layer-wise assembly of components, additive manufacturing methods are working especially

Schematic sketch of the aerosol-jet method



resource- and cost-efficient and almost without waste. These are the reasons for an increasing interest in using additive manufacturing methods for production of individualized components, single parts or small series. The possible applications are manifold ranging from medical, patient-specific instruments or implants to special tools or customized jewelry and luxury goods. The trend in the field of ceramic materials goes to increasing the material portfolio, enlarging the dimensions of the manufactured products by increasing the building area of the AM machines and improving the properties of the manufactured components, i.e. improved surface quality and enhanced mechanical properties. For an increasing multifunctionality of ceramic components multi-material applications for the combination of different properties will play a growing role.

By further work on material and technological development, it will be possible to exploit the huge innovation potential of additive manufacturing also for ceramics and to foster its industrial application. In this development process, Fraunhofer IKTS will be a competent and innovative research partner for both ceramic component producers and applicants.

7 LCM method: Al_2O_3 mixing structure.
8 3D printing: Demonstration component (petrous part) from hydroxylapatite, data of Phacon GmbH.
9 Selective laser sintering: Detailed picture of SiSiC tool usage.
10 MEMS packages on wafer level.
11 Chip bonding via aerosol-jet printing.

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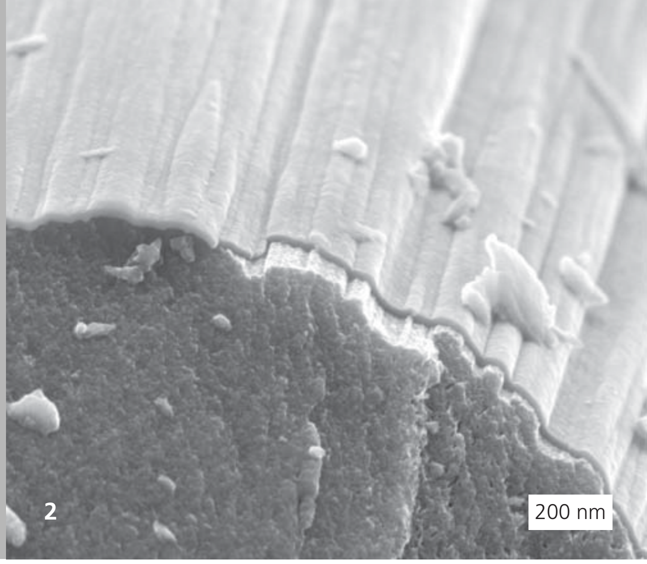


FIBER COATING FOR THE DEVELOPMENT OF NEW COMPOSITE MATERIALS

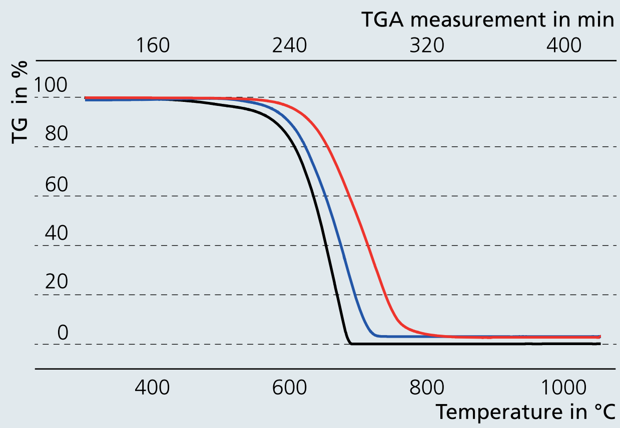
Dr. Ingolf Endler, M. Sc. Alfaferi Zainal Abidin, Dipl.-Phys. Mario Krug, Dipl.-Ing. Katrin Schönfeld, Dipl.-Ing. Clemens Steinborn, Dr. Hagen Klemm

Fiber-reinforced composites are widely used in industry due to their variable design options. The utilized fibers have different functions. Aim of the combination of e.g. glass or carbon fibers with a ductile matrix like polymers or metals is the improvement of the strength and stiffness of such materials. In the case of ceramic composites, an increase of fracture toughness and damage tolerance can be achieved by reinforcing with ceramic or carbon fibers. For all composites, the fiber-matrix interface has a crucial role in the setting of optimal properties. Taylor-made fiber coatings offer manyfold opportunities, for example, a strong bonding with the matrix, an effective protection of the fiber from undesired reactions with the matrix and an adjustment of a weak fiber-matrix interface for a damage-tolerant failure behavior. Currently, coating opportunities for different fiber materials are extended at IKTS. In the future, the new coating equipment offers a batch processing mode for fiber textiles as well as a continuous operating mode using a roll-to-roll process for rovings and fibers. It enables novel technological possibilities for fiber and textile coatings using CVD and ALD processes.

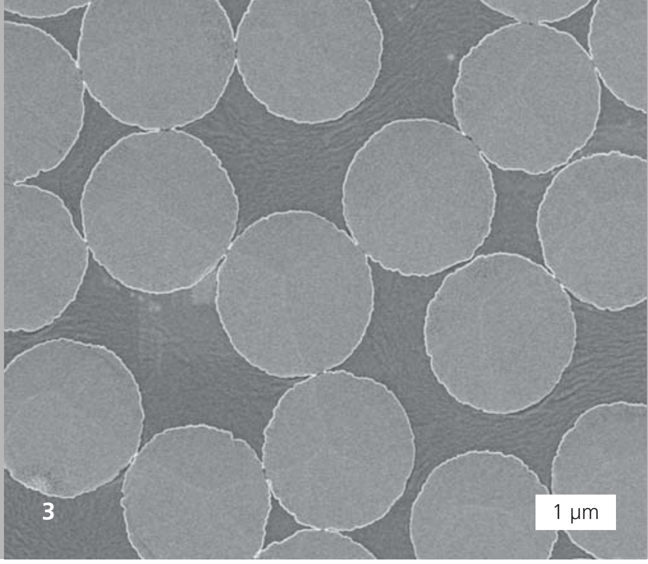
Carbon fiber-reinforced metal-matrix composites

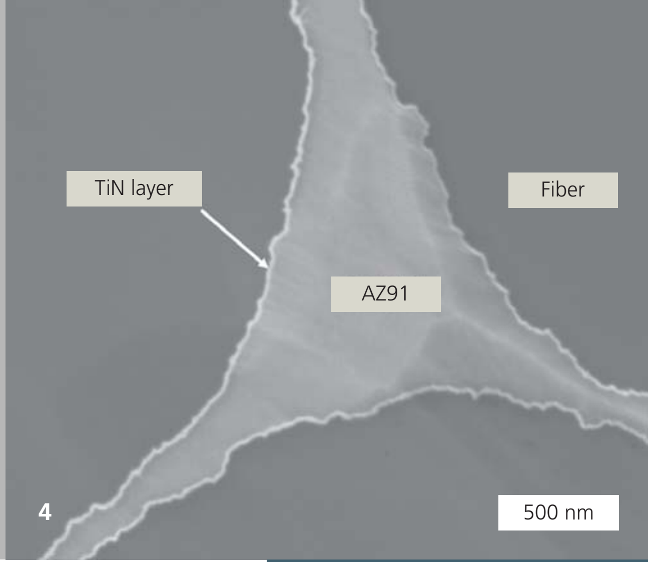
Production of modern metal-matrix composites apply 3D and 2D carbon fiber fabrics, which consist of fiber bundles with thousands of single filaments in each bundle. Protective layers made of titanium nitride (TiN) and aluminum oxide (Al_2O_3) are deposited on the carbon fiber fabrics in order to prevent undesired reactions between the fibers and the metal matrix. At Fraunhofer IKTS, two coating technologies for deposition of protective layers are applied: chemical vapor deposition (CVD) and atomic layer deposition (ALD). Figure 1 shows a new coating equipment offering the possibility of a continuous operation in both ALD and CVD processes. So far promising results have been obtained with ALD-Al_2O_3 coatings as well as CVD-TiN coatings, which were prepared at different laboratory scale facilities. In the ALD process, the precursors are sequentially injected and separated by purge gas pulses. At IKTS, Al_2O_3 deposition is carried out with an ALD process with substrate temperatures below 300 °C. The used precursors are trimethylaluminium (TMA) and ozone or water. However, preparation of the TiN protective layer is conducted by means of CVD. The deposition is carried out with a gas mixture of $TiCl_4$, N_2 and H_2 in the temperature range between 800 °C and 850 °C. With both methods, a homogeneous coating on all single fibers in the fabric could be obtained. In Figure 2, the fracture surface of a single fiber coated with a conformal and well-adherent ALD-Al_2O_3 layer is shown. Figure 3 demonstrates a homogeneous coating of a whole fiber bundle, which is taken from the 3D fabric. The Al_2O_3 layer has an amorphous structure with a smooth surface whereas the TiN layer has a nano-crystalline structure. Both layers increase the oxidation resistance of the carbon fibers. The best protection against oxidation is offered by Al_2O_3 layers as illustrated by thermographimetric analysis in the figure below.

TGA analysis for determining oxidation resistance



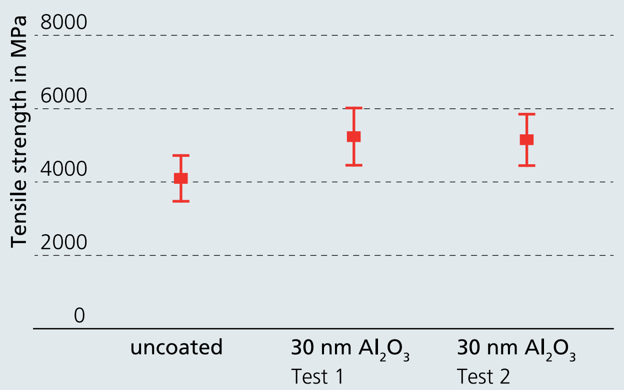
TGA at 2.5 K/min (DIN 51006) — uncoated fibers — TiN coated 35 nm — Al_2O_3 coated 40 nm



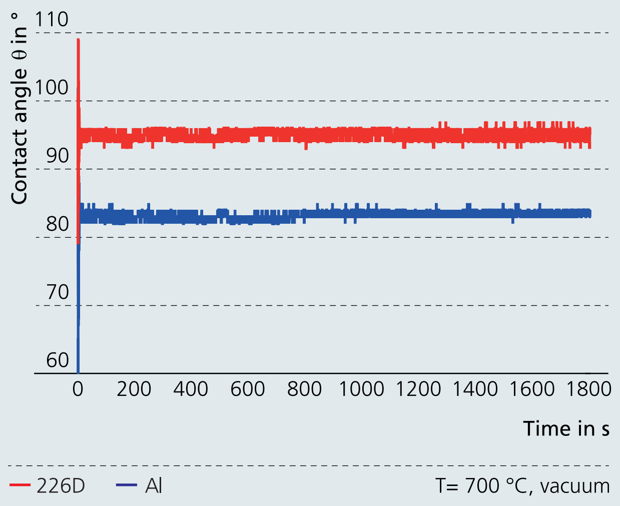


However, the coating affects tensile strength of the fibers. A significant decrease in the tensile strength is observed for TiN-coated fibers. At a coating temperature above 850 °C, formation of a brittle TiC_xN_y intermediate layer favors and reduces tensile strength of the fiber dramatically. Applying a thinner layer (about 30–35 nm) at low deposition temperature can minimize this behavior. An acceptable tensile strength of 2000 MPa is achieved when TiN layer thickness is limited to 30 nm and a coating temperature of 850 °C is not exceeded. Al_2O_3-coated carbon fibers show no loss of strength. In the case of high modulus carbon fibers, the tensile strength is slightly improved after the deposition as can be seen in the diagram below. This is caused by the low deposition temperature of ALD (below 300 °C) and by the thin layer thickness of 30 nm. The preparation of composites is performed by infiltration of coated 2D and 3D fabrics with molten metal of aluminum and magnesium alloys. Both coatings (Al_2O_3 and TiN) show good wetting behavior with metal melts. However, based on measurements at FRI Krakow, contact angle with pure Al and Al alloys show significant differences for both types of layers. The measurements for comparing the two layer systems with pure Al showed a contact angle of 83 ° for the Al_2O_3 layer and approx. 130 ° for TiN layer in conjunction with pure Al. The better wettability of the Al_2O_3 layer is an advantage for manufacturing MMC with Al alloy.
Gas pressure infiltration (GPI) was employed to infiltrate coated textiles using commercial Mg-Al-alloy (AZ91) and Al-Si-alloy (226D). Infiltration was carried out in corporation with the Institute for Lightweight and Polymer Engineering at the Technical University Dresden. The Al_2O_3- as well as TiN-coated fabrics were successfully infiltrated with both alloys. Investigation of infiltrated Al_2O_3-coated 2D carbon fiber fabrics shows a dense composite with low porosity. The undesired aluminum carbide formation is completely avoided. The same is observed for a TiN protective layer. A composite of TiN-coated 3D fabric infiltrated with magnesium-aluminum alloy AZ91 also shows a dense structure without Al_4C_3 formation at the fiber-matrix interface. Both TiN and Al_2O_3 layers are effective diffusion barriers and protect carbon fibers from the aggressive molten metal in the MMC manufacturing process.

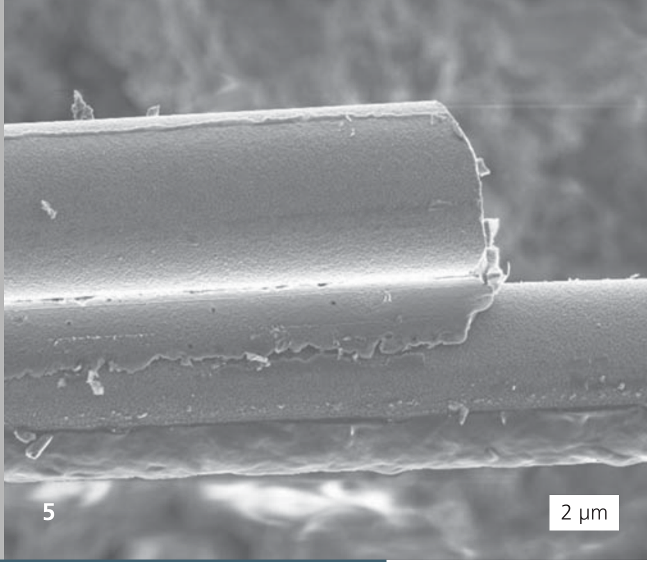
Tensile strength of Al_2O_3-coated high modulus carbon fiber

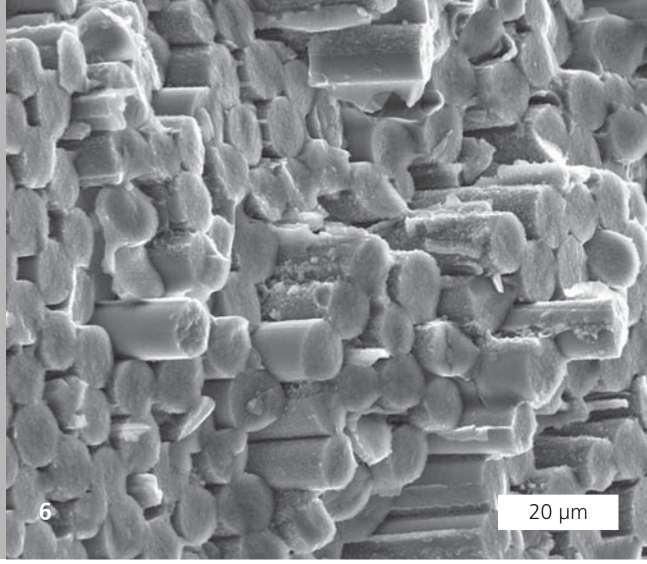


Contact angle measurement of Al_2O_3 layer with molten Al und 226D alloy



1 *New equipment for continuous fiber coating.*
2 *Al_2O_3-coated single fiber.*
3 *Cross-section of fiber bundle with homogeneous Al_2O_3 coating.*
4 *SEM micrograph of a composite from TiN-coated carbon fiber infiltrated with AZ91 alloy.*





Ceramic matrix composites

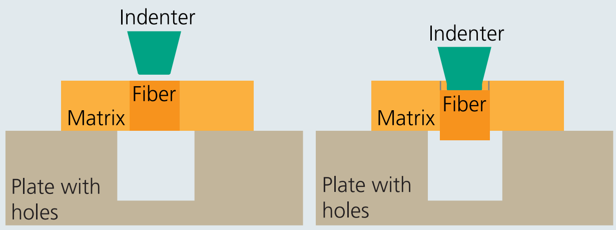
Even in ceramic fiber composites (CMC), used e.g. as lightweight material or in high-temperature processes, fiber coatings are needed. Besides the reliable oxidation and corrosion protection of the ceramic fibers, the guarantee of a damage-tolerant composite behavior is the main function of the fiber coating. Thus, in contrast to other composite materials with a ductile matrix, like carbon fiber reinforced plastics (CFRP) or metals (MMC), the focus of the material design of CMC must be placed on the adjustment of a weak bonding between fiber and matrix, which allows crack propagation in the fiber-matrix interface.

Usually, a strong bonding between fiber and matrix was obtained as a consequence of chemical reactions in the heat treatment during the fabrication of the composites. These reactions prevent toughening mechanism, such as crack deflection or fiber pull-out and finally a damage-tolerant behavior of the composites. With an additional coating of the fibers, however, the bonding at the interface between fiber and matrix can be purposefully adjusted.

In case of non-oxide composites, layers of carbon or boron nitride have prevailed since their hexagonal-layered structure resulting in crack propagation at the fiber-matrix interface promoting the pull-out. However, these layers are not suitable for long-term use at elevated temperatures in air, as they do not have sufficient oxidation stability. For this reason, the focus of future CMC developments must be placed on new coating material systems featured by a superior chemical and mechanical resistance at temperatures > 1000 °C.

Two different technologies for continuous fiber coating were applied at IKTS. In case of the CLPC method, continuous liquid phase coating, a liquid precursor as coating material was used. During thermal treatment, the precursor was pyrolized to a thin ceramic layer. Pyrocarbon-coated SiC fibers are shown in Figure 5 as an example of these processes. The microstructure of the fracture surface of a SiC_F-Si_3N_4 composites with carbon fiber coating is demonstrated in Figure 6. The damage tolerant behavior was obtained by pull-out of the fibers from the ceramic matrix.

Description of single fiber push-out test



Position of sample and indenter before testing

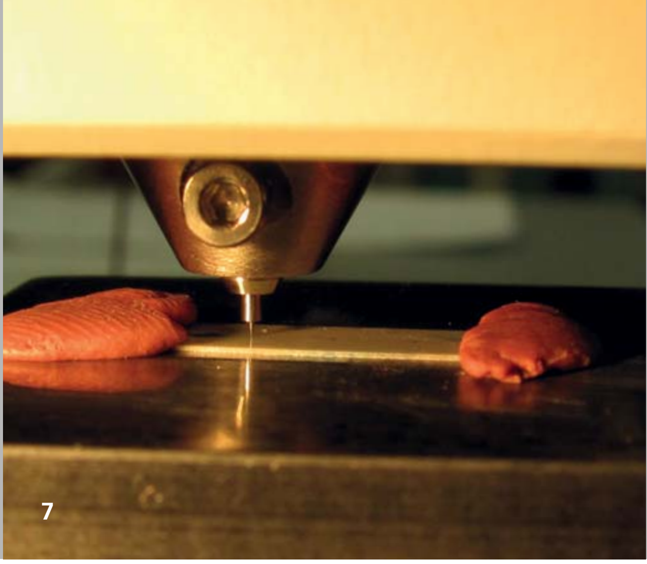
Fiber displacement after debonding the loaded fiber

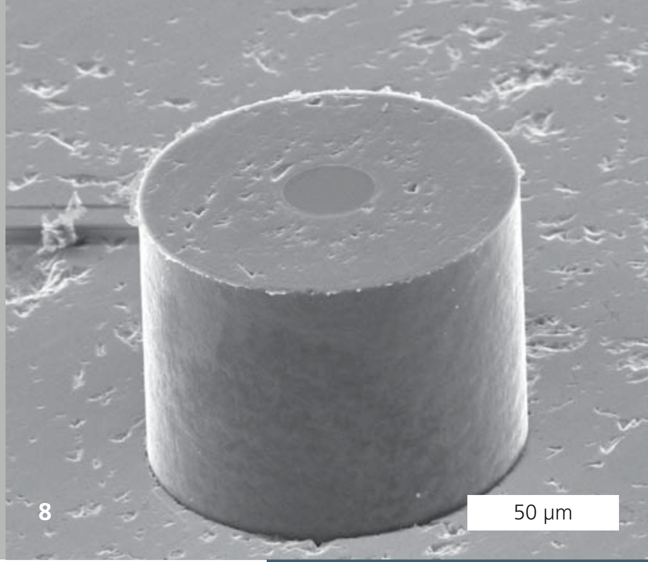
By separating the fibers, a damage-tolerant crack behavior is realized. Fiber coating by means of chemical vapor deposition (CVD) is another method. Advantages of this method include the layer deposition by transporting materials via vapor phase into the smallest intermdiate space so that coatings are also detectable in the fiber bundle or in fabrics. Thin, homogenous layers can be created, as shown in Figure 3.

As mentioned above, the purposeful adjustment of the fiber-matrix interface strength was found to be the essential factor influencing the damage-tolerant fracture behavior of the composite. Single fiber push-out tests have been performed at IKTS in order to characterize the mechanical interaction between fiber and matrix. The measurement of interfacial shear strength on a CMC sample with a microhardness tester is shown in Figure 7. In this way, it is possible to characterize the fiber-matrix connection in dependence on the type of coating and coating technology and to define the requirements for the development of such materials.

By purposeful preparation of thin samples of model composites, it was possible to obtain reproducible force-displacement curves via the described test and to calculate the characteristic shear stress for fiber debonding. A low shear strength is characterized by a weak fiber-matrix interaction. The fiber can be pushed out quite easily as shown in Figure 8. The weak interaction was the consequence of the homogeneous fiber coating. In case of uncoated fibers, however, a strong interaction with a high shear strength was obtained.

The results of the push-out tests are demonstrated in the diagrams on the right-hand side. A significant displacement of the indenter was observed in the composite with fiber coating re-

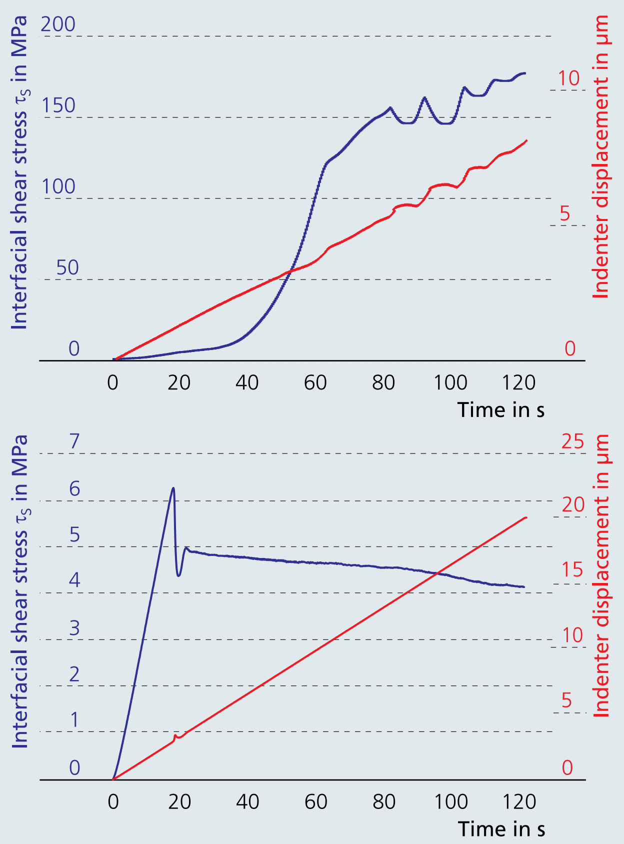




sulting in a shear stress of 6 MPa. Much higher stresses were found in the uncoated material with strong fiber-matrix interaction. There, a significant displacement of the indenter was not observed up to a stress level of about 120 MPa.

The formation of cracks observed inside the fibers show that the compression strength level of the fiber was reached. A brittle failure behavior should be expected in case of such a strong fiber-matrix connection. In this way, correlations between the interface properties and the macroscopic mechanical behavior of the composites can be determined. Based on the results and interpretation of these tests, the fiber-matrix interface of CMC's can be designed. According to the application and the chemical and mechanical requirements, oxide or non-oxide fiber and matrix systems will be chosen. The coating composition and technology will be selected in the last step of the composite design in order to realize a damage-tolerant behavior of the composites. Thus, it is possible to fabricate composites with reproducible properties.

Interfacial shear stress over time for weak fiber-matrix bonding and strong fiber-matrix bonding



Services offered

- Functional design of fiber-matrix interface of CMC
- Continuous fiber coating by CLPC, CVD and ALD processes, coating of textile structures
- Fabrication and characterization of MMC and CMC

5 *SiC fiber coated with CLPC pyrocarbon.*

6 *Fracture surface of CMC with coating.*

7 *CSM equipment: Measuring instrument for push-out test.*

8 *SiC–SCS with low fiber-matrix bonding after push-out test.*

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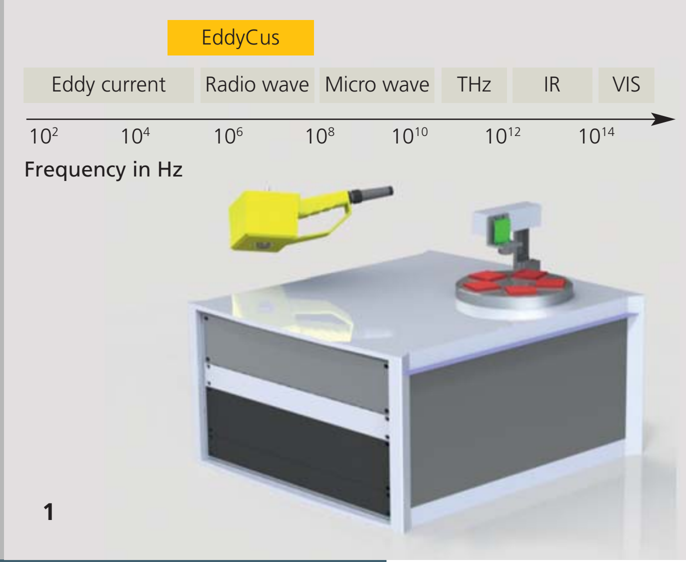


IMPEDANCE ANALYSIS FOR MATERIALS DIAGNOSTICS

Jun.-Prof. Henning Heuer, Dipl.-Ing. Iryna Patsora, M. Sc. Susanne Hillmann,
Dipl.-Ing. (BA) Martin Schulze, Dipl.-Ing. (FH) Matthias Pooch

Methods of impedance analysis

Impedance analysis methods are characterized by their versatility and convenient handling. The impedance is a material-specific parameter that describes the resistance of a material against the diffusion of an electromagnetic or mechanical wave. In the first case, we speak of electrical impedance, the second case is called acoustic impedance. Both methods can be applied to evaluate complex material parameters, such as density, elastic modulus, deviation of material composition, humidity and polymerization.

Electrical impedance analysis

The electrical impedance analysis can be performed by direct electrical bonding of a material or by capacitive or inductive coupling. Direct contact methods are usually bound to laboratory application and solid states. Capacitive and inductive methods are applied for fluids, pastes and green ceramics. Especially the inductive methods allow field focusing in the frequency range up to 100 MHz and sensors with high sensitivity, no contact and higher spatial resolution than capacitive transducers.

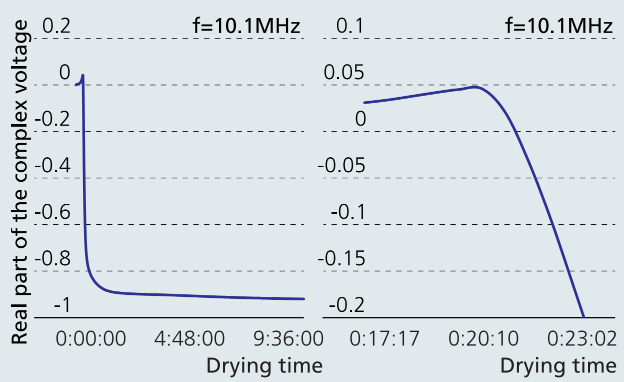
The method bases on an alternating electromagnetic field that will be coupled into the sample via an induction coil. This induces an eddy current flow in the material of electrically conductive samples. Dielectric materials can be analyzed by measuring the influence of dielectric currents and polarization effects on the field and, therewith, on the impedance of an inductive coil. Hence, materials diagnostics of conductive and non-conductive materials based on inductive impedance spectroscopy becomes possible.

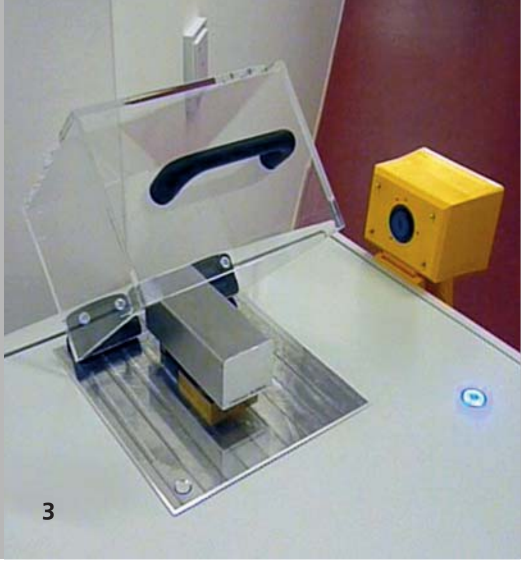
Electrical impedance analysis is applied, for example, to evaluate the drying behavior of electrically conductive coating systems. Such systems will be prospectively used for lightning protection in aircraft construction. In doing so, the surface of an airplane will be laminated with coatings of electrically conductive particles.

One purpose of the approach is to predict the conductivity of conductive coatings still in wet state after drying. Thereby, the coating can be reworked or removed in cases of defective layer thickness or differing particle concentration in the wet state. So far, the coating results can only be tested if the varnish is dry. This can be very expensive if the varnish on a defectively coated airplane surface has to be removed mechanically.

The inductive impedance analyzer "EddyCus® Wet", developed at Fraunhofer IKTS, allows for the determination of percolation behavior of particle-based coatings via contact-free impedance measurement immediately after layer deposition. Since the particles are not directly connected after the coating process, the layer shows dielectric properties. The percolation begins during drying, i.e. the particle concentration increases and conductive paths are created.

Changes of impedance by percolating particle-based conductive paint

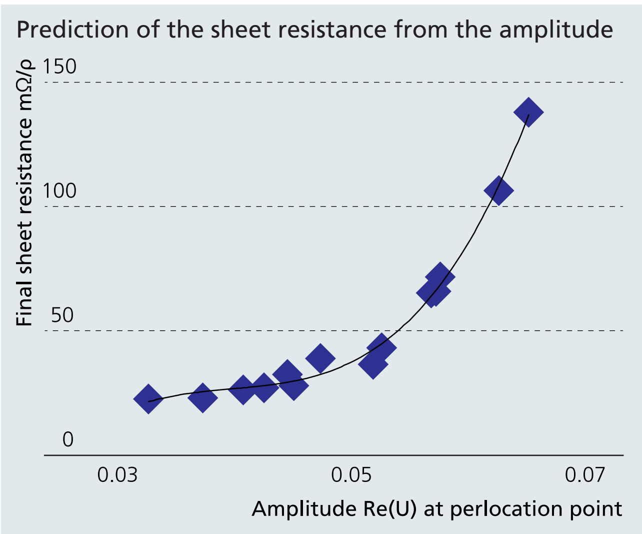


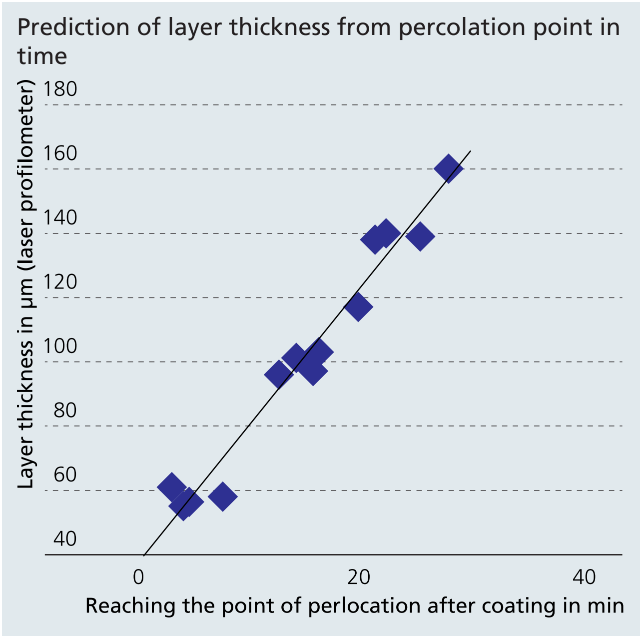


Just before the percolation point is reached, capacitive effects dominate between closely adjacent particles. After the percolation, the layer is electrically conductive but still moist. The percolation point in time can be determined by impedance measurement very well and correlates with the prospective thickness in the dry state. The particle concentration and, therefore, the layer conductivity in the dry state can be predicted from the amplitude of the percolation point.

By calibrating the measurement system, the future layer thickness and layer conductivity can be concluded from the percolation point.

The developed prototype "EddyCus® Wet" is equipped with a fixed and mobile sensor. The fixed sensor acts as referencing, whereas the mobile sensor can be used, for example, on a scaffold for overhead work on an airplane.





1 Classification of radio wave methods.
2 "EddyCus® Wet" prototype.
3 Fixed sensor for referencing of the developed impedance analyzer.
4 Mobile sensor for contact-free impedance measurement.

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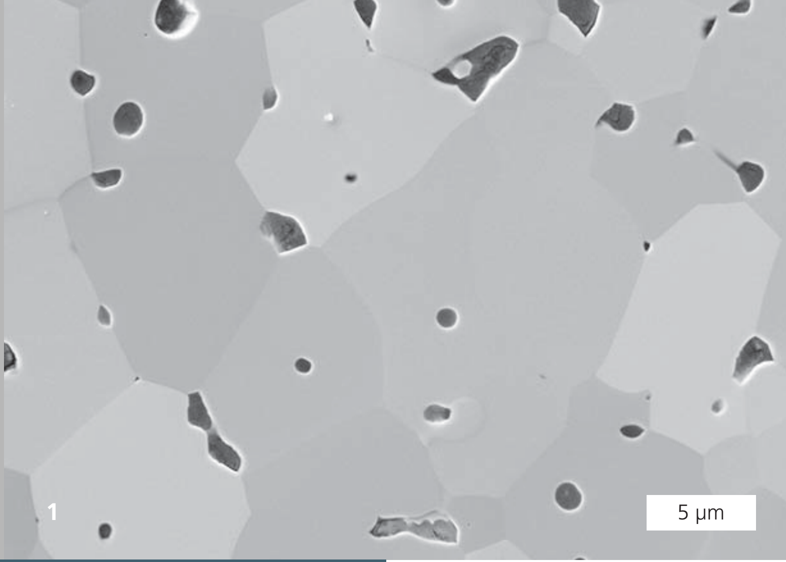
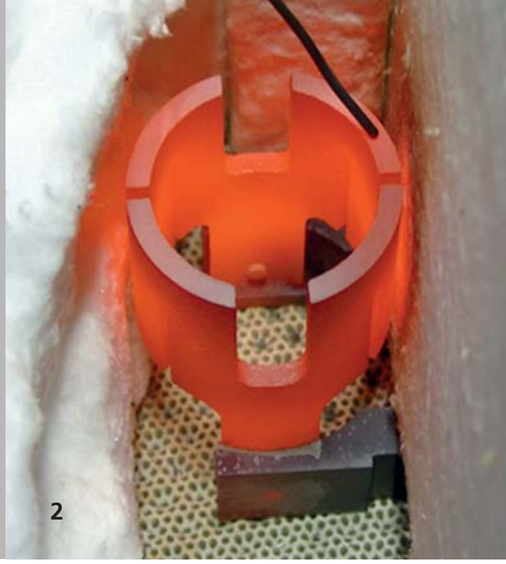




CONDUCTIVE CERAMICS AS ELECTRICAL MATERIALS AT HIGH TEMPERATURES

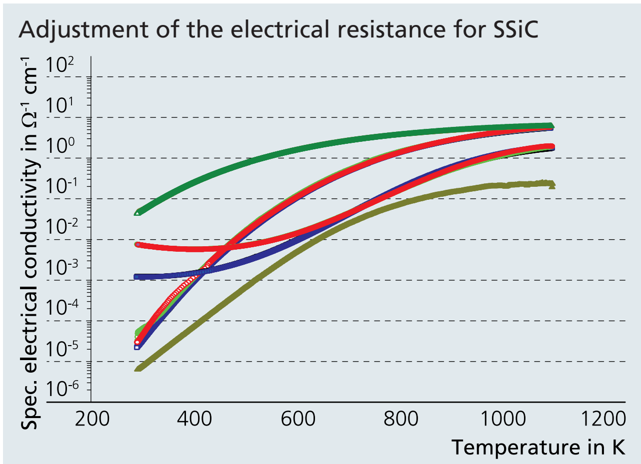
Dr. Hans-Peter Martin

Generally, one intends to expect that ceramic materials behave as electrical insulators. This is absolutely correct for many ceramics but ceramic materials are able to vary their electric properties much more than metals or plastic materials. Ceramic materials are particularly advantageous for electrical and mechanical requirements despite their inherent brittleness and tendency to break. Since there are only little material alternatives, ceramics are frequently used for high-temperature components. Even for temperatures < 500 °C the use of ceramic materials can be desirable because the inherent mechanical and chemical stability of ceramics is almost permanently given.

Metal-like carbides (ZrC, TiC) or nitrides (TiN, TaN), have high electrical conductivity up to 10^5 S/cm, which is decreasing with rising temperature. The mentioned materials are significantly harder, more temperature resistant and show better chemical stability compared to metals or metal alloys. Currently, industrially applicable manufacturing processes for zirconium carbide materials are developed at IKTS to replace tungsten or molybdenum materials for high-temperature applications. Zirconium carbide is characterized by a similarly low vapor pressure at 2000 °C k as tungsten.

Electrical semiconductor ceramics are, for example, silicon carbide, boron carbide or titanium suboxide. Besides a moderate electrical conductivity in the range of 10^{-2} to 10^3 S/cm at room temperature, which can be shifted considerably by several orders of magnitude for one ceramic type, all ceramics are heat resistant above 1000 °C and show outstanding abrasion resistance and chemical stability against aggressive atmospheres. The property spectra of those ceramic materials is extraordinarily flexible, which enables them to solve very specific functional tasks in combination with constructional demands. For instance, heating and sensor functions for temperature control together with mechanical support can be delivered by heating elements made of silicon carbide.

Ceramic composites made of metal-like semiconductive and isolating ceramic components (e.g. Si_3N_4 + SiC + MoSi) or any other composition of various semiconductive ceramics (e.g. SiC+ B_4C) have been manufactured at IKTS and tailored for specific requirements. Such ceramics offer an available base for a very variable multifunctionality. Precise knowledge concerning the specific processing can be gained, which is the fundament for economical competitive materials for future-oriented options in plant construction, mechanical engineering and sensor applications. Material and component development, measurement of electrical conductivity from room temperature up to 1000 °C and the investigation of electronic properties, like carrier concentration or Seebeck coefficient generate the base of application-oriented projects.



1 *Microstructure of pressureless sintered (2000 °C) zirconium carbide.*

2 *Silicon carbide heater.*

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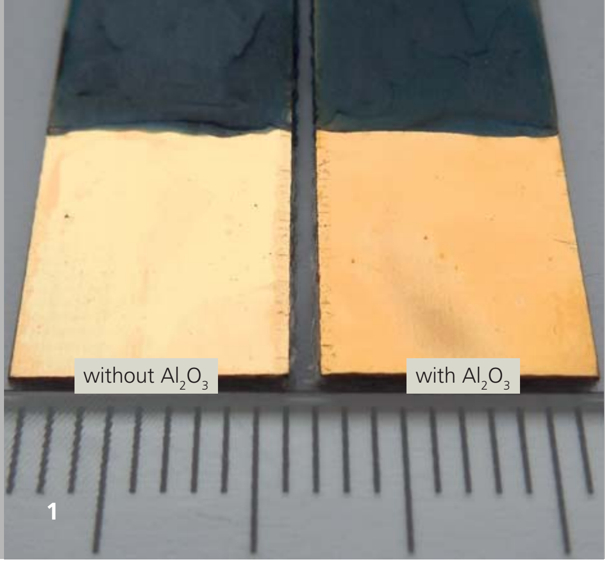
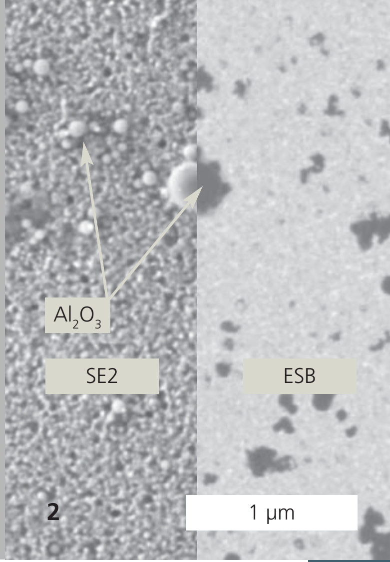




CERAMIC NANOPARTICLES FOR ELECTROLYTIC COMPOSITE COATINGS

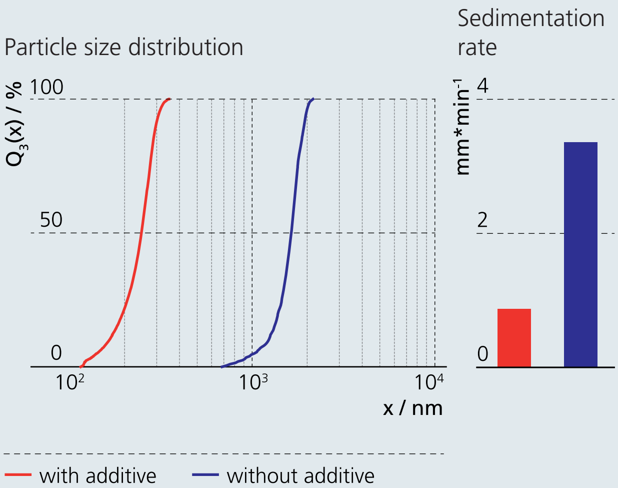
M. Sc. Mathias Weiser, Dr. Anja Meyer, Dr. Annegret Potthoff, Dr. Michael Schneider

Modifying coatings with ceramic particles to create new functionalities and features is a current trend in electroplating. Nickel layers, for example reinforced with ceramic microparticles (e.g. B_4C), are already well established. The hardness and wear resistance is increased. Using submicron- and nanoscale particles is the latest trend leading to even better mechanical properties and the application on thinner composite coatings.

Anyway, the incorporation of the particles should be homogeneous. This is highly important for a successful application of the composite coatings. Hence, the deposition rate of the metal and the particles should be constant. Two factors have to be coordinated. One important point is the prevention of agglomeration and sedimentation of the ceramic nanoparticles in the plating bath. The challenge is the high ionic conductivity of the plating bath since the electrochemical double layer of the particles is compressed. An electrostatic stabilization of the particles is impossible and agglomeration of the particles would be the consequence. Alternatively, the particle can be sterically stabilized by using organic additives, preferably not being incorporated into the composite coatings. The adjoining graph shows the successful stabilization of nanoscale Al_2O_3 particles in a gold electrolyte by using an organic additive. The equivalent diameter of the ceramic particles ($x_{50,3}$) including the additive amounts to 270 nm and excluding additive to approx.1.6 µm. It is evident that the agglomeration process is enhanced without additive. Smaller particles often represent better suspension stability and result in a slower sedimentation rate. A comparison between the sedimentation rate with and without additive is shown in the graph on the right-hand side. The additive significantly prolongates the sedimentation. This improved stability of the plating bath is of great benefit. Figure 2 illustrates a stabilized suspension used for the composite coatings.

In principle, nanoscale hard materials, such as Al_2O_3, WC and others, can be incorporated in electrolytic deposits. Gold composite coatings less than 1 µm can be prepared. The gold coatings are hard and wear resistant, which raises the lifetime and reduces the consumption of expensive precious metals in jewellery and low-voltage electrical connectors.

Particle size and sedimentation of Al_2O_3 particles in electrolytes with and without additive



Acknowledgements

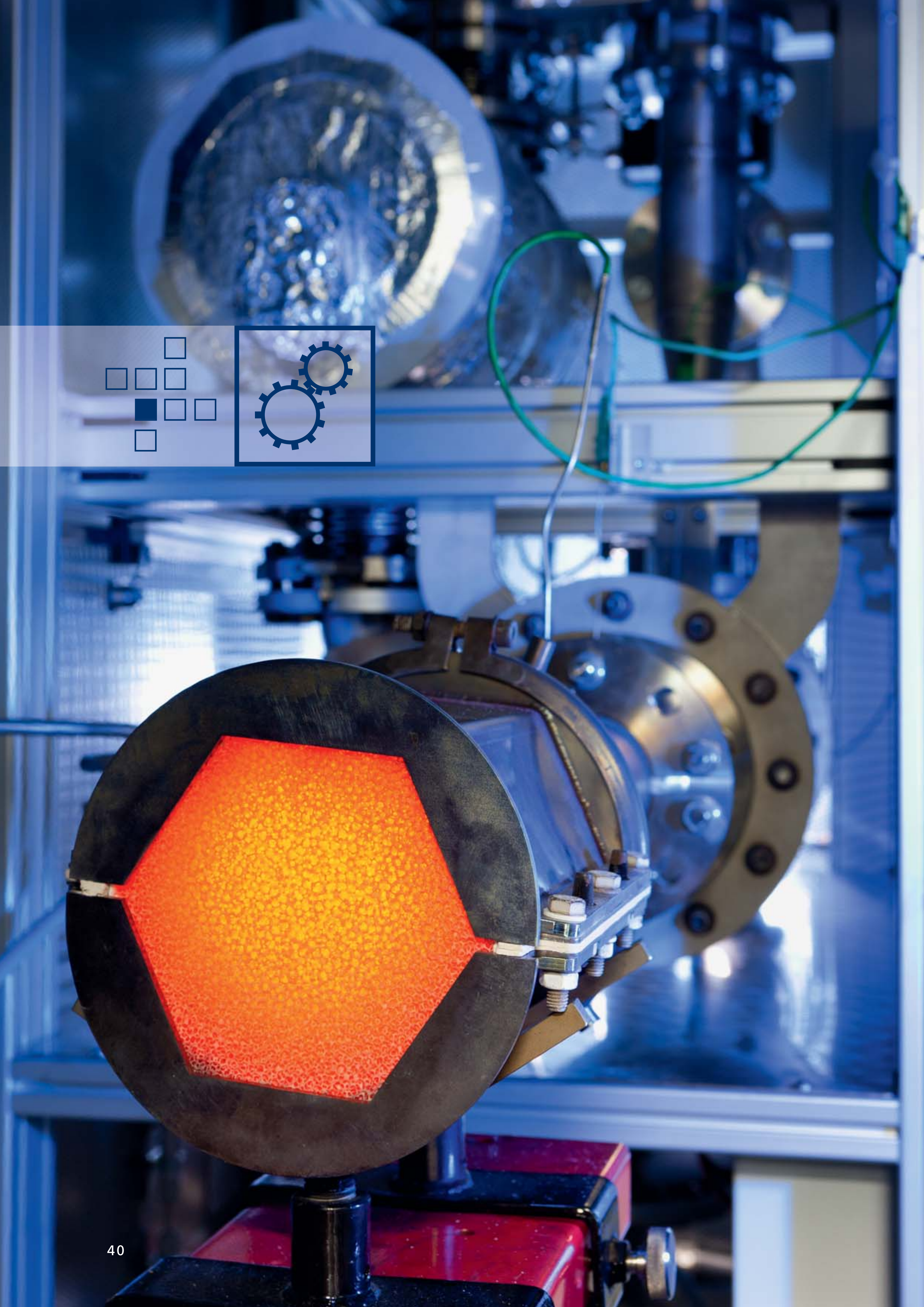
The authors thank the AiF (IGF no. 16864 BR).

1 *Gold coatings with and without Al_2O_3 nanoparticles.*

2 *SEM picture of Al_2O_3 nanoparticles in a gold composite coating (SE2 & ESB).*

3 *Gold plating bath without (l.) and with (r.) Al_2O_3.*

Forschungsnetzwerk Mittelstand AiF



BUSINESS DIVISION

MECHANICAL AND AUTOMOTIVE ENGINEERING

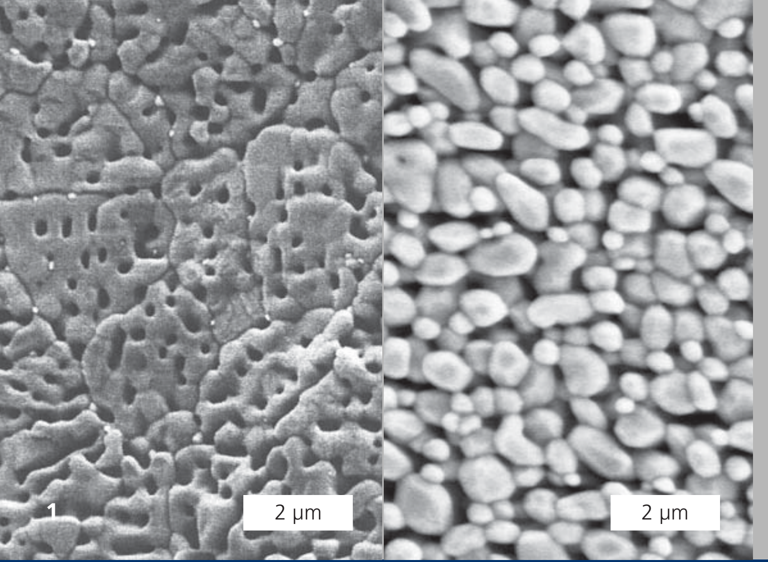
Project reports

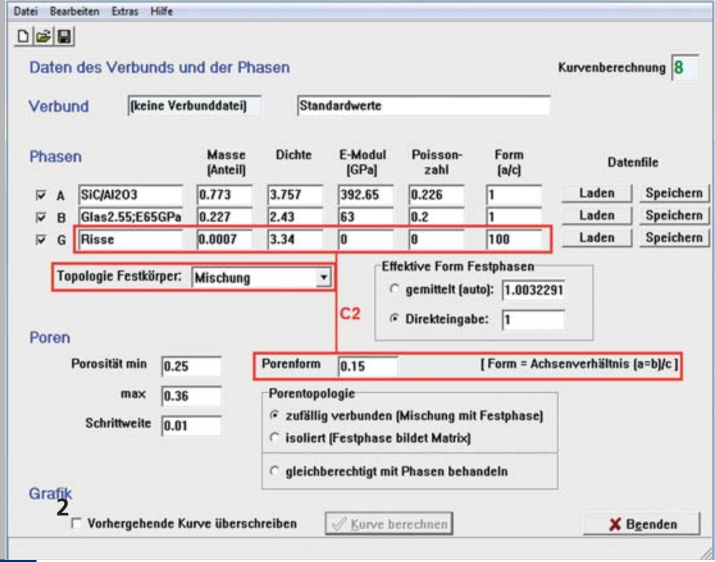
The "Mechanical and Automotive Engineering" business division at Fraunhofer IKTS offers conventional wear parts and tools as well as components subjected to specific loads – made from high-performance ceramics, hard metals, and cermets – that are used in mechanical, systems and automotive engineering. Optical, elastodynamic and magnetic test systems for the monitoring of components and production facilities constitute a new area of focus.

The rising costs of energy and raw materials – combined with intensified competition in the global markets and escalating demand for sustainability – collectively represent the tremendous challenges involved in mechanical and systems engineering. Ever-stricter exhaust standards add a further dimension to the factors that automotive engineers face today. Using high-performance ceramic components helps engineers to achieve dramatic improvements to existing and new systems.

Fraunhofer IKTS supports its customers with the application-oriented selection and development of materials, while utilizing both established material systems and new combinations as well. The IKTS team has decades' worth of experience in designing components that leverage the best qualities of ceramics and hard metals. It is also a veritable font of knowledge regarding the most economically feasible production processes and their successful integration into the user system. Thus, new application concepts are both swiftly and affordably implemented in prototype and small-scale series production. When selecting a production process, the team can choose from among a broad range of ceramic manufacturing processes that, from an international scale, is truly outstanding in terms of its sheer breadth and depth. The existing equipment and installations facilitate the institute's holistic approach: from upscaling processes on the pilot-plant scale to transferring these processes into industrial production.

Test and monitoring systems track the operational status of components and systems. They detect and localize defects early on. In doing so, staff members have access to a broad portfolio of unique methods for the non-destructive detection of critical material parameters, such as fiber structures and microstructures, mechanical stress, porosity, crack formation and delaminations. Signals are detected, processed through high-performance hardware components, then visualized and interpreted by IKTS',s in-house developed software.





GRINDING TOOLS AND POROUS CERAMICS: STRENGTH CONTROL BY YOUNG'S MODULUS

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

Compact grinding bodies as well as porous ceramics for filtration or catalysis need a high open porosity associated, however, with much higher mechanical loads of the tools. The safe control of their mechanical reliability is, therefore, essential for their successful use. In the manufacture of grinding wheels, the Young's modulus is regarded as a simply measurable tool of quality control. In research and development, however, it is commonly not known which theoretical modulus has to be attributed to a new composition or a modified sintering regime with resulting changes of the topology of the glassy (ceramic) binder and of the pores.

Any modeling calculation has to take into account a multitude of different theoretical approaches, which describe the Young's modulus depending on the pores' volume content, shape and topology. Such differences are illustrated in Figure 1 where the continuous matrix with isolated pores will, at equal porosity, exhibit a higher modulus and mechanical stability compared to the microstructure on the right with the partially sintered ceramic grains.

For microstructures of grinding tools (Figure 3 and 4), different manufacturing temperatures will change the viscosity of the glassy binder (introduced originally as a dry powder) with resulting consequences for the topology of the binder phase and of the shape of the pore channels. Of course, the calculation also has to integrate the total compositions with the moduli and Poisson numbers of the components, e.g. when diamond tools contain additional corundum grits or when the glassy binder is strengthened by very fine hard crystalline particles.

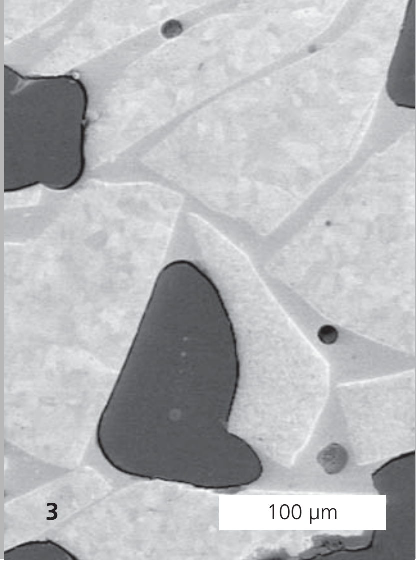
On behalf of Fraunhofer IKTS, a modeling program for windows was developed by Dr. W. Kreher at TU Dresden on the basis of complex theoretical investigations [1]. With IKTS data, e.g. for Al_2O_3, SiC, diamond and different glasses, the calculation gives Young's moduli and Poisson numbers for various hard material combinations. For compact grinding tools (Figure 4) or other porous components (Figure 5) with most different binder and pore configurations (resulting, e.g., from different compositions and firing regimes), the relation between porosity and Young's modulus can be calculated with a wide variety of input options (Figure 2):

- Different configurations of the glassy binder component
- Treatment of the glassy binder as a "matrix" or "mixture" of particles of the binder and of the hard ceramic
- Input of a shape factor for pores (with values < 1 for elongated channels) and selection of different pore topologies.

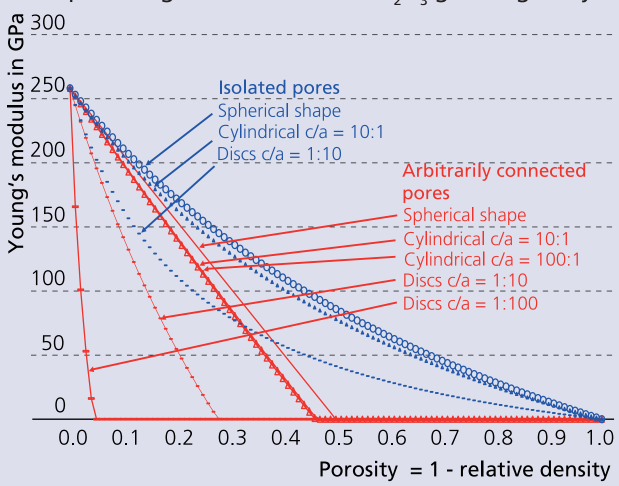
If necessary, supposed defects can additionally be considered in the description of flawed bodies and are entered as "Risse – Cracks" in the input example of Figure 2.

As an example, the first diagram shows the effect of different pore configurations and shapes on the modulus of grinding bodies made of 60 wt.-% corundum (Al_2O_3), 25 % cubic boron nitride (CBN) and 15 % glassy binder. The blue curves give the dependence on the porosity for a microstructure with isolated pores (topology of Figure 1, left) described by the effective field model, whereas the results for the case of connected pores (Figure 1, right; effective medium model) are plotted in red.

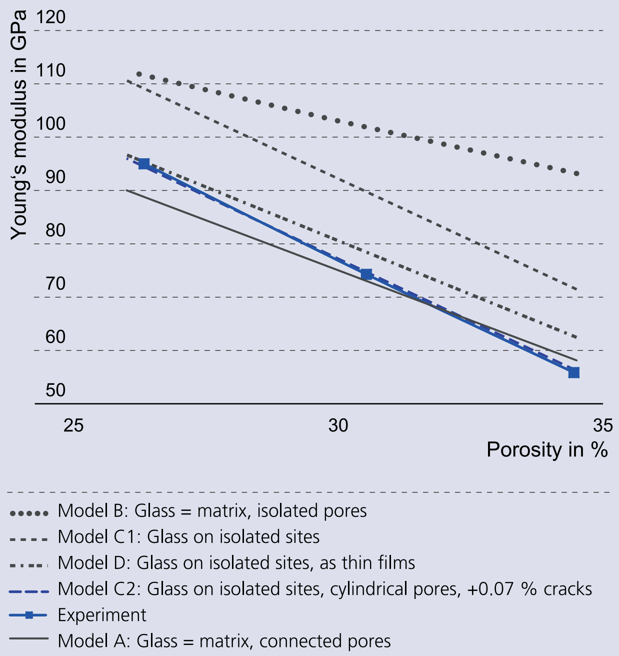
The second diagram demonstrates how the comparison of measured und calculated moduli of grinding bodies with 63 wt.-% corundum (Al_2O_3), 14 % silicon carbide (SiC) and 23 % glass indicates an insufficient sintering of these tools at 880 °C: An agreement of absolute values and of the slope is achieved for cylindrical pore channels if the glassy binder did not form a thin, homogeneous matrix yet and the grinding body contains a population of 0.07 vol.-% of cracks.



Influence of different pore structures on the dependency of the Young's modulus on the porosity using the example of a glass-bonded CBN-Al_2O_3 grinding body



Comparison of actual measured and modeled Young's moduli for different pore or defect structures using the example of a glass-bonded SiC-Al_2O_3 grinding body



Services offered

- Modulus/porosity modeling of complex grinding tools and of other ceramic components depending on composition and microstructural topology
- Development of grinding bodies and porous ceramics for use under mechanical loads

Reference

[1] W. Kreher, W. Pompe, Internal Stresses in Heterogeneous Solids, Akademie-Verlag, Berlin, 1989.

1 Porous Al_2O_3 microstructures with different pore topologies, described by approaches of an "effective field model" (left), "effective medium model" (right).

2 Input mask for the calculation of Young's modulus.

3 Complex microstructure of a grinding tool of polycrystalline Al_2O_3 grains, glassy binder (grey) and pores (dark).

4 Compact grinding wheel for metal work.

5 Low-defect porous Al_2O_3 tubes as substrates for filtration membranes, made by a casting process and sintering.

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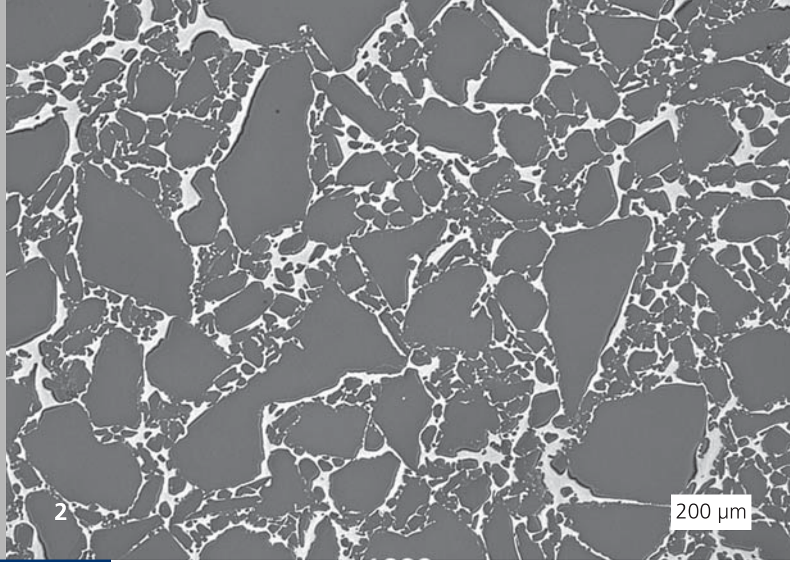


COMPLEX SISIC COMPONENTS VIA POLYMER CONCRETE CASTING TECHNIQUES

Dipl.-Ing. Steffen Kunze, Dipl.-Krist. Jörg Adler, Dr. Uwe Petasch

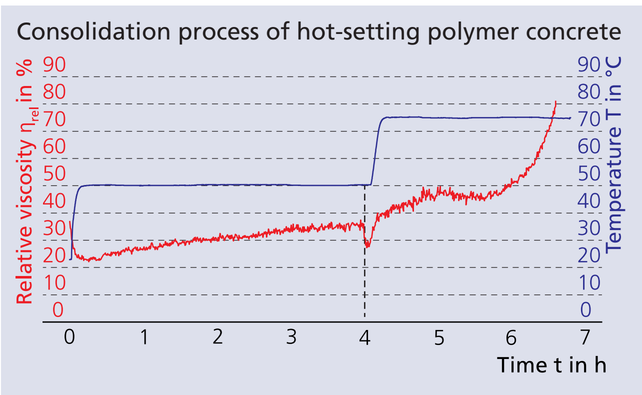
Initial situation

The virtually shrinkage-free manufacturing process of silicon-infiltrated silicon carbide (SiSiC) ceramics is ideally suitable for the production of complex shaped and large-volume components. Slip casting as well as the machining of isostatically pressed SiC green bodies are conventional forming processes for the manufacturing of such ceramics. However, these methods have technological limitations when used for the manufacturing of components with high differences in wall thickness and/or complex undercuts. Nowadays, the production of such geometrically complex parts demands a modular design in combination with other additional processes that lead to significant cost-intensive processes that incur from material, machine and personnel expenses.

Method of solution

The adaption of the polymer concrete production method offers an opportunity for the diversification of the molding with an economic processing method of SiSiC components.

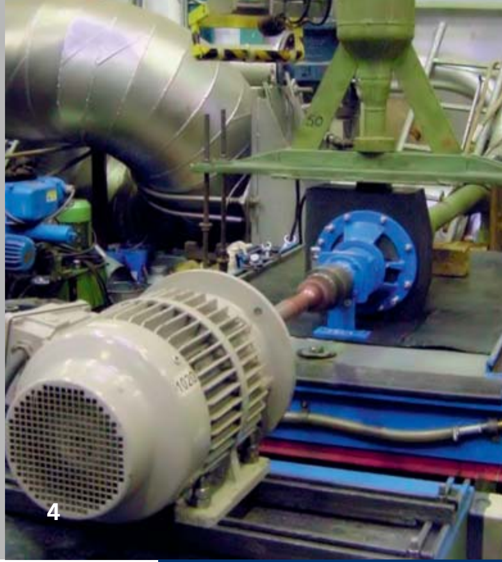
Polymer concretes that primarily consist of a mixture of polymeric binder system and coarse grain SiC can be cast in open molds without pressure. The usage of elastomers and wax cores in the casting mold enables a single step manufacturing of large and complex green compacts having undercuts and wall thickness differences.



In this process, the polymeric binder and its curing progress has a significant influence on the success of the casting procedure. In order to maintain the casting processes, which may take several hours, the resin primary requires an adequate pot life. However, during the casting process, the binder also needs to cure quickly to prevent the sedimentation of the SiC fillers. In the meantime, the resin needs to have high carbon yield during the pyrolysis stage.

In order to meet these requirements, a novolak with a high carbon yield was used. To achieve the specific curing characteristics of this resin, it was necessary to develop a hardener combination of amine (hexamethylentetramine) and epoxy (bisphenol A diglycidylether) additions. Using this approach, the cure temperature of the resin was reduced below 80 °C, which is an important condition for the use of wax and elastomer preforms. After the consolidation, the polymer concretes are converted into SiSiC in two steps. During the pyrolysis step that takes place up to approx. 900 °C, the polymer matrix converts into a glassy carbon due to the splitting and the subsequent vaporization of low-molecular compounds. Afterwards, the porous body is infiltrated with liquid silicon, forcing a reaction with the carbon binders to a secondary SiC phase.

After the pyrolysis and silicon infiltration steps, the length decrease of the components amounts to merely 0.1 %. The corresponding shrinkage-free manufacturable SiSiC is characterized by a very coarse-grained texture with grain size diameters slightly higher than 1000 µm. Nevertheless, its mechanical properties are considerably good. The material's Weibull strength, correlated to a unit volume of 1 mm^3, amounts to



175 MPa at a Weibull modulus of 17. Its fracture toughness of 2.8 $MPa\cdot\sqrt{m}$ as well as the achieved density of 3.05 g/cm^3 are in range of conventional SiSiC ceramics. The ceramics generally feature high hardness and wear resistance. Furthermore, it is gas-tight, chemically resistant against acids and solvents, temperature-resistant up to ca. 1300 °C and has a good thermal conductivity of ca. 150 W/m·K at room temperature.

Technical applications

The economic efficiency of this manufacturing method allows for the substitution of conventional materials used in chemical and plant engineering, such as steel or iron cast. Due to the outstanding chemical, thermal and tribological properties of SiSiC, longer lifetimes and/or higher productivity of machines are practicable.

Consequently, radial pump impellers were produced as first applications in cooperation with SICcast Mineralguß GmbH and Düchting Pumpen GmbH. In this context, the industrial casting units for the production of polymer concretes with batch sizes up to 600 kg were also successfully tested. The range of application of such ceramic pumps includes processes with challenging media, such as corrosive chemicals or abrasive particles-enriched suspensions. Recently, a radial pump impeller prototype with an external diameter of 436 mm, a load speed of ca. 1000 1/min and a nominal power of ca. 90 kW has passed a prototypical durability test.

In addition to the pump industry, there are further potential application areas, such as the production of nozzles, mills, heat exchangers or burners. Due to its high rigidity and its low thermal expansion coefficient, the ceramics are also well qualified for the production of housings and carrier systems in high-precision applications demanded in optical industry.

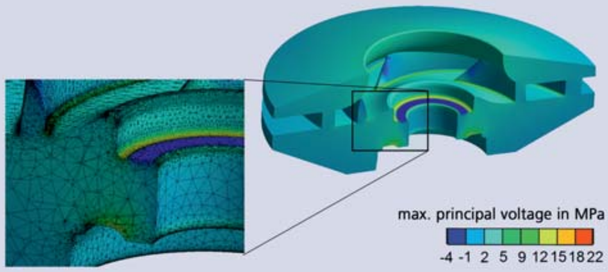
Acknowledgement

The presented works are results of the successful cooperation with the companies SICcast GmbH and Düchting Pumpen GmbH. Likewise, we want to thank the Federal Ministry for Economic Affairs and Energy for the sponsorship with-in the ZIM project KF2087322LL1.

Services offered

- Process and system development for reaction resin concretes and SiSiC structural ceramics
- Dimensioning and manufacture of application samples and prototypes
- Component and material characterization

FEM simulation of the stress distribution in the pump impeller



1 *Casting process of reaction resin concrete.*

2 *Structure of the coarse-grained SiSiC.*

3 *Ceramic radial pump impeller (diameter of 250 mm).*

4 *Pump test rig of partner Düchting Pumpen GmbH.*

5 *Deflection nozzle (350 x 250 x 250 mm^3).*

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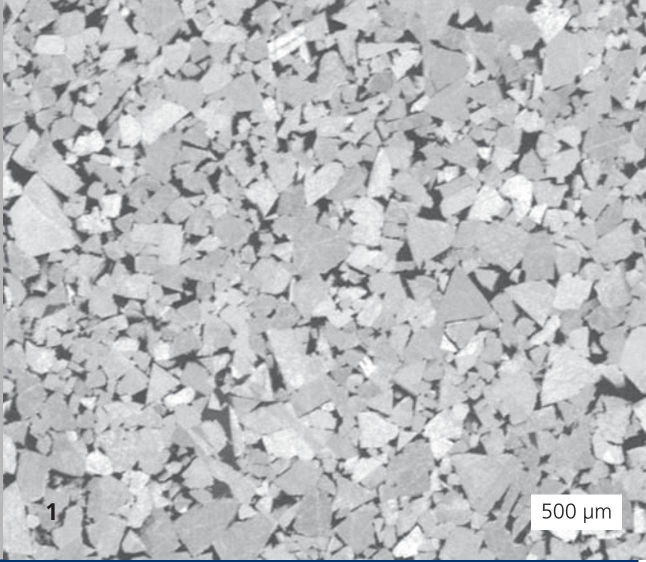


NANOSCALED TOOL MATERIALS FOR NEW MANUFACTURING TECHNOLOGIES

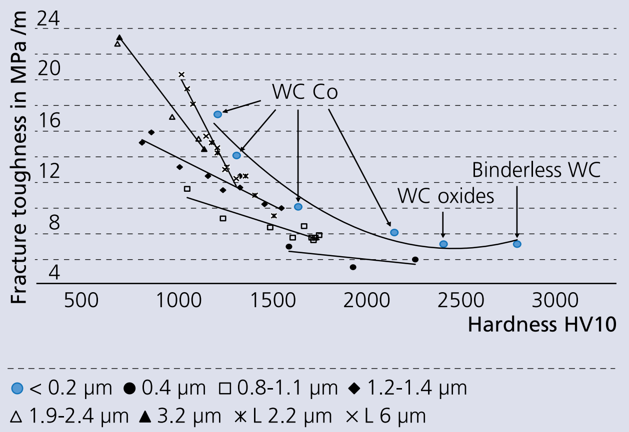
Dipl.-Ing. Johannes Pötschke

For challenging manufacturing tasks, like the machining of titanium- or nickel-based superalloys, the machining of hardened steels, the turning and milling of hard metals or ceramics as well as the pressing of high-precision glass lenses, a new and particularly efficient tool material is needed. During the last years, the group "Hard Metals and Cermets" has developed several nanoscaled tungsten carbide-based (WC) hard metals. By optimizing the composition and the powder metallurgical production method, tool materials with a significantly increased hardness and fracture toughness could be produced. The production is based on the use of very fine-grained tungsten carbide powders with a mean particle size d_{BET} of around 90 nm. Through the use of adjusted mixing and milling processes, very homogenous mixtures could be made. Green parts were produced by using conventional uniaxial as well as cold isostatic pressing techniques. The sintering of tool parts or blank parts depended on the kind and amount of metal or oxide binder at sintering temperatures from 1300 °C for nanoscaled hard metals over 1550 °C for nanoscaled tungsten carbide oxide composites to 1900 °C for binderless hard metals.

Due to a very fine grain size, these binderless hard metals possess a very high hardness of over 2800 HV10 units. Due to their small grain size as well as their very low surface roughness after polishing, they are the perfect material for the production of pressing dies for high-quality glass lenses. Together with composites made of tungsten carbide and zirconia or alumina, these kind of composites are also used as wear parts or sealing rings.

Nanoscaled tungsten carbide-cobalt hard metals with a metal binder content between 6 and 15 wt.-% show a significantly higher hardness as comparable ultrafine hard metals used today. As shown in diagram 1, both hardness and fracture toughness can be increased by using nanoscaled tungsten carbide starting powders. Furthermore, the bending strength can be increased to more than 4500 N/mm².

Hardness and fracture toughness of nanoscaled WC-based hard metals



Within the BMBF project NanoHM, turning tests on nickel-based superalloys done by Kennametal Widia Essen showed that nanoscaled hard metals have superior properties compared to conventional hard metals tested under the same conditions.

Services offered

- Optimization and production of binderless tungsten carbide ceramics for special applications and production environments
- Development of cemented carbides or tungsten carbide-free cermets
- Characterization of hard metals or cermets
- Failure analysis

1 *Structure of a nanoscaled hard metal WC-10Co, chord length < 100 nm.*

2 *Tools made of nanoscaled hard metal (grinding by Fisch-Tools, Austria).*

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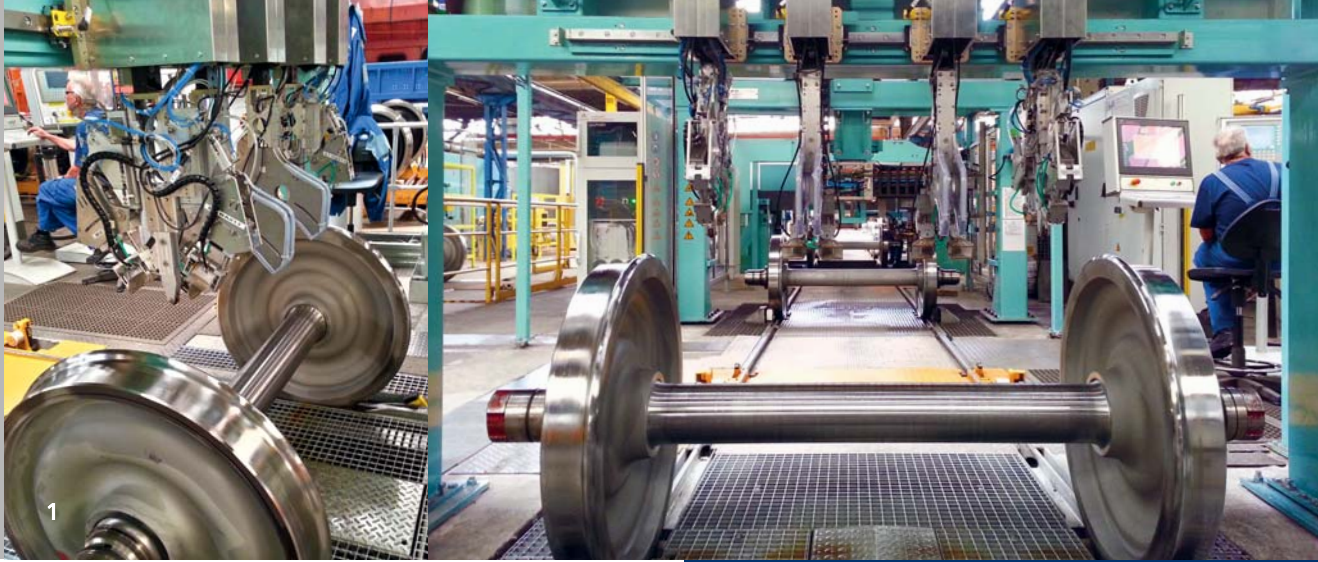


PHASED ARRAY ULTRASONIC TEST SYSTEM FOR WHEELSET SOLID SHAFT TESTING

Dipl.-Ing. (FH) Christian Richter, Dipl.-Ing. Andreas Floet, Henry Scholz

In order to avoid accidents and incidents in rail operation, non-destructive test methods are used for the maintenance of railway vehicles. By applying complex measurement systems, fine cracks or corrosion can be identified and evaluated.

Regarding vehicles in the rail freight transport, wheelset solid shafts are mainly used. These parts are susceptible to defects and fatigue due to their usage profile (high alternating load, operational performance, rail condition). The wheelset solid shafts are removed as part of the scheduled maintenance and tested for possible defects with ultrasonic technology. So far, the Deutsche Bahn used partly automated phased array inspection systems of the first generation.

Within the scope of an industrial project involving Fraunhofer IKTS, the system integrator arxes-tolina GmbH and the mechanics partner BIP-Industrietechnik GmbH, these inspection plants were replaced by optimized ones.

In the new plants, several ultrasonic devices type "PCUS® pro Array" are utilized together with the fully automated test software "PCUS® pro Lab". The ultrasonic devices, developed at IKTS and optimized for industrial operations, are characterized by a compact design, high channel numbers, an extraordinary signal-noise ratio as well as an outstanding data transmission rate. Their compact design allows the assembly close to the test probes. So, interferences and signal distortions, which are accompanied by long signal cables, are minimized.

The test software developed at IKTS was improved and optimized as part of a project together with arxes-tolina GmbH. It enables a fast and reliable evaluation of ultrasonic images while simultaneously operating the software intuitively and ergonomically. In the process, the software is capable of parallel actuating all ultrasonic test devices integrated in the inspection system and therefore, minimizing the predefined cycle time by simultaneously using several phased array probes.

As part of the industrial project, phased array probes were manufactured at IKTS and adjusted to the requirements provided by arxes-tolina GmbH, to be able to test varnished and coated wheelset solid shafts with high susceptibility. Hence, the previously necessary mechanical pre-treatment of the shaft surface, for example, by sandblasting is omitted. In addition, the specifically curved probes can be applied for all shaft designs.

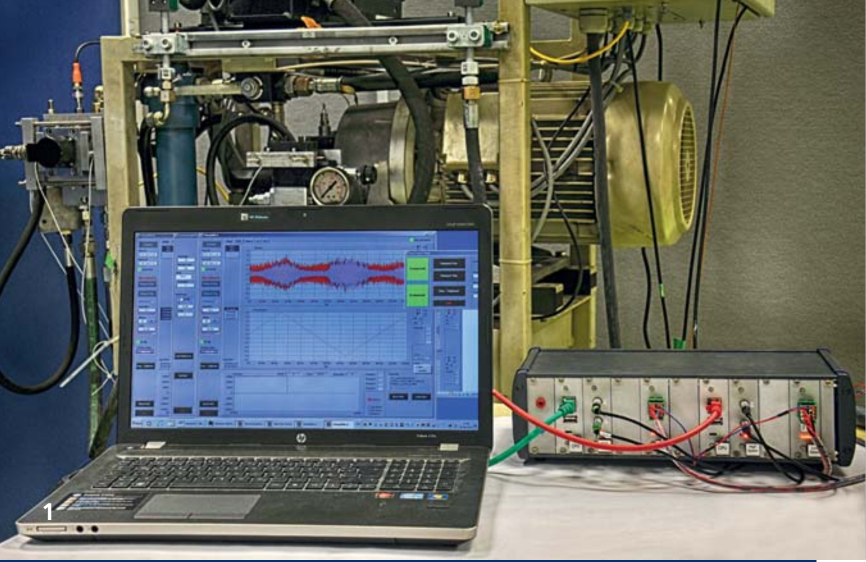
The newly developed ultrasonic test systems are optimized with focus on high reliability, long lifetime, minimal wear and, thus, low maintenance and repair cost.

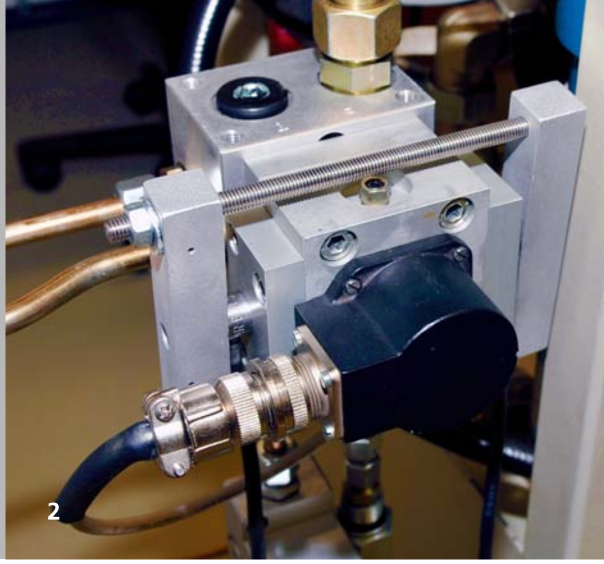
Two plants were already set up by the DB Fahrzeuginstandhaltung GmbH (heavy maintenance) and accepted after the test operation. These systems serve as reference for international industrial partners. Currently, there are ongoing negotiations about further plants.

Services offered

- Ultrasonic systems according to customer specifications
- Development and adjustment of test software
- Development of high-performance test electronics

1 *Optimized non-destructive testing of wheelset solid shafts used in rail freight transport.*





MONITORING OF HYDRAULIC COMPONENTS

Dipl.-Ing. Mareike Stephan, Dipl.-Geophys. Eberhard Schulze

Task

The aim of the development work was an effective monitoring of hydraulic test stands with the help of different methods.

Until now, it is necessary to do regular maintenance checks, even if there is no fault in the system. Using the developed system, a more cost-efficient and condition-based maintenance shall be possible.

Method

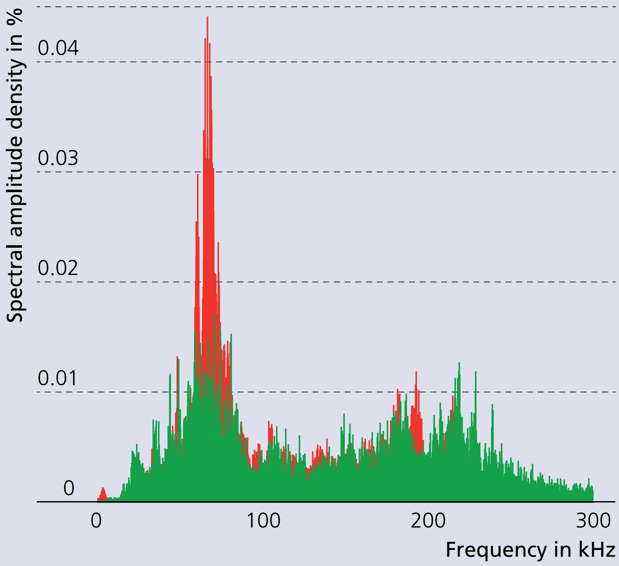
The focus of the method is the monitoring of the valves, in particular the servo valves, using structure-borne sound sensors. By means of oil flow, acoustic structure-borne sound signals are generated in a very broad frequency spectrum between 10 kHz and 500 kHz, which characterize the hydraulic processes. Changes in the state of perfused components, e.g. due to the abrasion of valve cones, lead to varying signal properties. Features, which are suitable for the monitoring of hydraulic components, can be extracted from the envelopes of time signals and the amplitude spectrum.

Hard- and software

The hydraulic monitor consists of digital modules that can process two channels of high-frequency acoustic signals with a possible sampling rate of up to 4 MHz and 4 channels of low-frequency variables, such as temperature, flow volume, pressure and valve control current.

The data collection and transmission to the PC is based on a microcontroller within the measurement device. The measurements can be executed continuously or at defined time intervals.

Amplitude density spectra of acoustic signals from intact and defect valves



1 *Test stand for monitoring hydraulic components.*

2 *Servo valves with acoustic sensors.*

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AUTOMOTIVE ELECTRONICS – MATERIALS AND RELIABILITY

Dr. Martin Gall, Dr. André Clausner, Dipl.-Ing. Christoph Sander, Dr. Matthias Kraatz, Prof. Ehrenfried Zschech

The amount of electronic devices in vehicles increases continually. Several causes exist for this phenomenon: On the one hand, the application of most modern electronics drastically increases the functionality and operability and, on the other hand, the efficiency is also significantly improved (combustion control, gearshift, etc.). In addition, automotive networking plays an increasing role. Next to an increasing range of infotainment, autonomous driving becomes more important, which in turn requires higher standards in performance, information density and transfer rates of micro- and nanoelectronics. While only "older" technology nodes were used until approx. 2010 because of their higher and better reliability (completed maturation cycle), latest technologies, such as 20/22 nm CMOS processes, are applied in the automotive industry. In order to ensure operating stability of these new technology nodes, Fraunhofer IKTS together with Volkswagen AG and Fraunhofer II-EAS cooperate in the field of reliability of micro- and nanoelectronic devices. The most important differences in requirements for "consumer electronics" and "automotive" are shown in Table 1. While most of the semiconductor manufacturers cover the less rigorous requirements for "consumer electronics", it is definitely not the case for "automotive". Particularly the targeted lifetime (15 years as compared to merely 3) and the failure rate (0 % "zero defects" as compared to < 10 %) show significant differences.

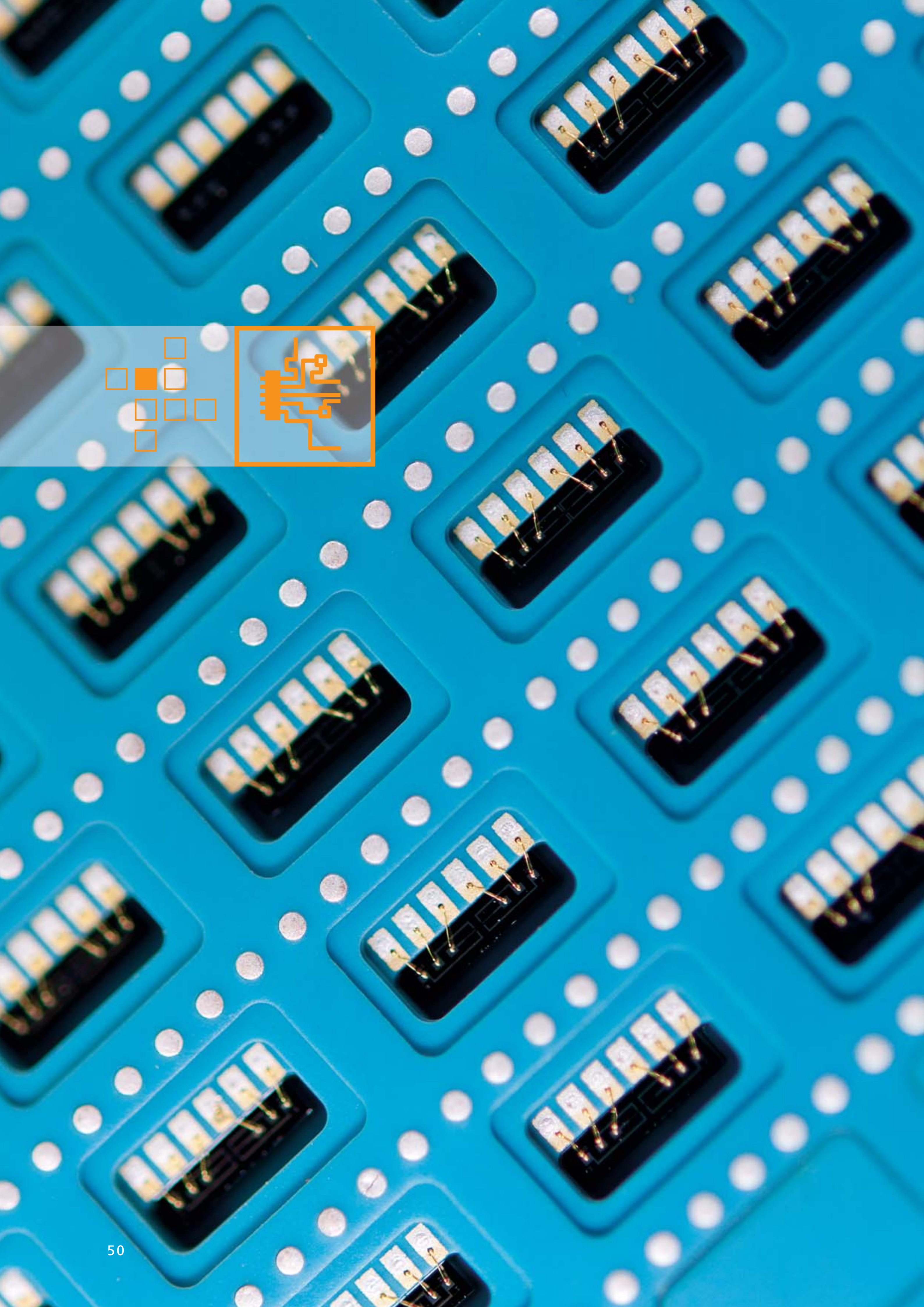
Based on today's state of the art microelectronics, which are qualified with respect to automotive applications, properties, potentials and challenges will be realized for future microelectronics in this scope. Essential construction and process components of microelectronic products will be evaluated in terms of reliability assessment, including electromigration (EM), stressmigration (SM), time-dependent dielectric breakdown (TDDB), temperature cycling (TC), gate oxide integrity (GOI), etc. Standard models for extrapolations under application-specific operating conditions are critically analyzed and tested for validity.

On the basis of a multiscale materials database, developed at IKTS and describing the characteristic thermomechanical properties of applied materials in semiconductor processes, the reliability-limiting mechanisms, which determine the lifetime of a component deployed in the automotive field, will be further analyzed. This lifetime is characterized as a function of the automotive application area. The entire construction process of new electronic systems (e.g. an electronic control unit) is considered.

Different requirements for microelectronics

Property	Consumer	Automotive
Temperature range	0 °C to +40 °C	- 40 °C to +155 °C
Operating time	1–3 years	10–15 years
Vibration	Negligible	0–2000 Hz
Acceleration	Negligible	500 m/s^2
ESD safety	Up to 3 kV	Up to 15 kV
Tolerated failure rate	< 10 %	Goal: zero defect
Documentation of failure behavior	No	Yes
Long-term supply	No	Up to 30 years

Important applications of micro- and nanoelectronics:
1 *Consumer electronics (Source: commons.wikimedia.org).*
2 *Automotive (Source: Volkswagen AG).*



BUSINESS DIVISION

ELECTRONICS AND MICROSYSTEMS

Project reports

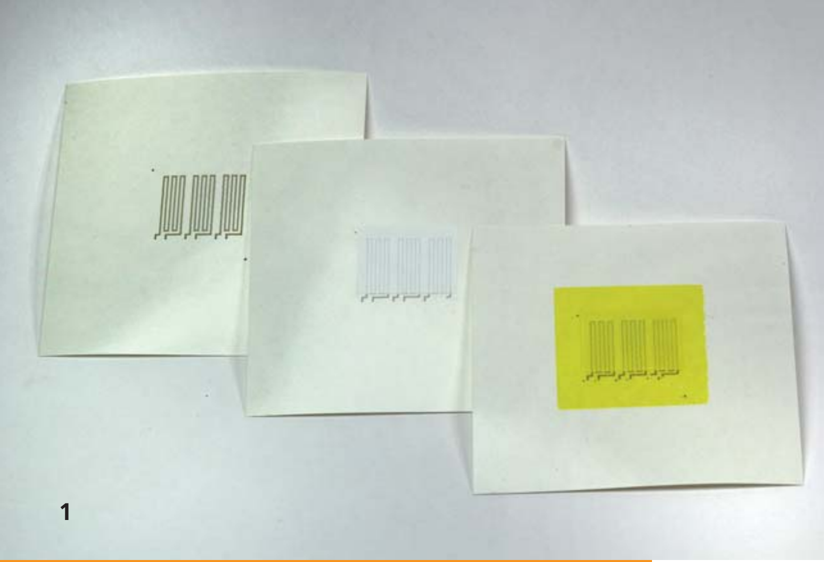
"Electronics and Microsystems" is a business division in which Fraunhofer IKTS offers materials, technologies, components, and systems for microelectronics and nanoelectronics, energy engineering, sensors and actuator technology as well as for industrial testing systems.

In the future, microsystems will not only become substantially more sophisticated, more robust and smaller, they will also increasingly interact directly with their environment through enhanced functionalities. This will result in ever more complex demands being placed on the development of more cost-effective and reliable materials as well as production solutions for miniaturized assemblies. Fraunhofer IKTS resolves these challenges by taking an integrated approach to materials, processes and system design.

Fraunhofer IKTS engineers develop functional ceramic materials with extraordinary properties that make them suitable for use in harsh environments. These materials can be processed using an array of technologies (synthesis, packaging, joining, deposition and structuring technologies), depending on general requirements and customer preferences, and then be applied to sophisticated microsystems. Using standardized production processes as well as tried-and-true methods, they succeed in attaining competitive cost rates. Ceramic components can also realize additional fluid, thermal, sensor, and actuator functions that interact directly with the electronic components of signal processing and power electronics. Fraunhofer IKTS has special expertise in relation to multifunctional materials, such as piezoceramics, electrocaloric materials and shape memory alloys. These kinds of materials can be used to engineer so-called "smart" systems in which the material itself connects multiple functions with each other.

Sensors and complex sensor systems represent a focus within this business division's portfolio, enabling the team to record multiple chemical, electrochemical, electrical, thermal, acoustic, electromagnetic, mechanical and optical parameters. Adapted to customized process specifications, evaluation electronics – together with its hardware and software – are created entirely in-house at IKTS. These systems are utilized in automotive engineering and energy engineering, non-destructive testing as well as condition and process monitoring.

In the "Electronics and Microsystems" business division, customized materials, design rules, and testing technologies are available so that it can continue to expand the fields of application for miniaturized systems, attenuate development cycles, and ensure systems reliability. Its comprehensive technical infrastructure and specific offerings to the industrial sector ensure that its development processes retain their industrial focus, for efficient transfer of expertise and technology to the customer.



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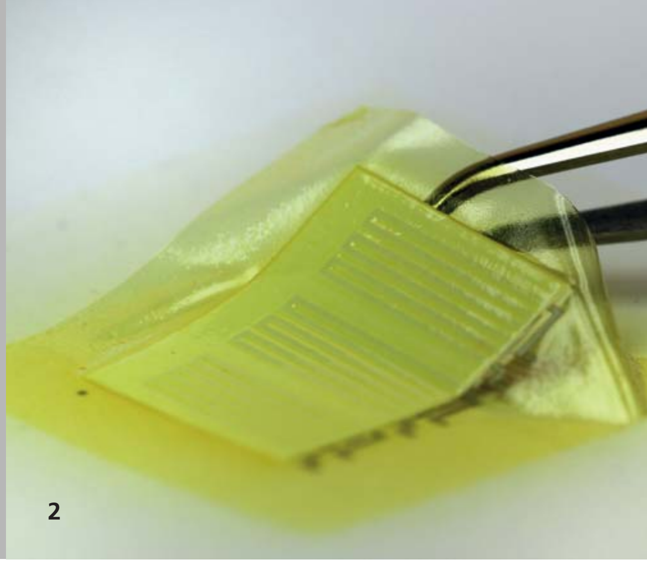

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PREDESIGNED THICK-FILM SENSORS FOR VARIABLE COMPONENT SURFACES

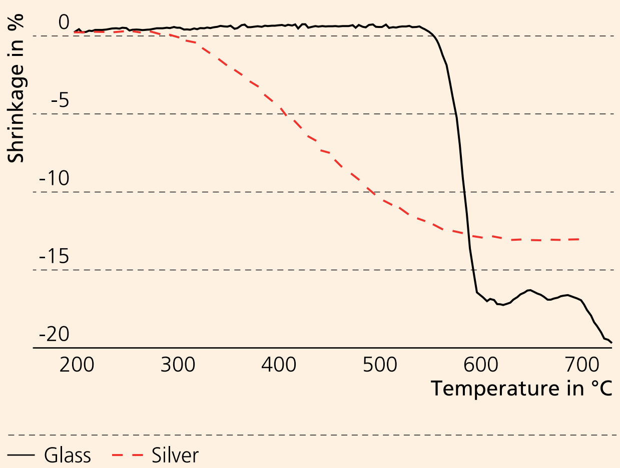
Dipl.-Min. Thomas Seuthe, Dr. Markus Eberstein

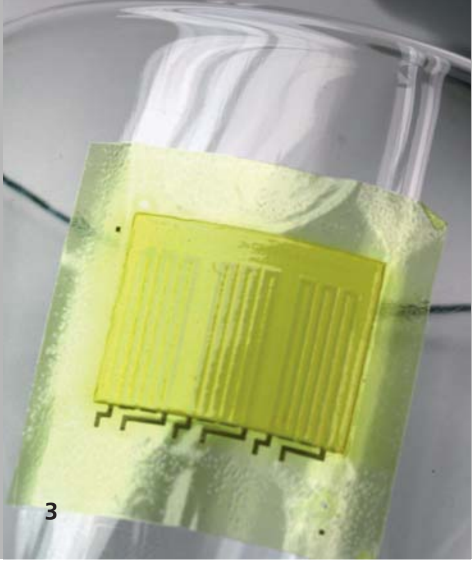
The production of functional ceramic multilayers via deposition methods, such as screen printing, dispensing and aerosol printing is a common practice today. However, in some cases significant effort is necessary in a production environment in order to perform the printing and firing process with required precision and reproducibility (clean rooms, staff). The application areas are also limited by the size of the substrates to be processed. Thus, printing on substrates exceeding an edge length of one meter is difficult to realize with a conventional laboratory printer. To avoid these effects, a decal method was analyzed where the issued structure, fulfilling all requirements for layer thickness and contour characteristics, was first printed on a non-sticking pad with a multilayer structure, then dried and, finally, transferred to substrates of any size using a transport layer as it has already been used for the color design of decorative ceramics. This type of substrate processing allows transmission of thick-film sensors on substrates of various size and shape, whereby the scope of thick-film technology is expanded. Therefore, a two-layer safety circuit for tempered safety glass could be realized within a research project.

The production of tempered safety glass is carried out by a heat treatment process, where a conventional float glass plate is rapidly heated in a tempering oven above its transformation temperature (T_g) and is then chilled to room temperature. Thus, the frozen thermal stresses lead to a significant hardening of the glass. Tempered safety glass can be applied for, e.g., sliding glass doors, glass tabletops, wall cladding, car side windows and safety glasses for shopping windows. Here, the need for two-layered alarm circuits arose, consisting of a conductive path covered with a glass insulating layer, which are co-sintered during the short heat treatment inside the tempering furnace. The first challenge was the precise deposition of both superimposed layers on a coated paper substrate by screen printing. An extensive optimization of the printing parameters allowed for the exact and flawless deposition of the superimposed layers (conductive path, glass insulation, transfer paint). These layers must adhere to each other and be transferable from the paper substrate to the glass substrate without damaging either of the layers, which would affect their functionality. Because tempered safety glass must not be reheated above T_g, the second challenge consisted of sintering the assembled circuit directly inside the tempering furnace at high heating rates of up to 100 K/s.

Furthermore, the decal-applied layers must densify sequentially and non-simultaneously during the co-sintering process, so that escaping gases in the lower layer (conductive path) can evaporate through the upper, still porous, layer (glass insulation). In order to meet this requirement, the silver and glass powders used to create the layers were adjusted in their sintering behavior, so that the firing during the co-sintering process with heating rates up to 100 K/s can gradually take place and the layers do not need to be processed post-firing.

Shrinkage behavior with increasing temperature of the used glass powder (black line) and the silver powder (red line) using hot stage microscopy





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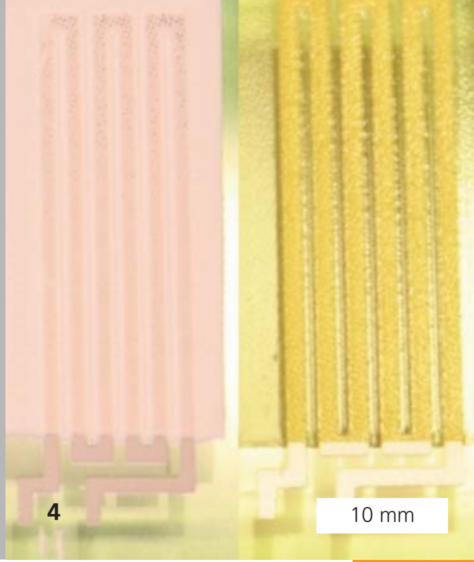

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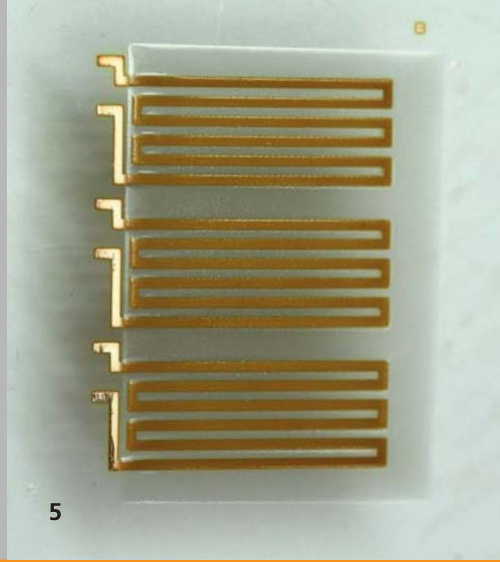

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The optimized sintering process of the silver powder and the glass powder used are shown in Figure 1. The sintering of the silver powder starts at about 300 °C and is almost completed at above 550 °C. Then, the sintering of the overlaying glass paste (insulation layer) begins. Decals optimized for the firing process in the glass tempering furnace allow for the production of robust and defect-free layers for alarm circuits. The specific resistivity of the conductive paths nearly reaches values of pure silver. The insulation layer shows dielectric strength of more than 1 kV at a thickness of about 20 µm.

The new decal process for the production and transmission of technical ceramic multilayer structures ensures reproducible quality and easy handling of high-resolution multilayer constructions and also avoids the limitations of the printable substrate size. Therefore, it is suitable for the realization of high quality active and passive electrical elements (sensors, antennas, smart labels) on substrates of variable sizes or curved surfaces, completely opening up new areas of application of thick-film technology.

Acknowledgements

The Federal Ministry of Economics and Technology and the AiF are greatly acknowledged for supporting the research project KF 2087336AG3. Furthermore, we thank our project partners H. J. Amann and R. Petersen of Amann GmbH in Rehau, Germany for their excellent cooperation.

1 *Functional multilayers printed on paper consisting of conductive path, insulation layer and varnish layer (from left to right).*

2 *Separation of the functional layer from the carrier paper.*

3 *Multilayer ceramics before sintered on a drinking glass with a curved surface.*

4 *Conductor loop with insulation layer on tempered safety glass before (left) and after (right) firing.*

5 *Conductive path with insulating layer on tempered safety glass after firing.*

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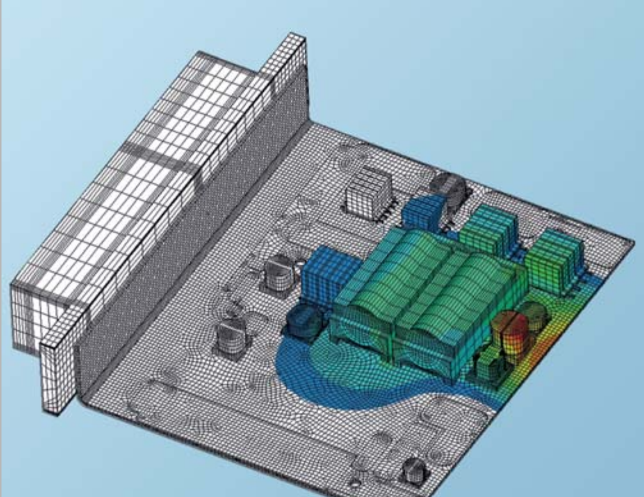

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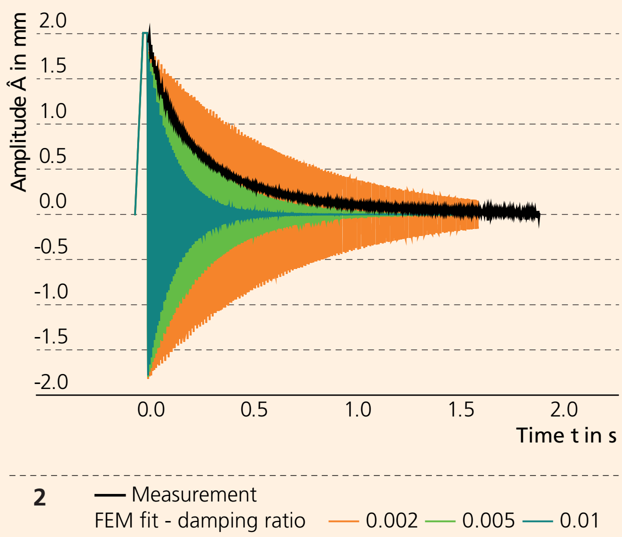

2

ELECTRONICS AND MICROSYSTEMS

DESIGN SUPPORT TOOL FOR SAFEGUARDING VIBRATION-RESISTANT ELECTRONICS

Dr. Mike Röllig, Dipl.-Ing. René Metasch, Dipl.-Ing. Robert Schwerz

Reliable electronics are a key component for high-value and safety-relevant products. The focus of the presented project rests on reliability of engine control units (ECU), which every automobile is equipped with. Their operational stability under mechanical shock as well as vibrations has to be guaranteed for every driving situation.

The structural-mechanical simulation by Finite Element Method (FEM) crucially contributes to the design and construction of ECU components. The simulation allows for the comprehension of complex mechanical interactions and the rapid realization of different construction and material variations. Providing a robust design for the ECU in preferably short time is the aim here so that no critical mechanical stresses lead to malfunction or early failures of electronic components.

In the framework of the project, a design support tool was developed, which realizes an extremely accelerated mesh generation of FEM models. The time factor is 1:250. Complex ECU packages can now be modeled within 10 minutes instead of 5 working days (Figure 1). The model includes the geometry, materials and load profiles. The design support tool is based on a FEM programming language (APDL-ANSYS) and accesses a created database, which carries parametric submodels for creating electronic components. This database can be tailored to the customer database of qualified components, i.e. small effort is required to extend the database with new qualified components.

Via a graphical user interface (GUI), all relevant design parameters are retrieved, which are necessary for a load calculation under vibration. The current version of the tool allows the load calculation in the form of Power Spectral Density (PSD) and harmonic vibrations.

The evaluation of well and less well placed components is based on the calculated mechanical stress. Within the project, a criterion was defined, which allows for the comparison of overused or unused components. Beforehand, a calibration of the vibration behavior of substrates based on experimental vibration measurements on a variation of real printed circuit boards was conducted. The results lead to the variable material dataset for the PCB with a copper, fiber glass and polymer mixture. Later, the substrates were equipped with electronic components. Furthermore, the mechanical stress limitations of the electronic components, which exist as criterion for their failure, were determined on the basis of vibration-mechanical step tests.

Right after the calculation, the tool hints at critical component positions or at stabilization steps of the whole package. The designer receives crucial results to stabilize the ECU package in short time.

The design tool approach shall also be transferred to thermal-mechanical stress analyses. Here, a combination of roughly and finely meshed components will be integrated into a solution routine.

Acknowledgements

The team thanks the Continental Automotive GmbH Regensburg for the confidence invested in us.

1 FEM mesh of an electronic assembly of an engine control unit modeled in 10 min, plot of calculated deformations and white noise vibration.

2 Measured damping behavior of a substrate and calibration of damping coefficients by FEM.

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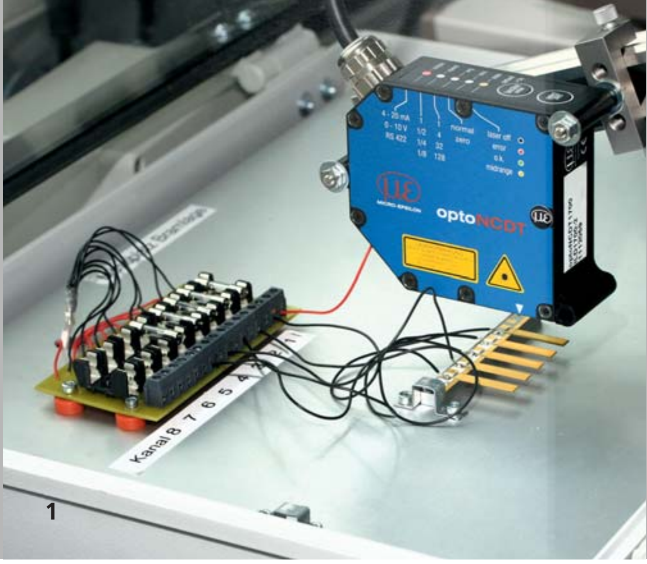

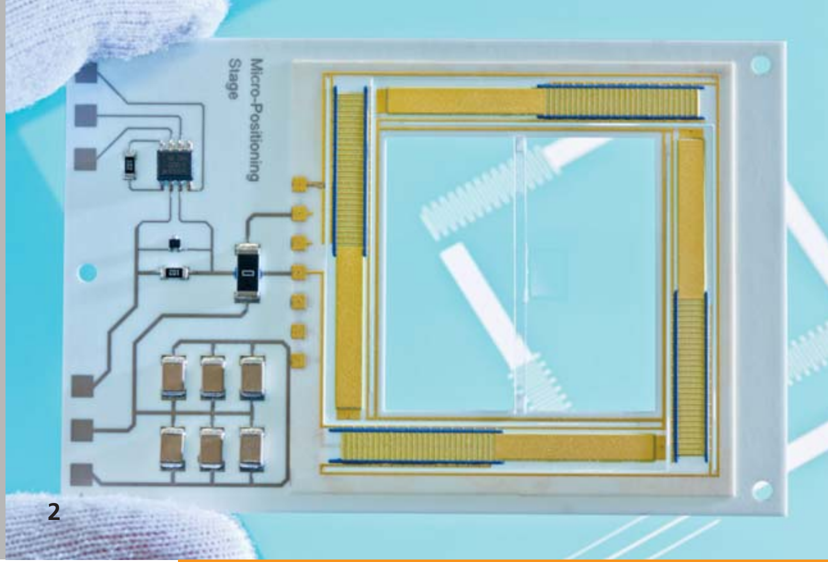

SMART TRANSFER – TECHNOLOGY PLATFORM FOR THE DEVELOPMENT OF SMART PRODUCTS

Dr. Andreas Schönecker, Dr. Holger Neubert, Dr. Peter Neumeister

The here introduced technology platform "Smart Transfer" is part of the initial concept "smart³ I materials-solutions-growth" [1] supporting the development of marketable products of high functionality combined with structural simplicity and is based on the BMBF framework program "Twenty20 – Partnership for Innovation" [2]. The proposition of networking and cooperation addresses primarily SMEs, which are interested in increasing their economic success by overcoming limitations due to lack of integration technologies, path-limited innovation processes and unexplored market shares. Therefore, these SMEs search for means to extend their added value chain. Advanced technologies allowing for the development of smart products are part of the smart³ network and are open for use to the contract partners. For this purpose, appropriate organizational and operational regulations are developed and tested in practice. The general aim is an open technology platform in technical and organizational terms, which also protects the specific know-how of the users.

The main focus of the technology offer incorporates services concerning design and technology development for the integration of piezoceramic components in microsystems. Particular emphasis is placed on additive manufacturing, two-component injection molding and ceramic thick-film technology. Materials, component and end product manufacturers of different markets can benefit from the technology platform. A first leading application is represented by electromechanical generators extracting energy from mechanical vibrations of the surrounding to drive low-power electronics. Key technical questions concern the manufacturability of the generator module using the available processes of microsystems technology, the possibility of electronic integration into the package and the proof of evidence to power a certain electrical load. A further important issue concerns economical production. The attainable prices on the market are estimated to guide the development of the production technology. Further exemplary applications will be deduced through dialog with contract partners.

Technology partners developing the platform „Smart Transfer" comprise Fraunhofer IKTS, IWU and IAP, and XENON Automatisierungstechnik GmbH, supported by experts in the fields of application of shape memory alloys and synthetic materials. Appropriate organizational and cooperational structures of the technology platform are analyzed by the Chair for Inter-firm Cooperation at Freie Universität Berlin and will be implemented by the partners of the platform. Triple Helix DIALOG develops the principles of internal and external communication. The perception of end consumer as part of the research and development processes is ensured by incorporating skills in design and art. The technology partners are able to demonstrate the existing technology know-how practically and exemplary, and are willing to transfer it to applicants within the framework of funded or directly assigned research and development projects. An internet-based tool will be used to efficiently and systematically organize appropriate partnerships between service providers of the smart³ technology platform and service recipients.

Services offered

- Demonstration of marketable value chains by utilizing the technology platform (shared production) as part of product development processes
- Evaluation of value chains for new products by shaping trial production processes
- Support of marketability tests of innovative products

Sources

[1] www.smarthoch3.de
[2] www.unternehmen-region.de/de/6829.php

1 *Field test of bender actuator.*
2 *Micropositioning system for optical lenses.*

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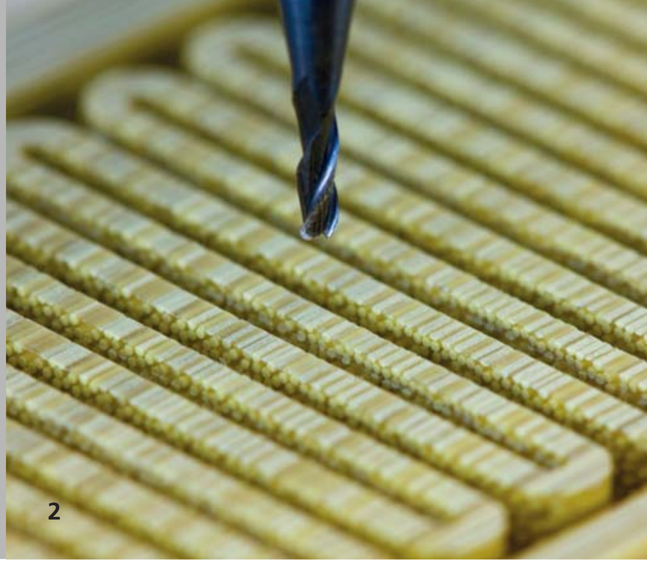

2

TAILORED COMPOSITE TRANSDUCERS BASED ON PIEZOCERAMIC FIBERS AND PEARLS

Dr. Sylvia Gebhardt, Dipl.-Ing. Kai Hohlfeld

Piezoelectric transducers based on piezoceramic polymer composites are predominantly used as sensors, actuators, ultrasonic transducers or energy harvesters applied in adaptronics, medical technology and non-destructive testing. In respect of high-performance and cost-effective production, piezoceramic components as well as thereof derived piezoelectric composites have to be tailored to application needs. While piezocomposites with aligned fiber arrangement are advantageous for actuators and ultrasonic transducers, sensors and energy harvesters also accept random arrangement of piezoceramic components within the polymer matrix.

At Fraunhofer IKTS, a fiber spinning plant is available, which allows for quasi-continuous fabrication of dense piezoceramic fibers. The basic principle of the technology relies on a phase inversion process by which a solvent-based slurry consisting of binder solution, piezoceramic powder and additives is spun through a spinneret into an aqueous precipitation bath. By substituting the organic solvent inside the ceramic slurry with water as a dissolvent, the binder coagulates and a rigid green fiber is formed. Diameter of the piezoceramic fibers can be adjusted by setting of spinneret diameter D, extrusion velocity v_E and running speed v_R during the fiber spinning process. Piezoceramic fibers with diameters d = 100–800 µm have been fabricated so far.

For fabrication of spherical piezoceramic components, the solvent-based slurry is dropped into the precipitation bath. Fall length l and spinneret diameter D define geometry and diameter of the resulting components. By optimizing the fall length, spherical pearls can be produced. Stretched or flattened objects occur when a too low or too high fall length is used. The dropping rate can be controlled by the pressure p. Piezoceramic pearls with diameters d = 0.8–1.6 mm can be fabricated using spinneret diameters of D = 0.2–0.8 mm. Both technologies allow for an efficient production of dense piezoceramic components in a broad geometrical variety.

For transducer manufacturing, piezoceramic components are embedded into a polymer matrix combining functionality of the piezoceramic with mechanical stability of the matrix material. Piezocomposite transducers can be used in a wide range of application fields. For vibration and noise damping as well as for structural control, piezoceramic fibers are aligned in parallel and infiltrated with an epoxy polymer. After exposing the fiber surface by grinding or dicing, interdigital electrodes for poling and electrical operation are deposited. As a result, a patch transducer particularly suitable for sensor and actuator function as well as for energy harvesting purposes is developed.

For fabrication of ultrasonic transducers for non-destructive testing, medical and sonar applications, piezoceramic fibers are also aligned in parallel but in a three-dimensional arrangement. After the infiltration with a polymer and subsequent curing, the piezofiber polymer block can be easily shaped into any form by dicing, CNC machining and grinding. By varying the fiber arrangement (defined/random), thickness and shape of the so-called 1–3 composite, ultrasonic transducers can be tailored for different tasks (high frequency/low frequency, focused/non-focused, segmented/single element).

Piezocomposites based on piezoceramic pearls seem to be suitable for sensor or energy harvesting applications. In this approach, a monolayer of piezoceramic pearls is integrated into a polymer matrix. Surface of the spheres is exposed by grinding or polishing. Then, planar electrodes can be applied. The technique is very suitable for cost-effective fabrication of large-area transducers with lower power density demands.

1 *Fabrication of piezoceramic fibers by fiber spinning process.*

2 *CNC machining of piezofiber composite.*

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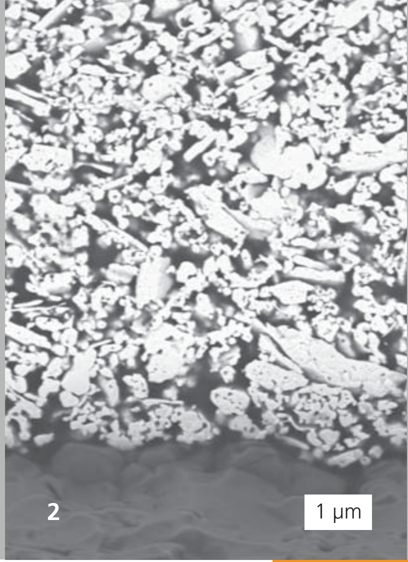

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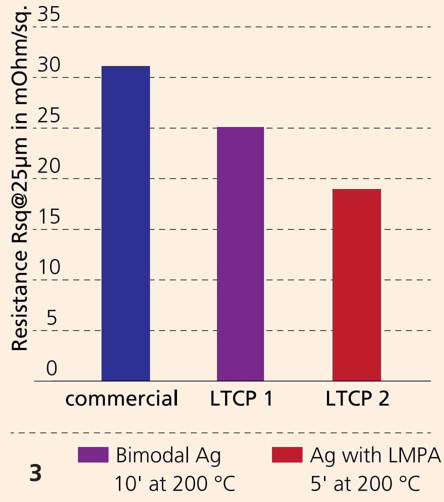

3

FUNCTIONALIZATION OF CERAMIC THICK FILMS AT 200 °C

Dipl.-Chem. Stefan Körner, Dr. Markus Eberstein

Ceramic thick-film technology enables the creation of electronic circuits on ceramic substrates from different materials (silicon nitride, silicon carbide, glass, steel). The layers can be adjusted with regard to different properties. By means of high-resolution depositing methods, conductive, resistance or isolation layers can be printed and burnt variably and highly selective. Conventional thick-film pastes require firing temperatures of about 850 °C. Therefore, substrates, which are sensitive to high temperatures, like polymers, tapes or ITO layers cannot be functionalized with conventional pastes. IKTS develops special pastes on the basis of polymers, which thermally harden at 200 °C and are mixed with a functional phase, for this range of applications. Depending on the application requirements, the functional phase can be silver or copper for conductive pastes or carbon in various modifications (carbon black, graphite, carbon nanotubes) for resistor pastes.

Using conductive pastes (LTCP – Low Temperature Conductor Pastes), a sheet resistance of 25 mΩ/□ can be reached using a curing time of 10 minutes at 200 °C. The conductivity in this composites is adjusted with the amount of percolation between conductive particles using powders that have a bimodal particle size distribution (Figure 2, Figure 3 – LTCP 1). As an alternative, LMPA powders (Low Melting Point Alloy) can be used. These powders melt during curing and generate additional conductive paths between the metal particles. With these pastes, the resistance can be decreased to 19 mΩ/□ using a curing time of just 5 minutes at 200 °C (Figure 3 – LTCP 2). These paste systems are currently used for the fabrication of high-efficiency MWT+ solar cells (Metal Wrap Through) [1] as shown in Figure 1.

Applications in the field of sensors often require functional layers with a well-defined electrical resistance. At IKTS, pastes (LTRP – Low Temperature Resistor Pastes) with different kinds of carbon modifications as functional phase are prepared and optimized. The layers can be adjusted within a broad resistance range from 103 – 106 Ω/□. For example, strain gauges with high sensitivity to length variation are a possible application for polymeric resistor pastes. The resistor pastes developed by IKTS have a resistance of 2 MΩ/□ and a gauge factor of up to 16.

Besides thermal curing, thick-film pastes with a polymer basis offer the possibility of hardening without thermal stress for the substrate. Therefore, flashlights are used or photochemical curing by UV light is induced. Using this kind of curing requires adjusted organic vehicles. For conductive pastes, inductive curing is another approach. Using low hardening temperatures facilitates the creation of circuits and sensors on substrates, which cannot be processed with conventional ovens due to large dimensions. Sensors can be selectively and directly applied onto a substrate due to this innovative curing technology. With this technique, the retrofit for already existing systems, like wind wheels, is a possibility.

References

[1] I. Dirnstdorfer et al., Development of Silicon Heterojunction Metal Wrap Through Solar Cells, Proceedings PVSEC, 2014.

1 *MWT+ solar cell with conductor paste based on silver filled polymer.*
2 *Polished cross section of MWT+ solar cell conductor path.*
3 *Conductive resistors of different low-temperature pastes depending on curing duration and composition.*

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BUSINESS DIVISION

ENERGY

Project reports

In the "Energy" business division, Fraunhofer IKTS offers innovative components, modules, and complete energy systems that are engineered, built and tested on a ceramic materials and technologies platform. The applications range from energy storage and fuel cell systems to solar cells, energy harvesting modules and thermal energy systems to solutions for bioenergetic and chemical energy sources.

Completing the transition to sustainable energy resources is one of the vital imperatives of the 21st century. To accomplish this, renewable and conventional energies must be used in a manner that is not only commercially viable, but also achieves the utmost efficiency while having minimal negative impact. When converting and storing electrical and thermal energy, the most salient issues are the robustness and the durability of the systems, as well as the costs of production and operation.

As a full-range service provider, Fraunhofer IKTS tackles these issues holistically because that is the only way to achieve truly innovative solution approaches. This fosters considerable competitive advantages specifically within the dynamic market segment of power generation and storage. In this regard, meticulous analysis always gets top priority, along with the modeling and simulation of ceramic components and systems where applicable, so that the use of specific properties can be optimized, as well as their integration into energy converters and systems. Working in close collaboration with partners in industry, Fraunhofer IKTS operates multiple pilot plants in which it maps entire process chains for the cutting-edge production of energy systems components. This offers the institute a unique opportunity to partner with customers to test and optimize the materials and processes it develops in-house within a quasi-industrial environment.


1


2

ENERGY

SOFC SYSTEM DEVELOPMENT AND FIELD TESTS FOR COMMERCIAL APPLICATIONS

Dipl.-Ing. Thomas Pfeifer, Dr. Sebastian Reuber, Dipl.-Ing. Markus Barthel

In addition to their use in residential buildings and micro-CHP applications, SOFC systems are especially suited for various industrial tasks and off-grid power supplies. In this context, the usability of different conventional fuels in SOFC systems, such as natural gas, LPG, biogas, ethanol, diesel and kerosene, provides crucial technological advantages for the development of application-specific and marketable power generators. At Fraunhofer IKTS, appropriate processes and methods for the development of customized, application-specific SOFC concepts and prototype systems were established within the framework of various past projects, funded by public bodies and industrial customers. During the implementation of these projects, professionals from different IKTS working groups are working together in interdisciplinary project teams.

Stack technology for the development of SOFC systems

As an outcome of the cell and stack developments in the past years, two SOFC technology platforms for system integration are readily available at IKTS. The eneramic® technology can be utilized for SOFC devices in the power range between 50 and 300 W_{el}. CFY stacks are available in standard sizes between 10 and 40 cells with a power output between 300 W_{el} and 1.2 kW_{el}. Higher power levels can be achieved by integrating multiple stacks in joint HotBox modules. The SOFC stacks, manufactured at IKTS, are based on electrolyte-supported cells (ESC), which are characterized by their durability and cyclization stability. The stack operation was demonstrated in various tests over more than 20,000 hours and 60 start/stop cycles, showing a power degradation rate below 1 % per 1000 hours and 1 % per 10 cycles, respectively. If required, SOFC stacks of external suppliers can be used for system development projects, as well.

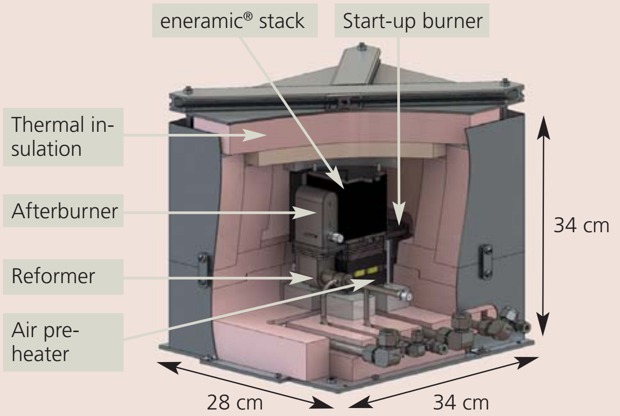
SOFC system development and prototype demonstration

For the development of SOFC systems, a detailed plant specification and process design is prepared initially. Here, all application-specific requirements are considered and a system concept with special consideration of the proposed operating modes and fuel processing technology is derived. Afterwards, the proposed concept is validated by means of laboratory tests on component, HotBox and systems level. Further design iterations and model-based analyses are used for the creation of optimized solutions to be implemented in prototype and demonstration systems. During the complete system engineering

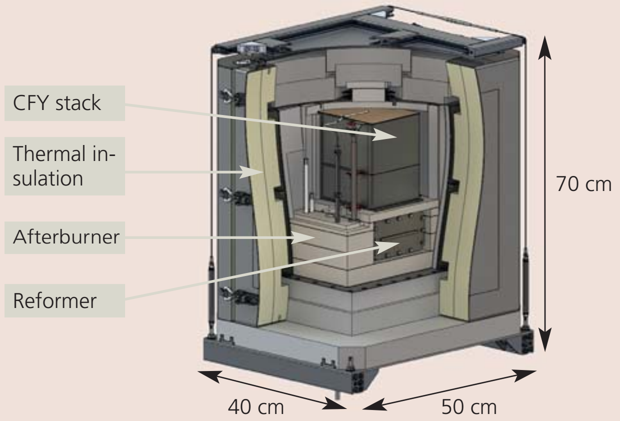
Project phases of the SOFC system development for commercial applications

	Phase I	Phase II	Phase III	
Application requirements	System concept definition	Proof of concept (PoC)	Technology demonstration	Product development
R&D focus	Model-based analyses and conceptual studies System requirements definition and process layout	Development, commissioning and test of PoC prototypes Concept validation through laboratory tests	Development, commissioning and test of demonstration prototypes Concept approval through environmental reliability and lifetime tests	
Final outcome	TRL 2* – Technology concept formulated	TRL 4* – Technology validated in lab	TRL 6* – Technology demonstrated in relevant environment	*) *Technology Readiness Level*

Cross-sectional model of the HotBox used in a portable 100 W_{el} SOFC power generator



Cross-sectional model of the stack module used in a stationary 1 kW_{el} SOFC micro-CHP system



process, the project partners, customers or users are directly involved. The transfer of knowledge and technology for a subsequent product development and commercialization might be included in the project, if desired.

Current development projects

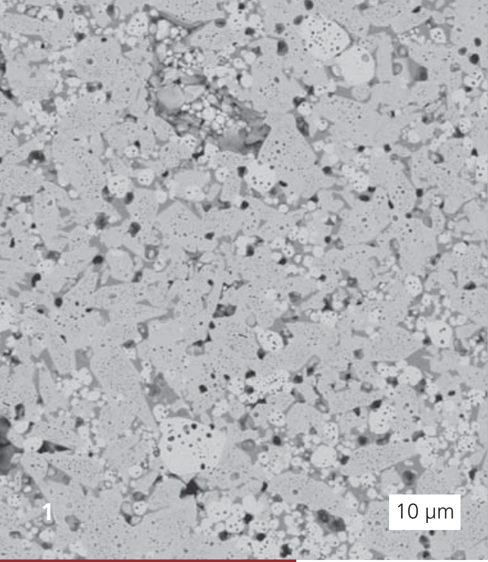
With financial support by the Fraunhofer Future Foundation, the LPG-fueled eneramic® system was developed for off-grid power supplies. The system is designed for industrial applications with small power consumption and very long lifetime. The latest prototype generation is currently demonstrated in field tests with traffic control systems and cathodic corrosion protection devices. For further development and commercialization of the eneramic® technology, the foundation of a spin-off company is prepared at present.

Contracted by the Indian company h2e Power Systems Pvt. Ltd., a stationary SOFC/battery-hybrid system for distributed power generation and micro-CHP has been developed since mid-2013. The h2e® system is intended for continuous power supplies in residential and commercial buildings in India. In addition to that, off-grid applications in rural areas are considered, e.g. for powering telecom towers or irrigation systems. The project includes a complete technology transfer for the later product development and local manufacturing in sole responsibility of the customer. During the first project phase, two proof-of-concept prototype systems were assembled and commissioned by the end of 2014. The following prototype generation to be developed within a one-year time frame will be used for on-site demonstration projects and field tests in India.

Services offered

- Development of application-specific system concepts, based on the SOFC stack technology of IKTS or external suppliers
- Model-based system analyses and techno-economic assessment of power generator concepts
- Assembly and commissioning of pilot plants and prototype systems for concept validation and device engineering
- Pilot manufacturing of SOFC system components, modules and prototype units
- Implementation of test campaigns, demonstration projects, field tests and type examination for certification purposes

1 *h2e® prototype system.*
2 *CFY stack.*
3 *eneramic® field test with cathodic corrosion protection devices.*
4 *eneramic® field test with remote traffic control system.*



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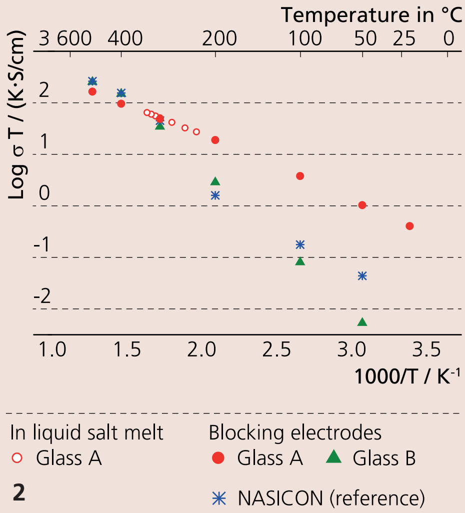

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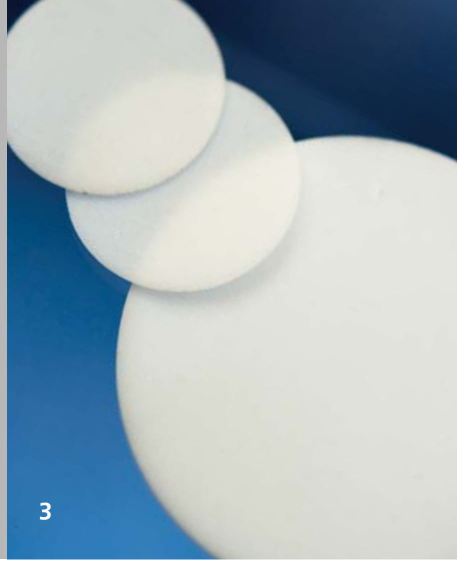


3

ENERGY

SOLID ELECTROLYTES FOR SODIUM-BASED BATTERIES

Dr. Matthias Schulz, Dr. Jochen Schilm, Dr. Roland Weidl, Dr. Axel Rost

Sodium-based batteries are especially suitable for stationary energy storage applications because all required raw materials are available cost-efficiently and cell concepts show high storage densities. While high-temperature batteries exist in an advanced stage of development, the low-temperature sodium-sulfur battery concepts are only available in the laboratory scale on an experimental level. With progressing development, it has turned out that in all known types of these battery concepts ceramic sodium-conducting separators can fulfill decisive functions in order to enable their operation in principle or to avoid degradation processes. Besides their function as separators, they also operate as solid-state electrolytes and, thus, have a major effect on the power density and the intrinsic safety of such batteries. Fraunhofer IKTS develops and characterizes materials and process technologies for ceramic components in sodium-based batteries.

Low-temperature Na/S battery concepts

In conjunction with liquid electrolytes, low-temperature sodium-sulfur battery concepts have been the subject of research activities for several years, as operation temperatures below 100 °C down to room temperature can be possible. The migration of dissolved sodium-polysulfides through porous polymer separator foils leading to an irreversible degradation represents, therefore, one major drawback of this cell concepts. This process can be prevented by the application of dense sodium-conducting separators with a solid-state electrolytic functionality. While Na-β-aluminate ceramics meet these requirements in the field of the high-temperature batteries, different prerequisites for the electrolytic materials result from lower operation temperatures. Here, it is necessary to realize hermetically dense and thin membranes with a high ionic conductivity and a good stability in liquid battery electrolytes. Promising materials are crystallizing glasses, which can be processed as powders at temperatures below 1000 °C. Suitable technologies include tape casting for producing monolithic planar substrates and screen printing for realizing conductive layers. In the basic system Na_2O-RE_2O_3-SiO_2 (RE = rare earth oxides), numerous different compositions can be molten as glasses and processed as powders for glass ceramics by using additives. Sintering and crystallization for the formation of the crystalline microstructure and the conductive phases can be performed below 1000 °C (Figure 1). Resulting conductivities of the glass ceramics are in the range of values known from literature for Na-β-aluminate and NASICON (Figure 2). Ionic conductivities up to 0.25 mS/cm at room temperature have been measured. Planar glass-ceramic substrates with ionic conductivity and thickness of 160 µm were produced by means of tape casting (Figure 3). Measurements of these substrates in low-temperature sodium-sulfur test cells in combination with liquid electrolytes yielded results comparable to NASICON- and Na-β-aluminate substrates. Possible applications for such separators and solid-state electrolytes are new concepts of low-temperature sodium-sulfur batteries.

Na-β-alumina for high-temperature batteries

Na-β-alumina ceramics are used for solid electrolytes in Na/$NiCl_2$ and Na/S high-temperature batteries. At operation temperatures of about 300 °C, ceramics provide an excellent sodium-ion conductivity. Furthermore, a good stability in the highly corrosive cell environment (molten sodium, sulfur and $NaAlCl_4$) is given. Generally, Na-β-alumina as well as the battery cells are made of cost-efficient and available raw materials, which are re-evaluated at IKTS by means of new approaches regarding a cost-efficient technology.

Materials development

In a raw materials screening, Na-β-alumina powder was synthesized in the lab scale. Aiming at optimized physical and electrochemical material properties, approaches were systematically varied. The powder synthesis resulted in a Na-β-alumina

with a desired β"-phase content of approximately 100 %. Sodium-stable high-temperature kiln furniture is used for sintering specimens (cups, sticks, discs – Figure 4) applied in electrochemical tests. Important material properties, such as density, phase and the sodium-ion conductivity were determined according to laboratory samples and, thus, an optimized raw material and treatment technology was developed. The sodium-ion conductivity of ceramic sample rods were measured by impedance spectroscopy in customized high-temperature test cells. The measured conductivities amounted to 0.24 S/cm at 300 °C and rank in the top range regarding the international comparison. Densities of about 98 % of the theoretical value and mechanical strength of about 200 MPa were reached. Final result of the lab-scale development is a process line for the production of Na-β"-alumina solid electrolytes from the raw material to the ready component.

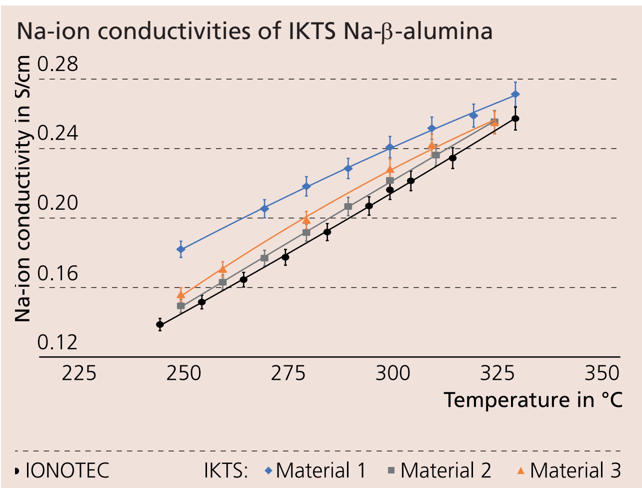
The R&D results were transferred from the lab scale to the pilot scale. Batches of 20 kg powder and granules were processed by using a scalable machinery. Based on the established power production, electrolyte tubes with a length of up to 300 mm and a diameter of 33 mm were manufactured by pressing (Figure 4). Using a laboratory extruder, a screening of different organic plasticizers and binders was carried out. After several optimization steps, electrolyte tubes with a diameter of 10 mm are currently extruded, resulting in densities about 95 % after the sintering.

Development of cells

At IKTS, several specific high-temperature test cells are available for the electrochemical characterization of the Na-β-alumina and the $Na/NiCl_2$ cathode materials (Figure 5). Starting with conductivity measurements on rod-shaped and cup-like samples up to full cell measurements in 5 Ah $Na/NiCl_2$ lab cells (Figure 6), in-house developments were constructed and tested. Currently, the gained experiences are transferred to a 40 Ah test cell. In CAD/FEM supported design studies, a cost-efficient, industrialized cell design including the sheet metal parts and the cell lid components was developed. The constructive realization of the first prototype is being prepared.

Services offered

- Materials development and manufacture of Na-β-alumina powders, granules and electrolytes
- Development of $Na/NiCl_2$ cathode materials and characterization
- Materials development of conductive glass ceramics
- Shaping and sintering methods for solid electrolyte components (pressing, tape casting, extrusion)
- Material-scientific and electrochemical characterization of materials and components
- Cell tests (cyclization, degradation)



1 Structure image of glass ceramics with a conductivity of 0.24 Scm^{-1} at room temperature.

2 Comparison of temperature-dependent conductivities of glass ceramics and NASICON.

3 Sintered glass-ceramic tapes.

4 Na-β-alumina electrolyte samples.

5 Granuled $Na/NiCl_2$ cathode material.

6 3D CAD of a 5 Ah $Na/NiCl_2$ test cell.

ESF EUROPA FÜR THÜRINGEN EUROPÄISCHER SOZIALFONDS

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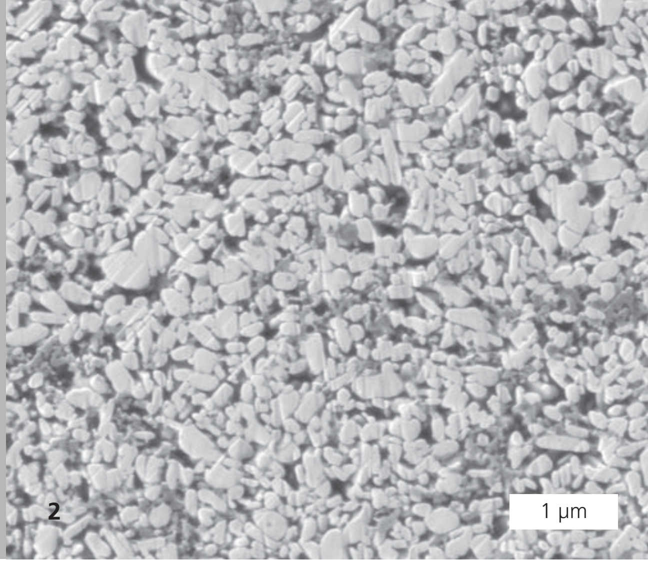
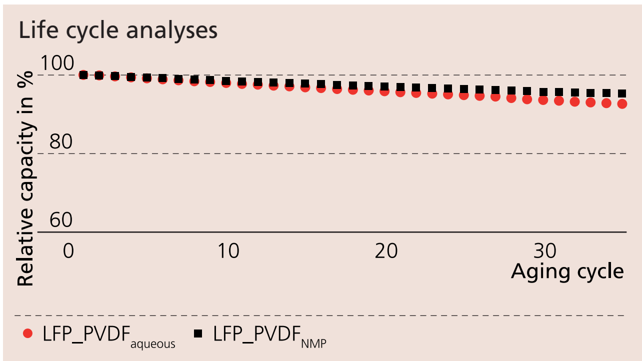


TOWARDS AN ENVIRONMENTALLY BENIGN MANUFACTURING OF LITHIUM-ION BATTERIES

Dr. Mareike Wolter, Dipl.-Phys. Diana Leiva, Dr. Kristian Nikolowski, Dr. Roland Weidl
Dipl.-Ing. Stefan Börner, Dr. Uwe Partsch

Reduction of manufacturing costs is still the main challenge for the large scale market introduction of Li-ion batteries in e-mobility as well as stationary energy storage. Value chain analysis of Li-ion battery production showed that the electrode manufacturing process is one of the major cost drivers. Therefore, the focus of our work is the development towards environmentally friendly and energy-efficient manufacturing processes. We emphasize the following topics: time- and energy-efficient mixing processes, environmentally friendly, aqueous electrode slurry recipes and energy-reduced drying processes. Slurries processing and electrodes manufacturing were investigated at the IKTS battery pilot line.

Commonly, organic solvents like N-methylpyrrolidone (NMP) are used in positive electrode manufacturing process, bearing potential health and safety risks. Furthermore, additional investments for safety equipment and high fabrication costs due to electrode drying and the recycling of the solvent are necessary. Development of aqueous formulations of the slurry for the manufacturing of Li-ion battery positive electrodes has been growing in interest due to potentially lower cost and environmental friendliness. Water-based slurries are state of the art for the production of graphite-based anodes. For the positive electrodes, it is still challenging to provide (i) good dispersion of the active material, carbon additive and binder, (ii) proper rheological behavior adjusted to the coating technology, (iii) assurance of the mechanical integrity of the electrode (good adherence between the components of the coating and between coating and current collector) and (iv) compatibility with the aluminum current collector with respect to corrosion behavior. To develop water-based slurries for positive electrode, we used carbon-coated $LiFePO_4$ (Südchemie) and carbon black (Timcal) as active material and conductive agent powders, respectively. For the binder, PVDF of Solvay combined with carboxymethyl cellulose (CMC) of Walocel as dispersing agent were used. Pilot scale equipment was used in order to study the correlations between mixer technology, slurry composition, slurry processing and the electrochemical properties like capacity, rate capability and cycling stability. The coating components were mixed using two different mixers (Netzsch planetary mixer and Eirich intensive mixer). The coating of the aluminum current collector was carried out by using the doctor blade method on a roll-to-roll coating system. After that, the electrodes were compressed using a calendar. The manufactured electrodes were characterized first in half cell arrangement versus lithium in order to evaluate the differences in the capacity and rate capability. For the life cycle experiments, the electrodes were assembled in full cell arrangement versus graphite anode. For both arrangements CR3220 button cells were used. The diagram presents results from cycle tests of water-based and NMP-based $LiFePO_4$ cathodes. The comparison shows that a successful aqueous processing is possible in a pilot scale. Performance and durability of the resulting electrodes are comparable to organic solvent based electrodes.



1 *Electrode casting at pilot scale.*
2 *SEM picture of water-based $LiFePO_4$ cathode.*

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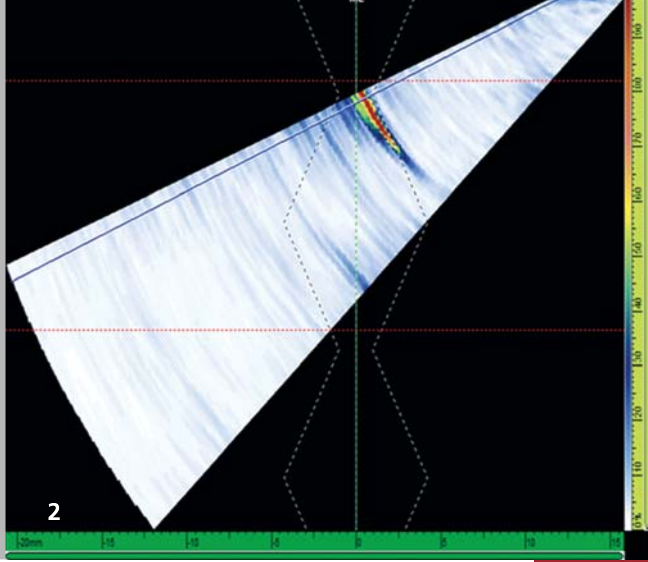

NEW ULTRASONIC PHASED ARRAY METHOD "HUGE-NDT"

M. Sc. Susanne Hillmann, Zsolt Bor, David M. Schiller-Bechert

The certain, simple and reproducible testing of circumferential welds on pipes is an important task in non-destructive testing, particularly in coal-fired power plants and chemical industry. In that area, the testing of thin-walled pipes with a wall thickness below 6 mm is only possible with the radio-graphic inspection regarding the current standardization. However, this very elaborate method extends the maintenance time due to small time periods for radiation. Using the ultrasonic method, such circumferential welds can be tested much faster, also in shift operating system. Evidently, defects with notch effect in the weld can be detected more easily using ultrasonic methods in comparison to radiographic inspection.

For testing thin-walled circumferential welds on pipes, suitable phased array equipment including semi-automated scanners is meanwhile available on the market. In the past, ultrasonic phased array methods could not be applied due to the complex sound propagation in the thin walls with wall thicknesses below 6 mm. Nowadays, the strong defocusing of the sound beam with extremely short sound paths between the defects are manageable with this method.

The HUGE-NDT test method was developed, optimized and then validated by the certified testing laboratory of Fraunhofer IKTS in close cooperation with the Ingenieurbüro Prüfdienst Uhlemann. The method consists of a special arrangement of phased array probes, special adjustment of the system, a special calibration as well as a selected assessment of the signals. Using this procedure, it is possible to detect defects with notch effect in welds of thin-walled pipes with a high detection probability of more than 95 %.

So far, more than 6000 welds of that kind have been tested in the controlled area of coal-fired power plants applying this method. These tests were randomly controlled by using radiographic inspection as well as metallography, and confirmed the high defect detection probability of the validation.

By using this procedure, the maintenance times in the power plants and chemical plants could be divided in more than half, which brings enormous economization for the operators. HUGE-NDT has the potential to completely replace the radiographic inspection for these components. Consequently, elaborate radiation protection can be omitted, which is very advantageous for the health protection of the employees. Additionally, this method can be successfully applied to alternative materials, such as austenites, which are hard to test using radiography due to the high scattering caused by columnar crystals in the welds. Another advantage of this technique is the fact, that it can be used at narrow points of the pipe construction, where radiographic testing cannot be used. Therefore, the number of tested welds can be considerably increased.

The Fraunhofer IKTS offers test services with the HUGE-NDT method. Furthermore, the qualification of external partners for the method or cooperations for further developing the test method with regard to specific applications is possible.

1 *Semi-automated scanning system for the HUGE-NDT method in practical use.*
2 *Example of a sector scan showing a lack of side-fusion.*

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DEVELOPMENT OF PROCESSES AND COMPONENTS FOR POWER-TO-GAS AND POWER-TO-PRODUCTS

Dr. Matthias Jahn, Dr. Mihails Kusnezoff, Dipl.-Ing. Erik Reichelt, Dr. Stefan Megel

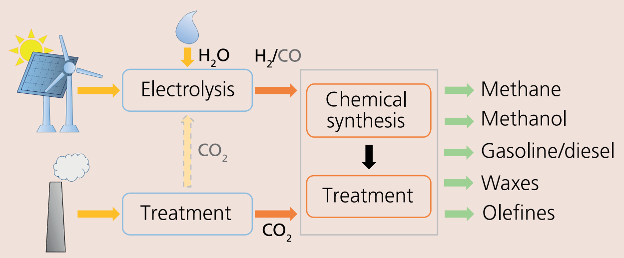
Motivation

An essential goal of the German "Energiewende" is the transition from fossil to renewable energy sources, like wind and sun. A disadvantage of these sustainable sources is their fluctuating nature. This necessitates the development of appropriate technologies for the storage of excess energy. Some concepts addressing this problem are based on the storage of energy in chemical compounds. Potential products could be conventional gaseous and liquid energy carriers as well as valuable chemical intermediates or end products. The decentralized production of renewable energy often requires decentralized process and plant concepts. The specifications of these plants differ considerably from large-scale industrial plants. The development of power-to-gas and power-to-product technologies as well as the necessary components is a focus of current research at IKTS.

Process concepts

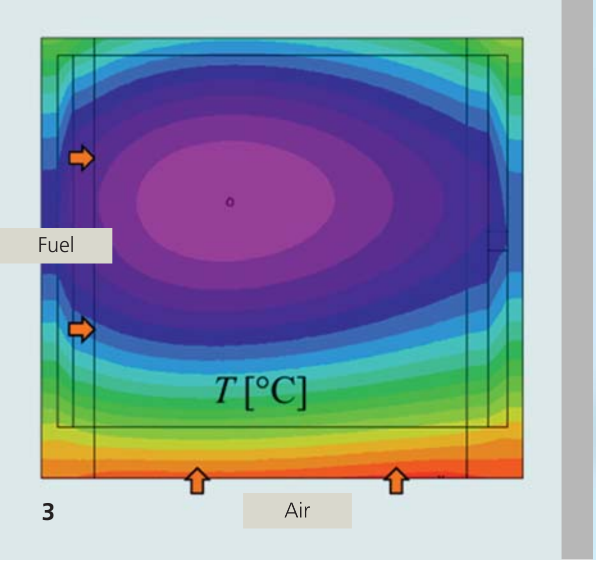
The basis of all concepts for the storage of electrical energy in chemical products is the supply of the chemical synthesis unit with hydrogen (H_2) and carbon monoxide (CO) or carbon dioxide (CO_2). Hydrogen can be produced from water in an electrolysis cell. Besides the well-established alkaline electrolysis and the PEM electrolysis (proton exchange membrane), the high-temperature electrolysis (SOEC – solid oxide electrolysis cell) is an interesting alternative. This process, currently under development, offers the potential to reach higher efficiencies. Besides that, it has another advantage with regard to the overall process concepts. For the synthesis of hydrocarbons from renewables, a carbon source is necessary, in most cases CO_2. In contrast to other electrolysis processes, the SOEC not only allows the conversion of H_2O but also the co-electrolysis of CO_2. Therefore, the process offers the potential to produce H_2 and CO for the subsequent chemical synthesis in one step. There are different CO_2 sources available. Besides off-gases of

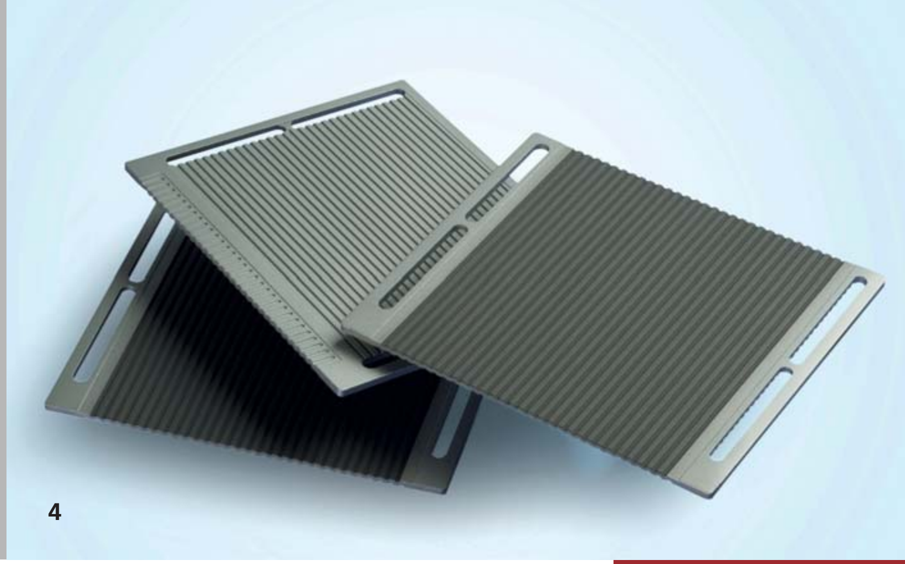
Scheme displaying the utilization of renewable energy for the synthesis of chemical products



combustion processes, e.g. in power plants, also CO_2-rich gases from several industrial processes can be utilized. Especially in the steel and cement industry, such gases are produced, which mostly need conditioning and CO_2 separation prior to CO_2 utilization. A completely renewable carbon source would be CO_2 from air but the low atmospheric concentration of CO_2 currently leads to cost-intensive and uneconomic processes. If CO_2 is not converted by co-electrolysis, it can be converted to CO in an additional process step. Some chemical syntheses can also directly utilize CO_2 as a reactant. Potential products might be methane, that can be fed into the existing natural gas grid or liquid energy carriers like gasoline or diesel. But also valuable products, like waxes or olefins, can be produced according to this approach.

Specific process concepts always depend on the desired product and the available CO_2 source. Thermal coupling of different process steps and therefore, a good heat integration are of high importance for small-scale decentralized plants, especially for achieving high efficiencies. An example is the utilization of heat from exothermic synthesis steps for the evaporation of water for the SOEC. Also the internal utilization of by-products has a huge impact on the efficiency of the respective process concept. In order to identify promising process steps, the application of process simulation tools is beneficial. In small-scale applications, dynamically operating conditions





occur more often than in large-scale industrial plants. The development of process steps, such as electrolysis and chemical synthesis, as well as of the materials applied therein has to take place with respect to these conditions.

Electrolysis

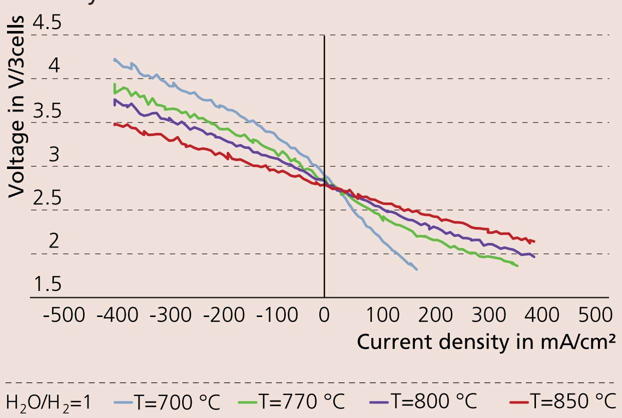
The high-temperature electrolysis cell offers a remarkable potential for highly efficient hydrogen generation by direct and well controllable conversion of electrical into chemical energy of the produced hydrogen. The simultaneous heat production and, therefore, the compensation of endothermic water splitting allows efficiencies of up to 98 %. Operating the cells at high temperatures (T = 700 °C – 1000 °C) leads to decreased resistances and allows the application of Pt-free catalysts in the electrodes.

The design of an SOEC module is very similar to that of a high-temperature fuel cell (SOFC – solid oxide fuel cell). As a result, it is possible to operate the module in electrolysis as well as in fuel cell mode. Depending on the conditions, they can, therefore, store energy from the grid or feed it into the grid. Furthermore, coupling with chemical processes, e.g. the synthesis of fuels, offers the advantage of using heat from these exothermic process steps for water evaporation. This leads to an improvement of heat integration of the overall process. In contrast to the more established alkaline and PEM electrolysis, there are still development needs for high-temperature electrolysis cells regarding their long-term stability. This also distinguishes the SOEC from the high-temperature fuel cell that has already reached a commercialization-state of development.

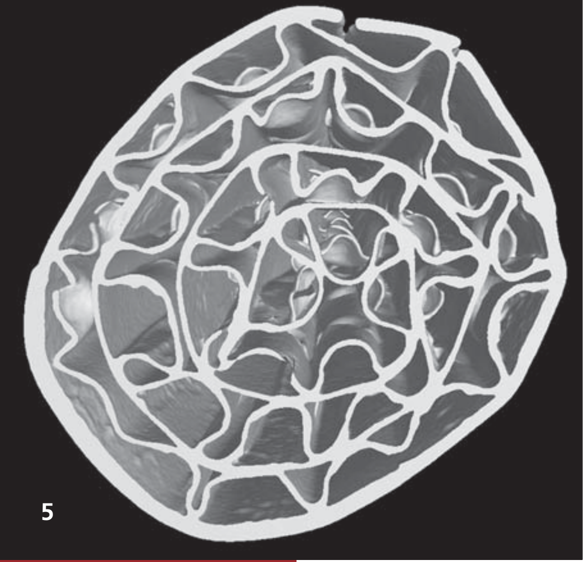
The high operating temperatures of an SOEC allow an efficient water splitting also in presence of other gas compounds at the anode of the cell. The anode consists of highly catalytically active and, in contrast to precious metals, cheap compounds, like nickel. The local coupling of endothermic water electrolysis and exothermic power dissipation of the cell simplifies the cooling efforts in contrast to other electrolysis concepts. For example, in the case of a PEM electrolysis cell a high additional air stream is essential for cooling the cell. Additionally, the electrical energy necessary for water is splitting is lower for 800 °C than for room temperature. This can be explained by thermodynamic considerations and was confirmed by experimental results.

The challenge of higher degradation in comparison to the fuel cell mode is currently addressed by researchers in USA (Ceramatec) [1] and Europe (Haldor Topsoe) [2]. The degradation of all stack components under water vapor atmosphere is mostly unexplored. Since it is expected that the components of the developed SOFC module can withstand these conditions, the research efforts are focused on cell development. An important additional goal of research is the demonstration of stable operation under increased pressure. For the development of electrolysis cells, vast knowledge from the development of SOFC modules can be used. Since 1998, a planar stack (so-called CFY stack) for SOFC application has been developed at IKTS, which has reached commercial maturity at the current stage. Based on this platform, stacks suitable for SOEC mode are currently developed. They use thin ZrO_2-based materials as electrolyte. Experimental results on long-term stability already show a very small degradation. One reason for this is a very homogeneous tem-

Current-voltage characteristic curve of a 30-cell stack in electrolysis and fuel cell mode



1 *30-cell CFY stack in transport device.*
2 *Lab-scale plant for methanation and Fischer-Tropsch synthesis.*
3 *Temperature distribution in a high-temperature electrolysis cell.*
4 *MK351 interconnector with protective coating developed with Plansee SE.*



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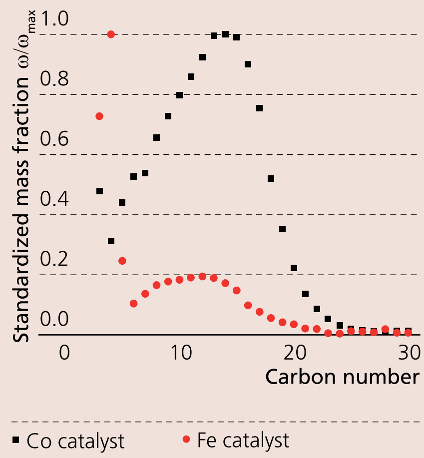

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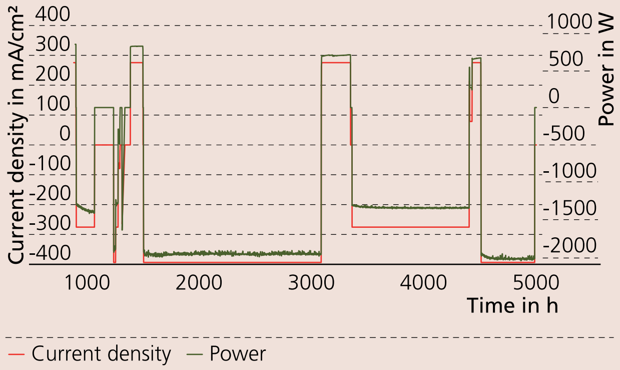
Long-term stability of a 30-cell CFY stack in electrolysis mode



perature distribution within the stack that is reached in the thermoneutral operating point. Under these conditions, the current within the stack produces the same amount of heat as necessary for the endothermic electrolysis reaction. This point can be calculated prior to the experimental tests by simulations. Therefore, simulation tools are an important element for the development of stacks and their integration within an SOEC system. It is also possible to operate stacks in a slightly exothermic operating point. The produced excess heat on a high-temperature level might be advantageous for other process steps when a highly integrated process is developed.

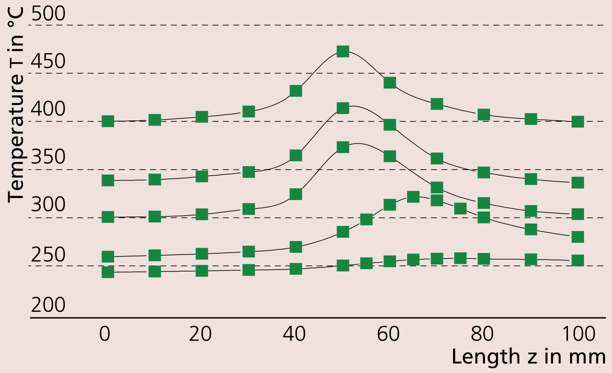
Chemical syntheses

The development activities on chemical conversion routes are focused on methanation and Fischer-Tropsch synthesis. For both reactions, novel structured ceramic catalyst supports are focused in current analyses. These supports based on ceramic tape casting technologies offer the advantage of allowing a targeted adjustment of residence time distribution and a reduction in temperature gradients and hotspot formation. The support structures are characterized by increased material and heat transfer in comparison to common honeycombs or pellet beds. Especially for multiphase reactions, like Fischer-Tropsch synthesis, heat and material transfer have a significant influence on product selectivity. The Fischer-Tropsch synthesis is characterized by producing a spectrum of hydrocarbon products. Therefore, a good adjustment of selectivity is advantageous because often only a specific fraction is the desired synthesis product.

The investigations on the application of novel support structures for Fischer-Tropsch synthesis are focused on waxes and short-chained olefins as products. Both are, in contrast to methane, gasoline or diesel, not only energy storage materials but also important intermediates or end products in chemical industry. Currently, they are produced from crude oil. In contrast to fossil source-based products, the products from renewable sources offer – besides their sustainable production – several advantages. For example, synthetic waxes are free from aromatic and polycyclic compounds and, therefore, particularly suitable for the application in the cosmetics industry [3]. This example demonstrates that power-to-product concepts also allow the production of compounds of highly economical value. For the production of waxes, Co-based catalysts are applied. In order to increase the reducibility and activity, Ru is added as a promotor. Short-chained olefins are of high importance as intermediates in chemical industry. For their synthesis, promoted Fe catalysts are used. High yields of olefins require short residence times and narrow residence time distributions. Therefore, the novel structures are highly suitable for the transition from fluidized bed reactors applied in large-scale industrial plants to fixed-bed reactors. The identification of suitable catalyst systems is also an essential part of the works on olefin synthesis.

Different Ni-based catalysts are prepared and tested regarding their activity for methanation. Focus of the research is the utilization of CO_2 from air or from off-gas streams for the synthesis of CH_4. As CO_2 can be converted to CO in an upstream electrolysis step, measurements with both CO and CO_2 are per-

Temperature profiles for different entrance temperatures regarding the methanation of H_2/CO



formed. Due to the higher exothermic reaction regarding CO methanation, this reaction is used for the evaluation of the support structures. Catalysts are used in the form of powders or applied to structured supports via washcoating processes. By means of measuring temperature profiles, the influence of support structure on the heat transfer within the reactor is evaluated.

State of development and current research

Based on past research regarding solid oxide fuel cells, a high-temperature electrolysis cell was successfully developed and tested. The current research efforts are focused on stack design, reduction of CO_2 to CO and on further improvements in long-term stability. In the field of chemical syntheses, novel ceramic catalyst supports were developed and applied to different synthesis reactions. Currently, an increase of selectivity for valuable products, like waxes and olefins, is focused. A process model based on Matlab/Simulink was developed allowing the identification of advantageous process concepts and an evaluation of the expected process efficiency. For the utilization of CO_2 from air as carbon source, additional research is necessary to reach economic feasibility. The coupling of high-temperature electrolysis and Fischer-Tropsch synthesis allows the production of alternative fuels as well as base chemicals and, therefore, offers a variety of possible concepts for the application of excess energy from renewable resources for chemical syntheses. Depending on conditions and possible application, customer-specific solutions can be developed.

Services offered

- Development of application-specific process concepts and reactors
- Process and reactor simulation
- Innovative ceramic support structures for the application in synthesis reactions
- Catalyst development and screening
- High-temperature electrolysis cells, stacks and modules
- Design and manufacturing of reactors and pilot-scale plants

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[2] M. Petitjean, M. Reytier, A. Chatroux, L. Bruguière, A. Mansuy, H. Sassoulas, S. Di Iorio, B. Morel, J. Mougin, ECS Transactions, 35 (1) 2905-2913 (2011).
[3] M. Bekker, N. R. Louw, V. J. Jansen van Rensburg, J. Potgieter, International Journal of Cosmetic Science, 35 (1) 99-104 (2013).

5 *Computed tomographic image of a ceramic tape structure.*
6 *Liquid and waxeous products of Fischer-Tropsch synthesis.*
7 *Product distribution of Fischer-Tropsch synthesis.*
8 *Catalyst preparation.*
9 *Preparation for joining stacks.*

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Andreas Junghans

BUSINESS DIVISION

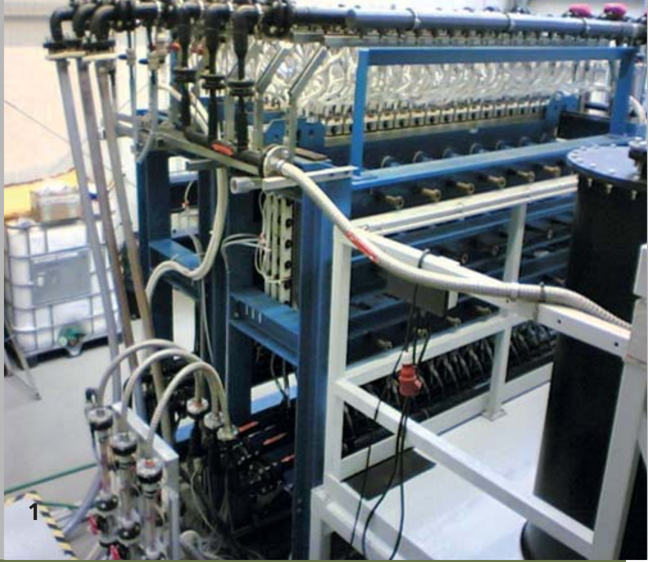
ENVIRONMENTAL AND PROCESS ENGINEERING

Project reports

For the "Environmental and Process Engineering" business division, Fraunhofer IKTS provides materials, technologies and systems that create the transformation of materials and energy safely, efficiently, and in a manner safe for both the environment and climate. The focus here is on processes in conventional and bioenergies, strategies and processes for air and water purification, as well as recovering valuable raw materials from residual substances. Ceramic technologies enable new reactor designs for the chemicals industry.

Fraunhofer IKTS is one of the world's top research institutions in the field of separation technology that applies ceramic materials. Materials, technology, and process expertise are all intertwined, thus enabling the achievement of complex process engineering systems for energy-efficient separation processes, chemical conversion as well as the recovery and reuse of materials. Ceramic membranes, filters, adsorbents and catalysts from Fraunhofer IKTS play an integral role in gas processing and water treatment processes. In addition, ceramic membrane processes are combined with innovative materials to make new reactor concepts.

Knowledge of process engineering for the milling, disintegration and mixing of biogenic substrates represents another core competency of Fraunhofer IKTS in the field of biochemical and thermochemical biomass conversion. At numerous laboratory and pilot facilities, the institute models, validates and optimizes fluidic, electrochemical and thermomechanical parameters used in material transportation processes and reactions. Through numerous laboratories, pilot facilities and the application centers for membrane technology as well as bioenergy, the business division possesses a superior infrastructure that allows it to realize a wide range of projects of various scopes and scales. The findings flow directly into demonstration systems that are installed at the customer's business premises and that Fraunhofer IKTS is able to maintain.



ELECTROCHEMICAL PROCESSES FOR WATER TREATMENT AND RAW MATERIALS RECYCLING

Dipl.-Chem. Hans-Jürgen Friedrich

Due to their selectivity, a relatively simple setup and good scalability, electrochemical processes have a substantial application potential in the areas of environmental and raw material technology.

For the treatment of highly mineralized, sulfate-rich mining waters, the RODOSAN® method was developed and tested on a technical pilot plant scale for different applications (Figure 1 and 2). It is a membrane electrolysis process, which allows for the extensively selective separation of sulfates while simultaneously converting them into usable products (sulfate fertilizer). For this reason, an unwanted water pollutant can be converted into a reusable material. This method represents an essential advantage in contrast to sparsely selective approaches, such as nanofiltration or reverse osmosis. Although water of drinking quality can be produced, the utilization of generated concentrates is still an unsolved problem in this case. In addition, such processes do not offer energetic advantages.

So far, a reduction of the salinity was possible up until 60 % on the technical pilot plant scale whereas on the bench scale, results of more than 80 % can be achieved in the meantime. Furthermore, heavy metal and aluminum ions are quantitatively separated and buffering capacity is produced. For this purpose, no process chemicals are needed.

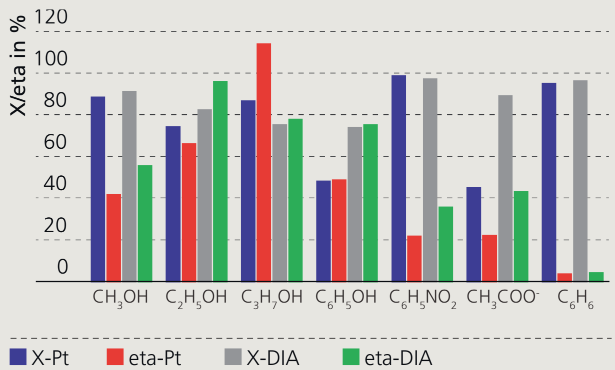
Initially, the treatment of calcium-rich waters caused problems due to considerable scaling in the membrane electrolysis cells. In the meantime, effective methods were developed and tested on the pilot plant scale. The process is primarily designed for the treatment of larger water volumes as typical for mining. However, the plants are modularly constructed so that a greater span width of plant sizes can be realized in practice (0.01–2 m^3/s). Alongside the treated water, produced fertilizer and H_2, CO_2 is used as process chemicals for the electrolysis to a considerable extent.

Membrane electrolysis processes are perfectly suitable for the destruction of persistent organic pollutants in contaminated waters. Numerous compound classes, e.g. nitroaromatics, are only partially degraded by means of alternative processes, such as photo- or ozonolysis. Biological degradation rarely takes place. In the case of electrochemical total oxidation, organic substances are completely converted to CO_2. In the process, the respective oxidized anions originate from heteroatoms, as illustrated in the following example (nitrobenzene):

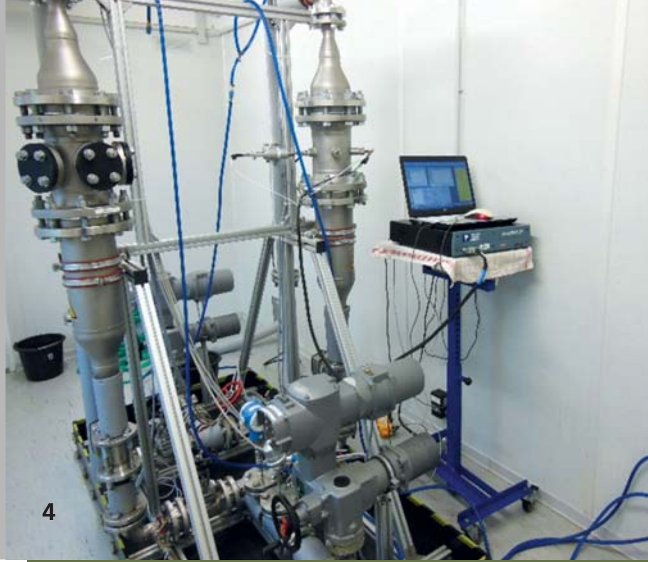
$$C_6H_5NO_2 + 13\ H_2O \rightarrow 6\ CO_2 + 31\ H^+ + NO_3^- + 30\ e^-$$

Meanwhile, the successful usability was shown for a complete series of application cases, partially up to the pilot plant scale (treatment of chemical waste waters, purification of contaminated ground waters containing residues of explosives, treatment of radioactive waste).

Conversions X and current efficiencies eta during the anodic oxidation after respectively 6 Ah



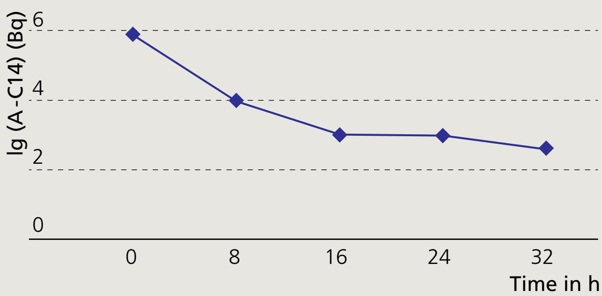
The latter is part of a current BMBF project with the goal of piloting (FKZ 02S9154). In this project, examinations concerning the influence of the electrode material and the reaction conditions on the conversion of various chemical compounds were



conducted on a broader basis. Here, boron-doped diamond proofed to be the superior anode material in most cases.

In the case of total oxidation of radioactive C-14 waste samples, whose composition is partially unknown in terms of material, a conversion was realized in first small scale tests (Figure 3), which allows for the disposal of the decontaminated liquid phase as conventional waste. In the process, the released C-14 CO_2 is transferred to alkaline earth carbonates suitable for final disposal in a downstream absorption step.

Time course of C-14 activity during the electrolysis of waste liquid

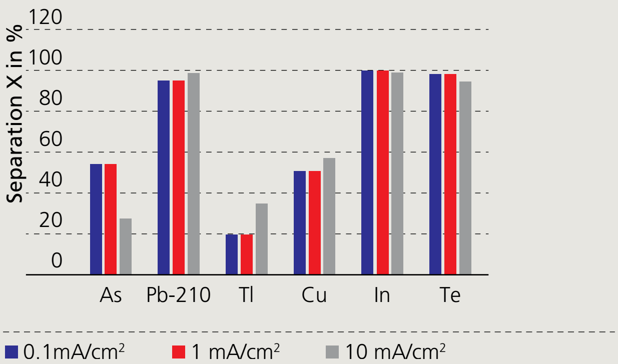


At the same time, the basis for recycling C-14 shall be established with this project.

The conditioning of thermal salt water in deep geothermics (BMWi project FKZ 0325696) is another application area, which focuses electrochemically on both the separation of radionuclides and the extraction of rare metals. Here, avoiding so-called scaling by means of naturally occurring radionuclides, such as Pb-210 and toxic heavy metals, has priority. Scaling in practice leads from operational malfunction through to safety-relevant component failure and to considerable additional cost for maintenance and disposal. The separation of unwanted components preferably downhole is the development objective. On the contrary, thermal salt waters partially contain rare metals in concentrations that basically allow for an extraction.

Within the scope of a funding project of the German Federal Environmental Foundation (FKZ 31916/01), both approaches are currently closely analyzed. The previous research results in model salt water show that both the electrochemical separation of toxic heavy metals and the deposition of rare metals, also regarding typically available concentrations <1 mg/l, are possible with mostly high yields.

Electrochemical deposition of scalents from model salt water, residence time per 240 s (10 mA/cm² = 120 s)



Particularly, the deposition of the critical nuclide Pb-210 appears to be very promising. Indium and tellurium can also be almost entirely separated. Regarding arsenic and thallium, further improvements are aimed at, being subject of further R&D activities. For the pending field tests, a mobile test with TÜV certification and mining-regulatory approval is available, which is also used for in-situ corrosion analyses (Figure 4).

The recovery of leaching chemicals from extracting secondary raw materials through electrodialysis and the development of electrochemical separation steps regarding the separation of rare earth elements and other rare metals are further fields of activity.

1 *Pilot plant for the electrochemical sulfate separation.*

2 *Overview of the plant site.*

3 *Laboratory test stand C-14 total mineralization.*

4 *Test stand deep geothermics.*

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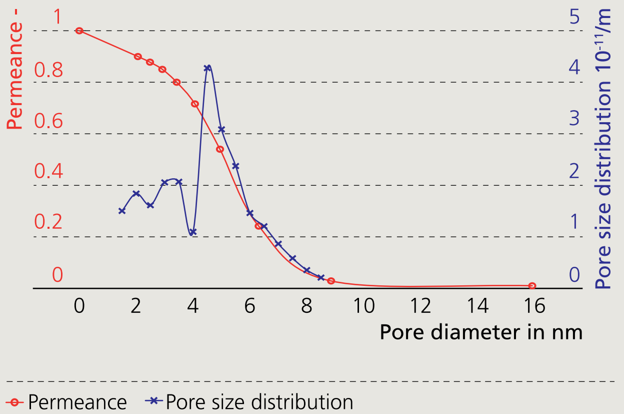
MEMBRANE TESTING IN PILOT AND FIELD TESTS

Dr. Marcus Weyd, Dipl.-Ing. Christian Pflieger, Dipl.-Ing. Steffen Wöhner

Membrane processes are widely used as energy-efficient separation methods. They do not need any chemical agents and are usually clearly superior to alternative separation methods in terms of selectivity. Inorganic membranes are characterized by high flow rates. In addition, they can be used under extreme chemical and thermal conditions.

At Fraunhofer IKTS, inorganic membranes for separation processes in liquid, vaporous and gaseous media are developed. These developments mostly aim at improving the separation efficiency and selectivity of the membranes. Further developments target at increasing membrane area per ceramic element or synthesizing and testing novel membrane types for separation tasks. Therefore, new support geometries are also under development, which need to be evaluated concerning material transport. Some types of membranes are also manufactured as prototypes. In addition to the membrane development, the properties of the membranes must be determined as well. Pore sizes of below one nanometer often require a special test procedure. Pore sizes and pore size distributions are determined and layer quality analyzed.

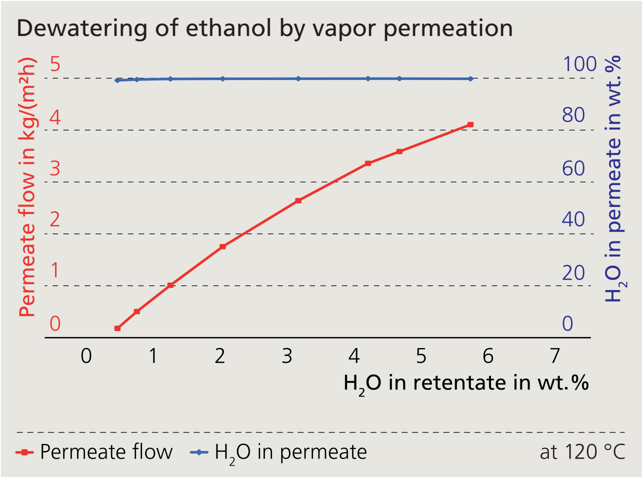
Pore size distribution of an ultrafiltration membrane determined by permporometry



These characterization methods are applied with 1.2 m long industrial-scale membranes as well as with lab samples of only a few centimeters in length. It has to be ensured that the membranes are suitable for the respective process conditions (pressure, temperature, process media and pH). The main methods that are used for membrane characterization are the following:
- Permporometry
- Bubble-point method
- Permeation measurement/clear water flux
- Cut-off determination
- Simulation of material transport and strength
- Burst pressure testing
- Contact angle measurement
- Determination of acid and alkali stability

Crucial for the economic use of a membrane process is the separation efficiency in the industrial process using real media. For the process evaluation, technical data are collected in a multistage process. First principle experiments in lab scale provide first qualitative results for the envisaged membrane processes. In case of positive results, tests with industry-relevant membrane geometries (e.g. multichannel tubes, length 1.2 m) are performed in pilot plants to capture first reliable performance data. IKTS has membrane systems in the laboratory and pilot scale for pervaporation, vapor permeation, gas permeation, micro-, ultra- and nanofiltration and organophilic nanofiltration.

A gas permeation plant for gas separation and drying of gas mixtures at high temperatures and a pilot-scale vapor permeation plant were commissioned in 2014. The vapor permeation plant, which can be equipped with up to 12 industrial-scale membranes in 3 membrane modules, is used for pilot and long-term tests for breaking azeotropes and dewatering solvents at temperatures of up to 220 °C and pressures of up to 25 bar.



For application tests in the field of liquid filtration as well as organophilic nanofiltration, Fraunhofer IKTS is operating an Application Center for Membrane Technology, which is located in Schmalkalden, Germany. The center focuses on membrane characterization, and on testing and developing membrane processes by practical feasibility tests. Mobile systems can be used for customer- and project-specific projects. At the application center, test plants are designed and constructed in the form of prototypes, as well.

In the field of liquid filtration, the following plants are available:

- Table plants (MF, UF, NF; PN16)
- Laboratory plants (MF, UF, NF, UO; PN16/PN100)
- Field test equipment (MF, UF, NF; PN25)
- Mobile explosion-proof plants (MF, UF, NF; PN25/PN40; Ex II 3/2G IIB T3)

Emphasis is put on the fact that each membrane process can also be operated with membranes of an industry-relevant geometry. For membrane characterization regarding the determination of the clear water flux and the retention of test substances, additional filtration equipment is held separately. The determination of the acid or alkali stability takes place in various special plants for the usage of the respective media. Furthermore, static exposure tests of membranes in aggressive media can be carried out at temperatures of up to 150 °C.

For membrane testing in field tests, specialized field test systems were designed and constructed. These systems are characterized by the following features/characteristics:

- Automated batch or feed-and-bleed operation
- Filling and level monitoring
- Regulation of pressure or permeate volume flow
- Intelligent retentate/product discharge
- Heating and cooling function
- Backflush (2 modes)
- Data storage

The field test plants can process a defined number of cycles in batch mode and refill automatically. The temperature is controlled automatically by a thermostat or externally available tempered water. In the feed-and-bleed mode, the product/retentate discharge can be realized proportionally to the permeate flow in order to operate at a given concentration point. The systems can also be integrated into a loop of an industrial plant.

Services offered

- Customer- and application-specific membrane testing and process validation
- Piloting of membrane processes
- Process development for the mentioned membrane processes
- Design and construction of suitable membrane housing
- Development and construction of membrane (test) systems
- Development of membrane cleaning strategies for, e.g., existing customer membrane plants
- Processing and/or monitoring or evaluation of field tests
- Delivery of membrane prototypes
- Concept development for integrating membrane systems/processes into customer-specific production processes

1 Membrane testing at IKTS pilot plant.

2 Mobile filtration container for treatment of organic solvents.

3 Mobile filtration plant with back-flushing device and temperature control unit.

4 Pilot vapor permeation plant at IKTS technical center.

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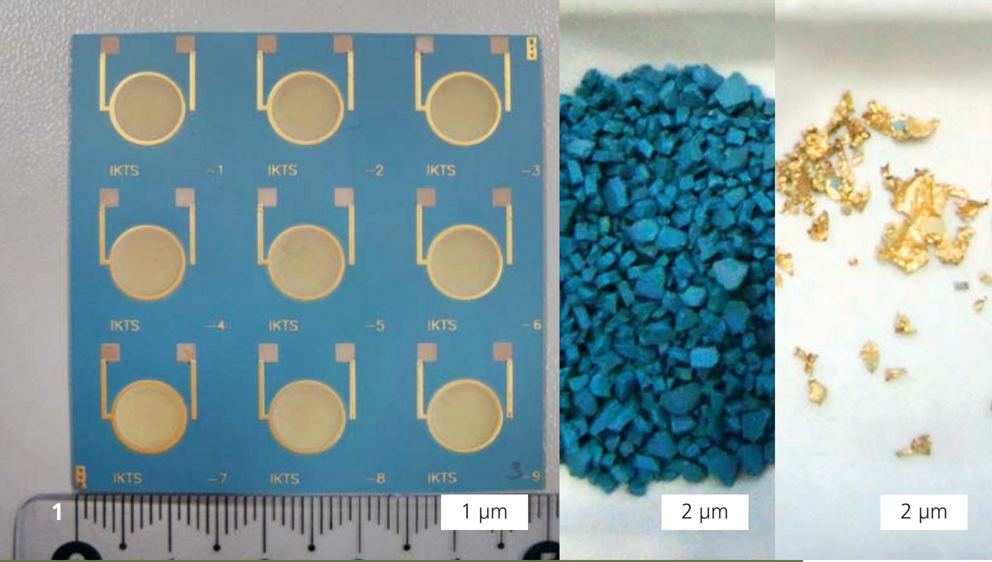

SHOCKWAVE RECYCLING OF CERAMICS AND CERAMIC NOBLE METAL COMPOSITES

Dipl.-Ing. Axel Müller-Köhn, Dipl.-Ing. Carolin Lohrberg, Dipl.-Ing. Kerstin Lenzner, Dipl.-Ing. Anne Bergner, Dr. Manfred Fries, Dr. Tassilo Moritz

The development of ceramic components and systems is characterized by the increasing integration of components and functionalities. Ceramic materials are applied as substrates, housing or even as independent functional components in the form of electrical conductors, isolators or dielectric components. These components are often firmly bonded with metals or noble metals by coating, brazing and bonding methods, as well as by co-sintering.

Examples for such material composites and composite systems are multilayer components, e.g. fuel cell stacks, sensors and piezoelectric actuators, catalyst substrates or medical devices. The metal bonding partners are often gold, platinum, silver and copper. Frequently, alumina, zirconia and rare earth oxides are used as ceramic materials.

Adensis GmbH developed an innovative material-selective milling technology, whereby an enrichment and recycling of the contained strategic metals, rare earth oxides and noble metals is possible. This technology operates on mechanical shockwaves in fluids for inducing energy coupling and therefore, milling. The shockwaves are produced with the help of the electrohydraulic effect, by which a fluid is ignited between two electrodes in a short-term, intensive electric arc causing an avalanche. In this process, there is no contact with a solid grinding medium, so that separation process can be called contact-free.

Within the framework of the joint research project (grant number 100119802) funded by the Saxon State Ministry of Science and Art, the most important advantage of a material-selective decomposition was emphasized regarding the separation of Low-Temperature Cofired Ceramics (LTCC) and printed gold or silver components as well as the milling of high-quality ceramic components. Economically sensible material systems are LTCC and zirconia ceramics as well as ceramic coatings. On basis of these exemplary systems, the milling and separation efficiency, and its recyclability, i.e. the refeed into the raw-material cycle, was analyzed and evaluated as promising recycling method for the purpose of resource conservation.

1 *LTCC component before (left) and after (right) milling and sorting.*
2 *Milled material of a zirconia monolith.*

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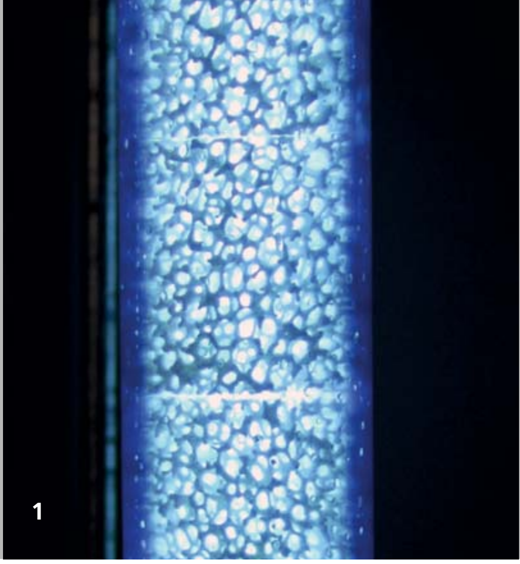
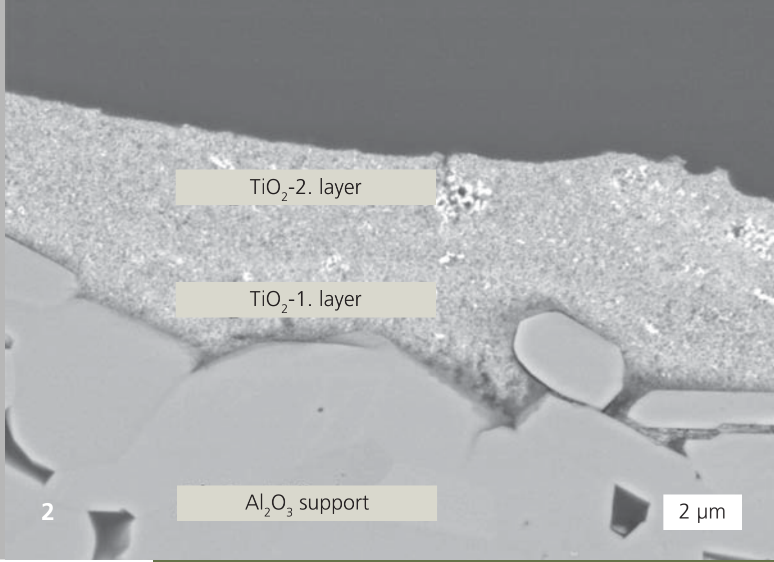




PHOTOCATALYTIC WASTEWATER TREATMENT WITH FUNCTIONALIZED CELLULAR CERAMICS

Dipl.-Ing. Franziska Saft, Dipl.-Ing. Heike Heymer, Dipl.-Krist. Jörg Adler, Dr. Burkhardt Faßauer

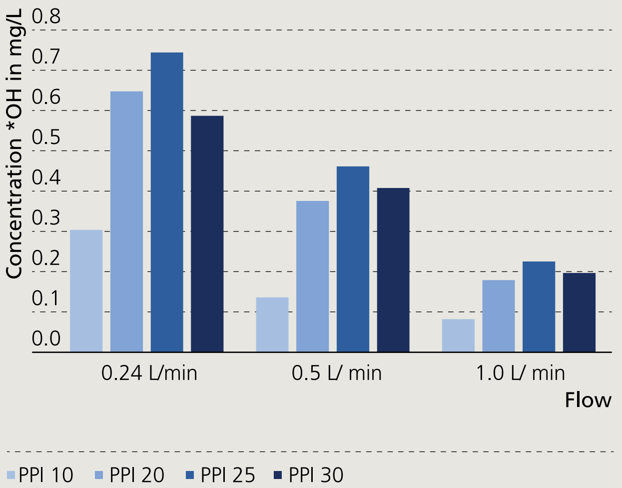
In the last years, micropollutants from anthropogenic sources, particularly persistent and bioaccumulative human as well as veterinarian pharmaceuticals come increasingly to the fore of public interest as they cannot be completely disintegrated by conventional wastewater treatment and are therefore enriched in the aquatic environment. AOP procedures (Advanced Oxidation Processes), like photocatalysis, with focus on the generation of hydroxyl radicals, which are not reaction selective, are able to achieve a complete oxidation of persistent substances and a simultaneous disinfection. The surface contact between pollutant and catalyst/light is most important for the photocatalytically initialized pollutant degradation. Large, optimally irradiated catalyst surfaces promote an efficient generation of hydroxyl radicals.

The immobilization of catalysts on cellular ceramic substrates permits higher interaction surfaces and advantageous penetration of light irradiation than low-efficient immobilization alternatives on membrane surfaces or container walls.

For that reason, Fraunhofer IKTS developed and produced TiO_2-coated cellular ceramics with different pore sizes (PPI – pores per inch) and geometries, which are photocatalytically activatable. AL_2O_3 foam ceramic supports between PPI10 (4–5 mm pore width) and PPI30 (2 mm pore width) were manufactured according to the Schwartzwalder method and afterwards coated with a TiO_2 suspension on all sides using immersion processes. The possible applications of the coated ceramics were analyzed under the usage of model pollutants and real wastewater.

A completely degradation of problematic pollutants, like Carbamazepin and Diclofenac, with simultaneous disinfection and a low-power consumption compared to other AOP-procedures was shown. IKTS offers application-oriented services for the development of materials and processes regarding the treatment of differently polluted water.

Hydroxyl radical generation in dependence of flow, pore size and irradiation power



1 *Cellular ceramics under UV-C irradiation in experimental set-up.*

2 *Electron microscopic image of two-time TiO_2-coated, cellular ceramics.*

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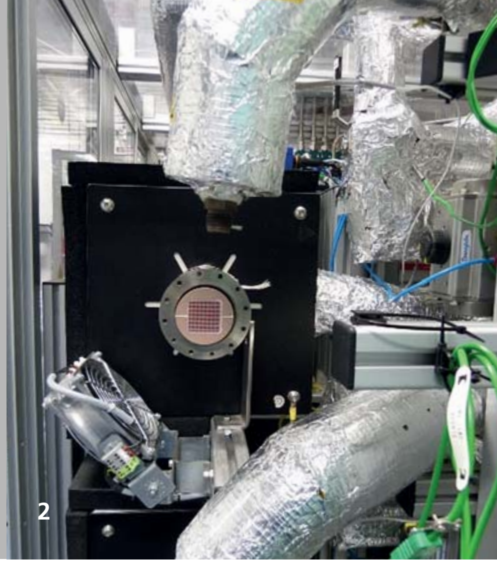

TESTING AND DEVELOPMENT OF DeNOx CATALYSTS

M. Sc. Marcel Hübner, Dr. Uwe Petasch

DeNOx catalysts decrease the content of nitrogen oxides in exhaust gases. Nitrogen oxides are not only detrimental to the health of human beings and the environment due to their irritant and poisonous effects but also because they form ozone with volatile hydrocarbon. According to the German Federal Environment Agency, the emission of nitrogen oxide decreased more than 50 % in Germany over the last 20 years. This trend was motivated by more restrictive exhaust gas legislation, which led to a considerable reduction of the NO_x emission values. Effective exhaust after-treatment systems particularly in automotive, engine and power plant area are necessary to achieve these limits.

Testing and development of catalysts for the after-treatment of exhaust gases is one of the main research areas of the carbide and filter ceramics group at Fraunhofer IKTS. On the one hand, the focus is on the investigation of properties and application behavior of conventional catalysts, and on the other hand, the development of new catalyst solutions. Thereby, the group concentrates on the development of catalysts on the basis of different substrates – highly porous honeycombs and filter segments, open-cell foams and foam pellets – for the application in typical SCR (selective catalytic reduction) and lean NO_x trap catalysts as well as DeNOx functionalized particle filters.

The different catalyst structures will be coated in a similar way with commercial catalyst powders in order to compare their application properties, like catalyst performance, pressure drop and flow distribution. For the analysis and optimization of the catalytic properties, a catalytic test bench with gas compositions close to real exhaust and realistic space velocities is used. For DeNOx catalysts, specific properties, such as NO_x conversion, NH_3 storage capacity, light-off temperature, secondary emission (e.g. N_2O) and resistance against catalyst poison are determined. The measurements are carried out while monitoring the temperature (RT to 1173 K), NO_2/NO_x ratio (standard and fast SCR), exhaust gas composition (NH_3, NO_x, O_2, HC, H_2O, SO_x) and the flow rate (10–100 l/min). The samples are typical drill core samples or specially manufactured shapes with adjusted to the application conditions (V_{max} = 1l) to get representative and significant results.

Apart from the analysis of the reactivity of DeNOx catalysts, other specific methods are used to characterize the properties of catalysts. Also deactivation mechanisms can be understood by analyzing aging-related changes of the catalyst composition, including the washcoat structure and surface as well as the mechanical and thermomechanical properties.

Services offered

- Material and technology development for manufacturing and catalytically coating of ceramic substrates (highly porous honeycomb and filter segments, open-cell foams, foam pellets)
- Application-related determination and optimization of properties of DeNOx components in terms of catalytic performance, structure and composition
- Testing of characteristic aging features (deactivation mechanism) of DeNOx components in post-mortem analyses

1 *Substrates for DeNOx catalysts.*
2 *Synthetic gas catalyst test bench for analyzing exhaust catalysts.*

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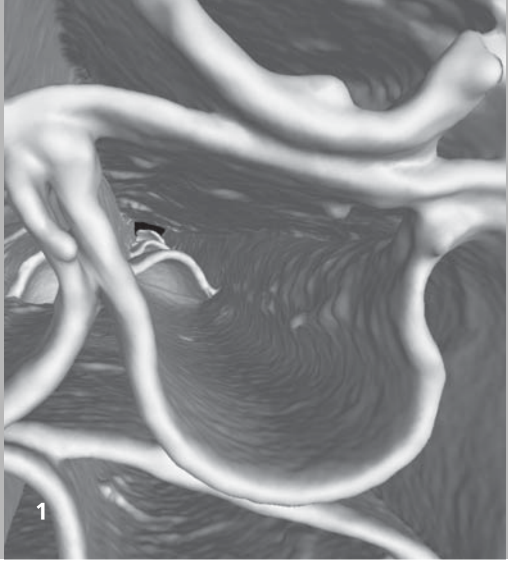

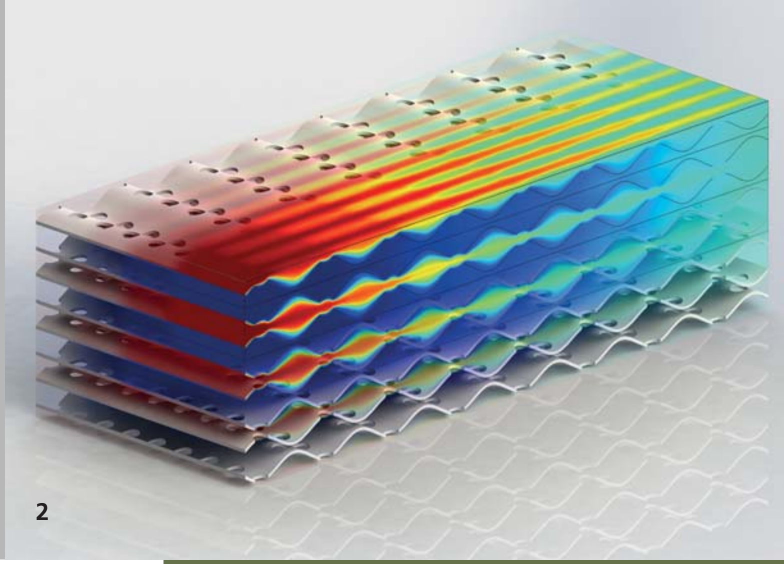

CERAMIC SUPPORT STRUCTURES FOR APPLICATIONS IN HETEROGENEOUS CATALYSIS

Dipl.-Ing. Erik Reichelt, Dipl.-Ing. Uwe Scheithauer, Dr. Wieland Beckert, Dr. Matthias Jahn

Due to the upcoming change in energy and material base, there is an increasing interest in decentralized plants for energy generation and synthesis of chemical products. The development of new processes for these small-scale plants or the transfer of well-known processes to this scale necessitates the application of novel reactor concepts. To reach an efficiency comparable to highly integrated large-scale processes, the improvement of the single process step efficiency is essential. Innovative ceramic support structures may contribute to this development target.

The catalyst support structures that are used in industrial applications today only allow a limited adjustment of mass transfer and pressure drop properties. While, for instance, pellets are characterized by good mass transfer properties, the associated high pressure drop is a major disadvantage. In contrast, honeycomb catalysts offer low pressure drops but also poor mass transfer properties. So far, a specific adjustment of these properties is only possible for metal supports. However, the application of a long-term stable coating with active material remains challenging for these structures. Novel ceramic manufacturing techniques allow the preparation of tailor-made catalyst supports that combine desired properties, like mechanical and thermal stability with the applicability of well-adhered washcoats. Therefore, these structures are advantageous especially for highly exothermic or mass transfer-limited reactions, such as methanation and Fischer-Tropsch synthesis. A possible manufacturing route towards these structures is offered by the application of ceramic tape technology. Raw material in form of powder is casted to tapes. Green tapes can be manufactured continuously and can be shaped, wrapped and joint to yield three-dimensional structures. The manufacturing process also allows the production of composites of different materials. This enables the realization of material and property gradients within the sintered material. Particularly the possibility of integrating metal layers is a promising approach for the improvement of thermal conductivity. By means of simple manufacturing steps, turbulence promoters can be introduced to the channels of the structure. The continuous manufacturing process allows an easy transfer to an industrial scale.

A manufacturing process with a very high degree of freedom regarding the producible shape is additive manufacturing. Although it is – due to higher manufacturing costs – by now only of minor interest for a broad industrial application, it might be an interesting option for special applications, like the production of high-priced fine chemicals. The possibility to increase selectivities might justify the higher production cost in this case.

Both manufacturing processes share the various possibilities for the structuring of the catalyst support. Connections between process design (e.g. mixing, catalytic reaction) and process parameters (e.g. velocity, composition, temperature, pressure) are too complex for an intuitive analysis and design. The application of simulation tools offers the potential to identify advantageous structures for specific applications.

Services offered

- Development and manufacturing of application-specific catalyst support structures
- Catalyst coating and screening
- Reactor and process design
- CFD and multiphysics simulation

1 *Computed tomography image of a ceramic tape structure with turbulence promoters.*
2 *Simulation of the concentration profile.*

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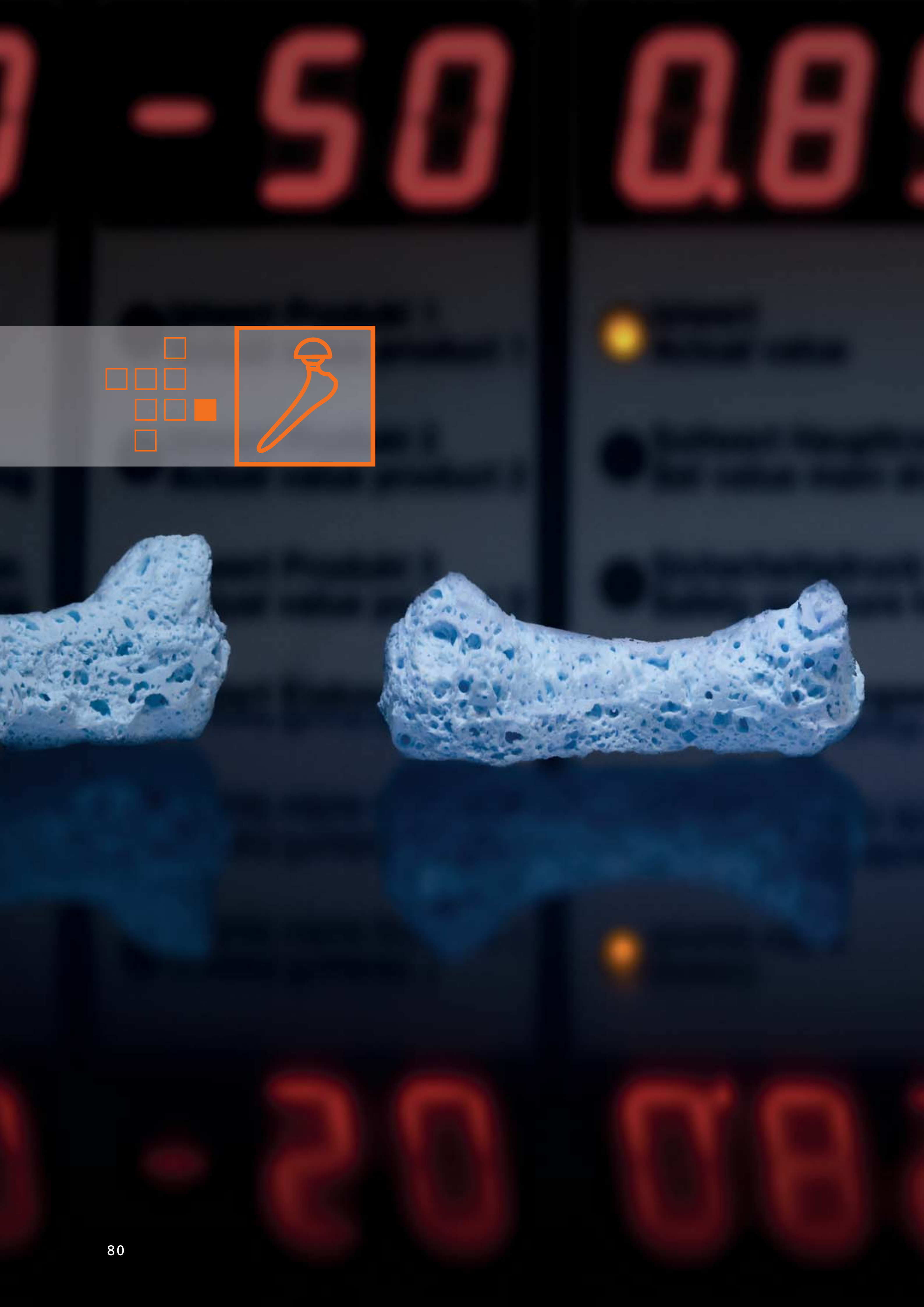


BIO- AND MEDICAL TECHNOLOGY

Project reports

Through its "Bio- and Medical Technology" business division, Fraunhofer IKTS offers ceramic materials, components, and systems for dental technology and endoprosthetics, as well as biomedical diagnostics and therapeutics.

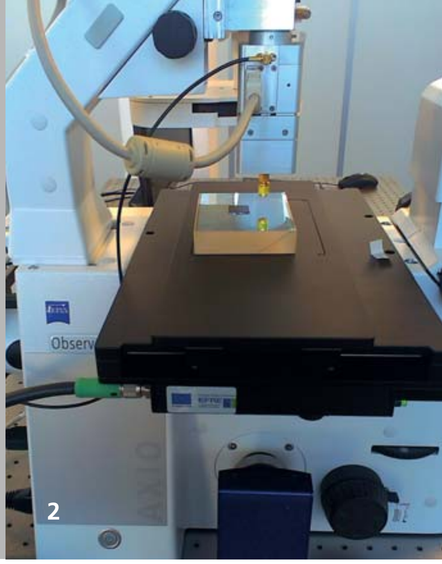
The vast wealth of experience with ceramic materials forms the cornerstone by which Fraunhofer IKTS is able to support industrial and research partners with product development, from raw materials to complete medical devices and equipment. Quality assurance, cost control and enforcement of regulatory requirements: these three pillars are a central part of the medical technology efforts at Fraunhofer IKTS and are guaranteed by its superior technical infrastructure, including certified laboratories. There are longstanding collaborative relationships for the processing of customer-specific tasks as well as in the framework of validation and certification processes.

Fraunhofer IKTS is certified under the German Medical Devices Act for its research and development efforts in the field of bioceramic materials and components, and the production of semi-finished products for use in medical technology. These materials are mainly used in dental technology and endoprosthetics, specifically as bone replacement materials, and in the design of bioceramic surfaces and ceramic bodies. With commercially available materials as a basis, IKTS scientists develop new ceramic materials and components with improved and modified properties. In doing so, the scientists use the latest foaming, molding, and slip casting technologies, apply plasma coating and sol-gel processes, as well as innovative approaches such as additive manufacturing.

Processes used in cell and tissue diagnostics – which provide insights into the behavior of cells within the body and against foreign substances – represent another focus, and thus contribute to the diagnosis and the treatment of serious diseases. The institute's extensive portfolio of physical characterization processes form the basis of these efforts. They are enhanced by its vast expertise in imaging methods, as well as the processing of large volumes of data. The focus here is on the processes, systems and instruments integral to stimulation and monitoring of cells and tissues, and for separating, detecting, and suppressing microbial organisms and toxins. These optical, acoustic and bioelectrical processes are also qualified for use in clinical laboratory diagnostics, point-of-care diagnostics, and home-care applications. The spectrum of services covers everything from design, process, and software development, to construction and assembly of prototypes, to assistance with transferring these to the production phase.

In addition to biophysical, biochemical and biomechanical test laboratories, Fraunhofer IKTS also possesses certified laboratories for cell and immune biology as well as for the analysis of environmental and health risks by nanoparticles.

1



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BIO-NANOTECHNOLOGY APPLICATION LAB (BNAL) IN LEIPZIG, GERMANY

Dr. Jörg Opitz, Dr. Kristin Alberti

The Bio-Nanotechnology Application Lab BNAL is a joint initiative of Fraunhofer IKTS and Fraunhofer IZI. At the location of the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig, the resources of both institutes are combined in a joint project. For the laboratory equipment, 3 million euros were granted by the European Regional Development Fund (ERDF).

The BNAL equipment enables, for the first time, the concentrated processing of interdisciplinary topics – from the biological-medical basic research, to process engineering, to the development and validation of the latest technologies and system solutions. The laboratory and process unit serves as basis for research and development cooperations with internationally leading companies or research institutes. By combining ultramodern equipment and technical expertise of two Fraunhofer institutes, it is possible to address new contacts and open up new topic areas for existing contacts.

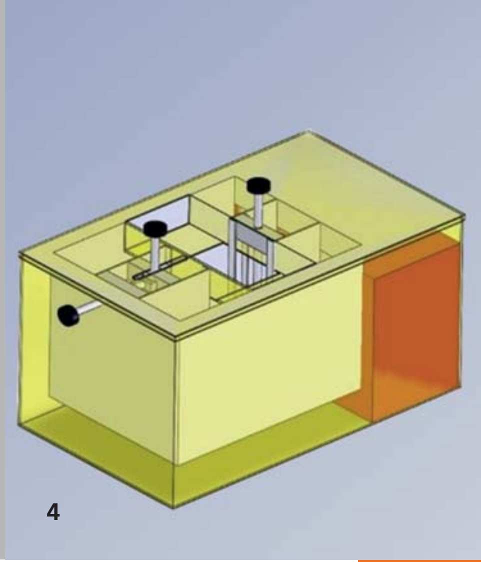
Fraunhofer IKTS uses this cooperation in order to advance its analysis methods and measurement devices according to current issues and, therefore, to tap into new applications and technology areas. At BNAL, biological issues should be processed with the following innovative measurement methods:

1. The Optical Coherence Tomography (OCT) provides spatial high-resolution information from the examination object. One essential aspect of cytological research is the characterization of cell surfaces. The planned systems target the structural and chemical analysis of biofunctionalized surfaces. In addition, plasmonic nanosensors enable the direct study of the temporal process course at cell membranes. Examples for such processes include the absorption of agents from the drug delivery systems, the coupling of viruses to the cell or the tracking of the cell division, e.g. for the evaluation of division rates.

2. The eddy current-based impedance spectroscopy allows for the temporally resolved and randomly repeatable measurement of a system (e.g. antigen/antibody, analytes) as contact-free measurement method. As the process is transferable to smallest volumes, differentiated proofs of substances can be performed, cell measurements for medical diagnostics taken, therapeutic substances developed or the temporal course of polymerization processes of organic substances analyzed. Drawing an inference regarding diseases of biological tissue by measuring the impedance spectrum opens up a broader application field in the medical sector.

3. The ultrasonic spectroscopy is currently applied not only in analytics of fluid media but also in medical diagnostics, e.g. the analysis of cell tissue and other biological materials. There, changes of the mineralization or molecular chains affect the mechanical properties of the system. The changed velocity and attenuation of an ultrasonic wave enables to quantitatively determine elastomechanical properties of biological tissue and large organic molecules. Thus, different tissue types can be identified or pathological conditions analyzed.

4. At BNAL, a scanning acoustic microscope is available, which prospectively integrates the photoacoustic microscopy in addition to the acoustic and optical microscopy. Via acoustic or photoacoustic excitation, spatial changes of the mechanical impedance can be detected within biological materials. This enables the analysis of the structural constitution of a sample over various length scales. Furthermore, organisms, organs and individual cells up to cellular components (organelles) can be mapped and characterized. This multiacoustic microscopy allows for deeper insights into the 3D structure of biological systems on a very small level.



5. Technical possibilities exist of late, which are able to miniaturize immunological and microbiological inactivation or sterilization and integrate them into process courses. For that reason, BNAL hosts a plant for electron irradiation as well as a dosimetry unit. By irradiating organic material with low-energy electrons, process in that material can be specifically influenced. Thus, cell division and reproduction rate can be controlled, which can extend to the sterilization of a surface populated with cells according to the dose. In addition, different properties of cells and cellular populated surfaces can be manipulated with high precision by irradiation. These properties include roughness, reactivitiy, and the condition of different chemical bonds or the charge. Not only are these parameters important for the behavior of living cells but also particularly for the interaction between substrate and cell.

6. By applying an innovative measurement method for determining the temporally resolved relaxation of the autofluorescence at biological tissue or individual cells, their so far insufficiently characterized properties shall be analyzed. For that reason, a specific fluorescence relaxation spectrometer is available. By means of characterizing non-analyzable properties, the possibility of answering medical or pharmaceutical question presents itself.

These devices are complemented by technical equipment of Fraunhofer IZI, which places its focus at BNAL on the fields of molecular diagnostics, flow cytometry and nanostructuring.

With the establishment of BNAL, ideal requirements are created for an optimal joining and usage of both Fraunhofer institutes' available know-how. The application lab has its sphere of activity in the intersection of cell biology, medicine, biotechnology, nanotechnology and medical technology, and therefore, presents an important connection of the special fields to the Saxon research landscape. At BNAL, the participating institutes offer their pooled expertise to potential customers and create added value through their close cooperation, which each institute could not have generated on its own.

Acknowledgements

We thank the European Regional Development Fund (ERDF) und the Free State of Saxony for financing BNAL's equipment.

1 *OCT measurement device (Source: Evonta-Technology GmbH).*
2 *Multi-Acousto-Scope (Source: PVA TePla AG).*
3 *Irradiation system (Source: COMET AG).*
4 *Impendance analysis system (Source: Suragus GmbH).*
5 *Dosimetry unit (Source: TISAD GmbH & Co. KG).*

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TOPICAL UV LIGHT GENERATING CERAMICS FOR THE REMOVAL OF BIOFILMS AND FOULING

Dr. Holger Lausch, Dr. Katja Wätzig, Dr. Isabel Kinski, Dr. Thomas Härtling

Biofilms on medical implants, dental restoration as well as fouling in the maritime and real estate industry still pose a great challenge. Regarding the development of new counter-strategies, central concerns for antifouling are particularly the extrication of toxins and, hence, the environmental compatibility as well as for biofilm prevention their cytotoxicity in the adjacent tissue.

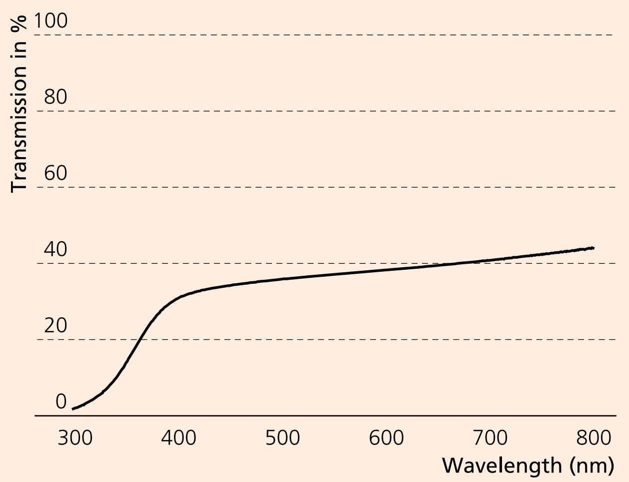
Normally, the removal of fouling and biofilm layers takes place mechanically. The effectiveness depends on the chemically toxic or biochemically cytotoxic pretreatment. The biochemically cytotoxic strategies for combating biofilm are confronted with tricky protection strategies of the biofilm itself, particularly at its surface. For eliminating the counterstrategies of the biofilm, the established traditional methods are inefficient and expansive. In contrast, the traditional mechanical prevention strategies often reach their limits because of the strong adhesion of the biofilm, especially in wet surroundings on surfaces, steps and fissures. As a result, the question of an alternative strategy in contrast to the traditional elimination arises.

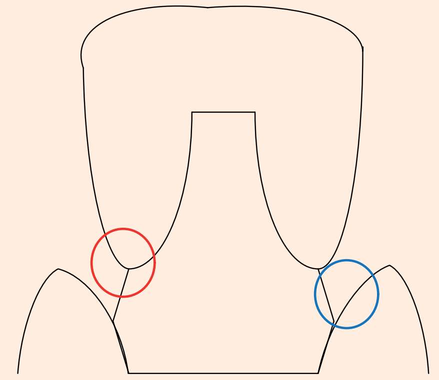
Research approach

As the biofilm adhesion is effective due to strong chemical bonds and at the same time changes or strengthens the bonds within the entire adhesive layer, the destruction of the adhesion of appositions and respectively biofilms on the surface is essential. When the biofilm's unprotected backside (adhesion side) is exposed to UV radiation, the new approach uses the effect of photodissociative decomposition of adhered biopolymers or biopolymer complexes at the biofilm adhesion-interface. For the application, the surface or the substrate needs to be transparent to UV radiation. However, the relevant dental ceramics, polymer composites, glasses, etc. are not transparent in the UV range. In order to generate a UV effect on the interface between biofilm and substrate, the UV radiation needs to occur locally and conditioned so that the healthy tissue is not simultaneously damaged. For attaining this effect, the property of translucency is used in the visible range (not UV!). After permeating the material, e.g. with blue light radiation, UV light is produced locally defined and topical at the adhesion side of the biofilm. This requires a light-converting layer (UV luminescent layer) on the substrate surface populated with biofilm, so that the unprotected backside of the biofilm can be irradiated. Luminescent materials, which can be equipped with a luminescent layer, are represented by the dental bio- and veneering ceramics of the IKTS with transmission rates of 20 to 60 % in the visible light spectrum (diagram below).

Irradiating this translucent ceramic with visible, non-cytotoxic blue laser light with a wavelength range from 450 up to 490 nm, a UVA/UVB radiation is emitted on the backside (adhesion layer) of the biofilm. The kind of luminescent material, its density and the exposure duration on the substrate surface allow a topical application of UV light. This topically applied UV light is only effective on the adhesion side of the biofilm without impairing the healthy tissue in the surrounding.

Translucency of IKTS bioceramics





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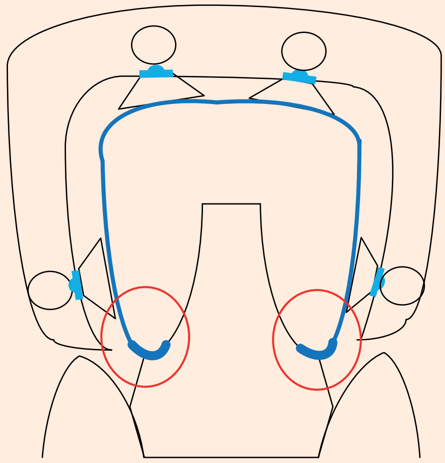

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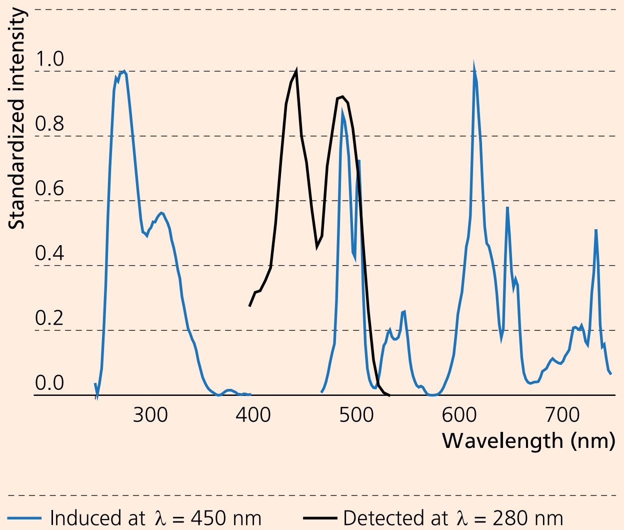
Application

One of the first applications can be seen in the protection of the preparation margin of dental restorations. At the lower final preparation margin, a more or less distinct cleavage range is formed between the dentin (dental neck) and the dental restorations (Figure 3).

Emission bands of the translucent material when irradiated with blue light (450 nm wavelength), excitation bands attested for UV radiation



There, biofilms, especially the periimplantitis (type of parodontitis) causing germs, find particularly attractive population areas. These areas are difficult to access with the current remedies and form biofilm islands, which seed biofilm germs again and again.

Due to their advantageous translucency (transmission rate) in the visible radiation range, the veneering, crown or bridge ceramics developed at IKTS offer particularly good requirements for the application of the above-mentioned UV effect, if they are equipped with a UV luminescent layer directly at the preparation margin and irradiated with intensive blue light, for example, with the aid of a luminescent jaw protection (Figure 4).

Services offered

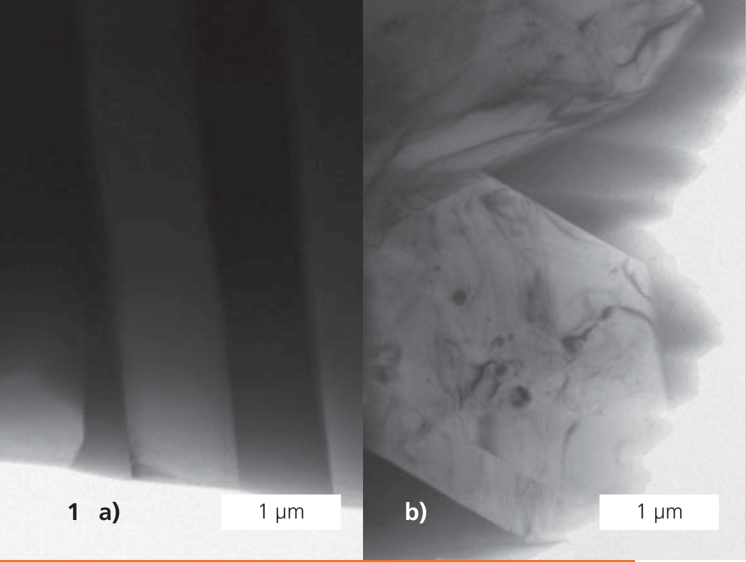
- Customized, application-specific syntheses and developments of ceramic luminescent materials including characterization
- Development of application-specific laminations and corresponding surface structures
- Technical realization of application options

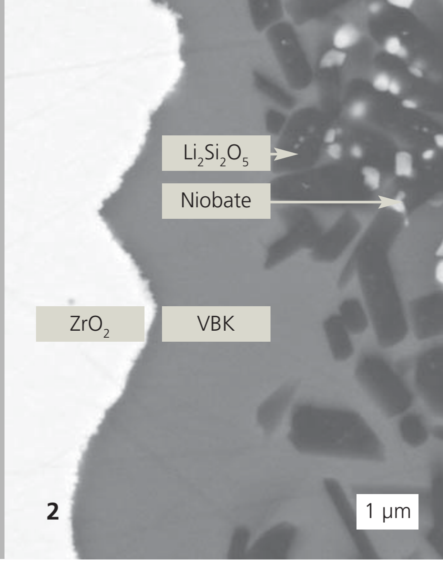
1 Veneering ceramics with transmission in visible light.

2 Crown framework with biological design.

3 Preparation margin (red), dentin gingiva range (blue).

4 Schematic illustration of a jaw protection with blue lighting.





CRYSTALLIZATION BEHAVIOR OF LITHIUM DISILICATE VENEERING CERAMICS

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

Lithium disilicate glass ceramics as veneering ceramics

Lithium disilicate glass ceramics have been known for a long time. The processing is carried out by milling and hot pressing from blanks. For the developed veneering ceramics, powders are used. At a temperature of 900 °C, lithium disilicate (LDS) crystallizes at a rate of approximately 10 µm/sec [1]. If powdered material is used, the corresponding particle is crystallized in a very short time. An increase of the viscosity is connected to the crystallization, which reduces the rate of reaction with both the adjacent grain and the TZ3Y substrate. In order to take advantage of the excellent properties of the lithium silicate glass ceramics as veneering ceramics (VBK), it is necessary to control the proportion of crystal and glass phase.

Ratio Li_2O:SiO_2 on the crystallization behavior

The TEM images [2] (Figure 1a/b) show the change in the morphology of lithium disilicate in dependence of the ratio Li_2O:SiO_2. Based on the molar ratio of 1:2 from the LDS, an excess of SiO_2 (1:2.6) can be seen in Figure 1a and a lack of SiO_2 (1:1.4) in Figure 1b. The Li_2O excess leads to sharper crystal contours, many stacking faults and inclusions in the crystal (1b). For veneering ceramics, the sample with higher SiO_2 content, less pronounced grain boundaries or the continuous transition between crystal and glass phase is better suited. In the crystals of the sample (1a), TEM micrographs show no inclusions and only a few stacking faults.

Interface/surface effects and diffusion processes

a) Interface between veneering ceramics and zirconium oxide

ZrO_2 diffuses out of the ceramic framework into the veneering ceramics. TOF-SIMS studies [2] show that the ionic components of Li_2O, Na_2O and Nb_2O_5 diffuse into the zirconium oxide ceramics. This leads to a depletion of Li^+ ions in the boundary region of the veneering ceramics and, thus, to the emergence of a glass phase. The diffusion behavior enables a very intense adhesive bond between the framework of yttrium-stabilized zirconium oxide and the veneering ceramics.

b) Interface between LDS crystal and the adjacent glass or crystal phase

For the developed veneering ceramics, Nb_2O_5 is an essential part. With the crystallization of LDS and the associated concentration shifts, sodium niobate crystals are formed directly at the LDS crystals (Figure 2). Raman spectroscopy shows an intense peak at the wave number of 860 cm^{-1} for both the niobate crystal and in the amorphous region. The niobate-analog structural units favor the melting of the powdered LDS glass ceramics and the formation of a smooth surface.

c) Surface of the veneering ceramics and application

After annealing process, the surface of the veneering ceramic is smooth, glassy and does not require glaze firing. The developed veneering ceramics type was handed to the project partners for the market launch phase. Figure 3 shows a dental restoration with sprayed veneering ceramics.

Sources

[1] T. Honma and T. Komatsu, Journal of the Ceramic Society of Japan 116(12) 1314-1318 2.
[2] TEM/TOF-SIMS in Kooperation mit Fraunhofer IWM / Prof. Höche.

Bundesministerium für Wirtschaft und Energie

1 Influence of Li_2O:SiO_2 on the crystal structure of LDS (TEM).
2 Interface between veneering ceramics and ZrO_2 framework (REM).
3 Zirconium oxide bridge with sprayed veneering ceramics.

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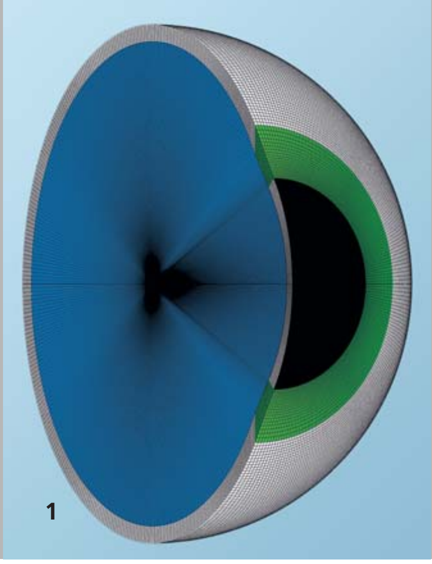

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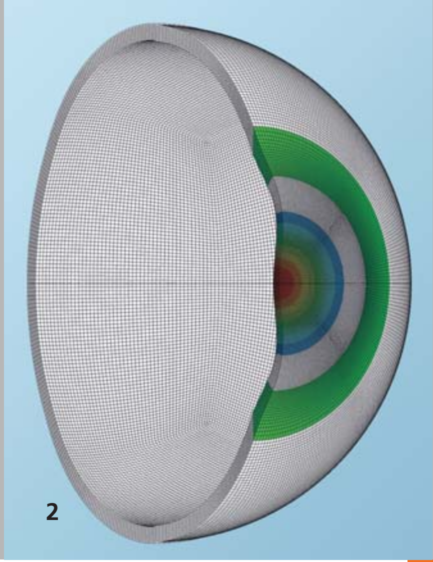

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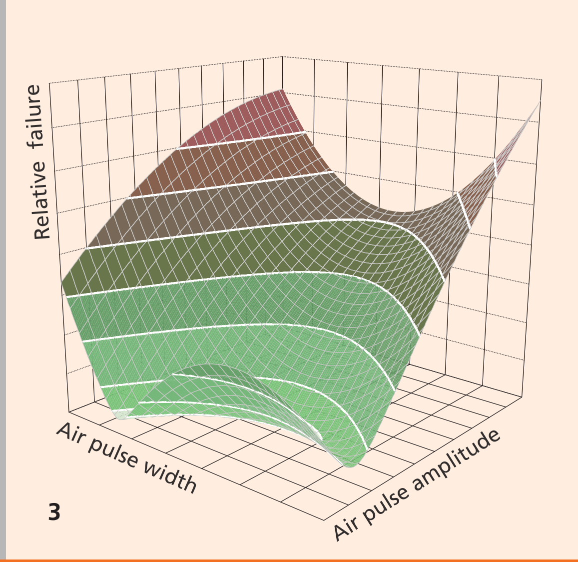

3

SIMULATION-BASED DETERMINATION OF BIOMECHANICS OF THE HUMAN EYE

Dipl.-Ing. Stefan Münch, Dr. Mike Röllig, Dr. Frank Schubert

The sooner you identify diseases, the sooner you are able to react. Previous possibilities to diagnose eye disease, like glaucoma, are limited, and therapies can just keep the current condition. The Keratokonus, a thinning and deformation of the cornea, is a similar example. In order to early diagnose the diseases, an effective method is necessary.

Changes in the biomechanical properties of eye parts are reasons or side effects of various diseases. To determine these properties non-destructively is the challenge. The company OCULUS Optikgeräte GmbH developed a medical device, the so-called Non-Contact Tonometer, for measuring the intraocular pressure contact-free. It uses an air pulse to deform the cornea and record it visually. Therefore, it offers the possibility to determine biomechanical properties of the eye on the basis of the deformations, if the functional relations are known.

In cooperation with OCULUS Optikgeräte and the ophthalmic clinic of the university medical center Carl Gustav Carus in Dresden, Fraunhofer IKTS is currently working on the advancement of the medical device targeting the identification of regression functions for inversely determining the material properties of the human eye.

Performing plenty of parameter variations with comparatively low effort is a potential of a numerical model. In combination with statistical methods, such as the significance analysis, the effects of different parameters can be systematically analyzed with regard to particular variables.

The determination of the air pulse parameters serves as initial point of the cooperation because these are not measurable due to the highly transient appearance of the impulse. Therefore, experiments with contact lenses were performed and simulated under variation of the air pulse parameters in order to identify the functional coherence.

The relative failure between the results of the regression functions and the experiments according to the air pulse parameters is visualized in the diagram. During the further course of the project, a geometrically detailed numerical model of the human eye was generated, which is gradually adapted to the reality. Currently, it includes anisotropic material characteristics, which are adjusted to the real course of collagen fibrils (= fiber reinforcement). Furthermore, there is an iteration algorithm implemented into the model, which adjusts the geometrical initial state of the eye under intraocular pressure with high precision. Prospectively, hyperelastic material models and a dependency between the material characteristics and the load type (tension/compression) typical for fiber composites are implemented.

Although the model is in development, medical questions were investigated in addition to the device-related ones. As an example, analyses regarding the influence of the vitreous body and its viscosity on the deformation behavior and the intraocular pressure were performed. Furthermore, simplified regression functions for determining the biomechanics were identified. In future, functions with higher accuracy and additional information will follow.

1 *Numerical model of the human eye.*
2 *Deformed model (fluid suppressed).*
3 *Surface plot of the relative failure regarding the air pulse parameters.*

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BUSINESS DIVISION

OPTICS

Project reports

In the "Optics" business division, Fraunhofer IKTS designs and supplies ceramic materials, components, and systems for lighting, medical and laser technology, optical measurement and diagnostic systems as well as ballistic applications.

Optical technologies are the drivers of innovation and growth. This fact applies to lighting – as in resource-friendly LEDs, for instance – but also to minimally invasive medical diagnostic systems and contact-free measuring devices. With the aid of competitive technologies, Fraunhofer IKTS transfers basic scientific expertise to products that demonstrate high performance capacity and solid reliability. This technology chain begins with the material and ends with integration into complex systems.

For years now, Fraunhofer IKTS has been and remains the global leader in the production of transparent ceramics with special ultrafine crystalline structures and superior mechanical parameters. These polycrystalline ceramics exhibit the kind of superior quality that makes them suitable for use in those optical or photonic applications that require a high degree of optical homogeneity and mechanical stability while simultaneously keeping absorption and scatter loss to a minimum. The targeted dosing or phase synthesis, by contrast, leads to optically active materials, such as luminescent materials for example, i.e. materials for which a high quantum yield, thermal stability of the color spectrum and long persistence periods represent quintessential parameters. If these two technologies are combined, active optoceramics with a homogeneous distribution of dopants in the ceramic or polymer matrix are developed at Fraunhofer IKTS. These components have both active and beam-forming properties as well as good mechanical and thermal properties, and are suited for a diversity of applications in the field of optoelectronics. Of increasing importance for the business division are optical systems – specifically those involving reflection instead of transmission, and are used as high-performance components in laser and aerospace engineering.

Optical methods hold particular appeal and potential for rapid and cost-effective condition monitoring of materials, modules, and industrial and biomedical processes. Optical procedures can demonstrate their benefits wherever measurements must be contact-free or performed in extreme conditions. At Fraunhofer IKTS, new and established methods are being developed and integrated as a comprehensive system into the respective process, based on customer specifications. In addition to processes built on the interaction of light and material, the institute also focuses on optically active nanosensors in the development of optical measurement and diagnostic systems.

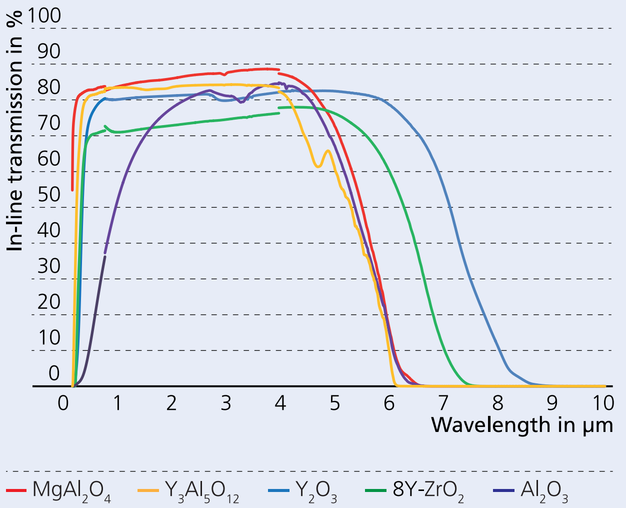
OPTICS

OPTICAL CERAMICS WITH SPECIFICALLY ADJUSTED SPECTRAL TRANSMISSION

Dr. Jens Klimke, Dr. Andreas Krell

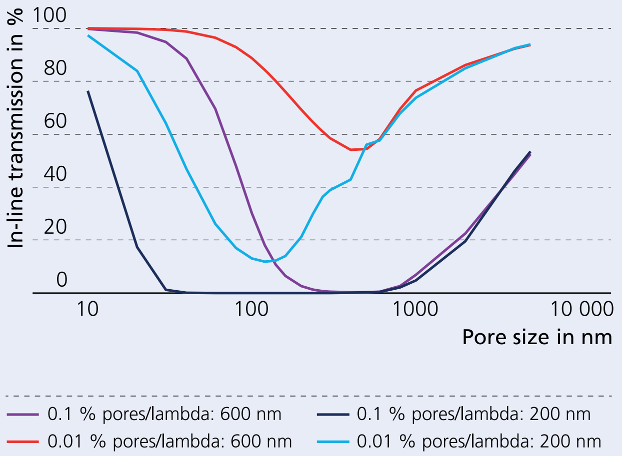
The light transmittance of solid-state bodies is determined by the atomic structure and can be described by the complex refractive index as a function of the wavelength. The real part of the refractive index detects the reflection on the surface and the imaginary part detects the absorption during the passage of the light beam. In the real crystal, the size of the light-transmitting area between the absorption edge in the short-wave and long-wave region of the spectrum is limited by the defect population and the purity of the material. The diagram below shows the transmission spectra of several different transparent ceramics from the UV to the IR region. The transparent ceramics can achieve spectral transmissions similar to single crystals but have special features to be discussed in the following.

Transmission spectra from UV to IR for transparent ceramics (thickness: 2–4 mm) developed at IKTS

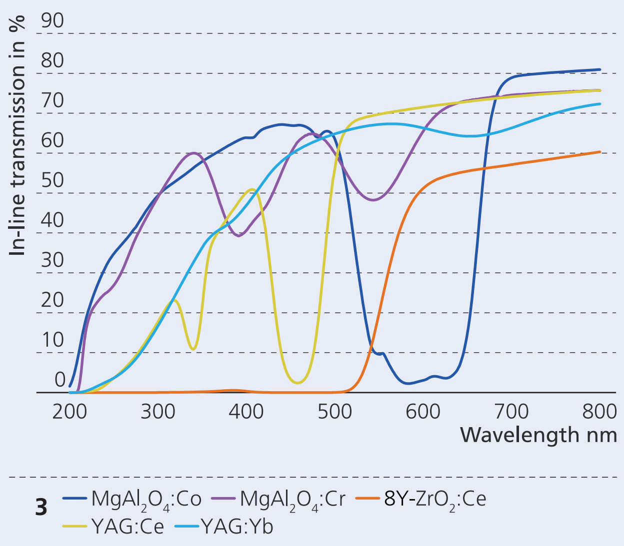


Due to their polycrystalline structure, the transmission in ceramics is influenced by stray light of pores and foreign phases. In anisotropic crystal systems (such as corundum and tetragonal ZrO_2), additional scattering of light by the directional dependence of the refractive index, which leads to a splitting of the light path of each crystallite, has to be taken into account. In order to achieve sufficient transparency, the scattering of light must be minimized. This is achieved by defect-avoiding manufacture of the ceramic green bodies and sintering methods that allow almost complete consolidation into pore-free ceramics. The strongest decrease of transmission by scattering can be observed for scattering centers, which correspond to the diameter of the wavelength of light. The influence of birefringence can be decreased by applying grain sizes smaller than the wavelength of light. Also, small pore sizes can contribute to a lower amount of light scattering. The diagram below shows a simulation of the reduction of transmission by Mie scattering of 0.1 % and 0.01 % spherical pores in spinel ceramic of 1 mm thickness as a function of pore diameter for the wavelengths of 200 nm and 600 nm.

Reduction of in-line transmission by scattering of pores in spinell ceramics



Microcracks, for example as generated during annealing in air, influence the transmission particularly in the short wavelength region of the spectrum. Individual coarser defects > 20 µm reduce the transparency on average only slightly but are perceived visually distracting and cannot be tolerated for optical



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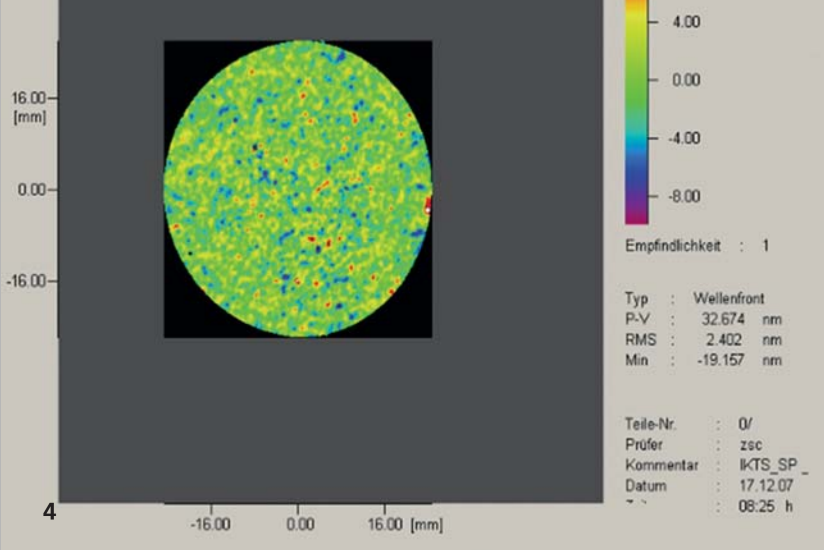

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applications due to the aberrations. A selective influencing of the spectral transmittance can be affected by the incorporation of dopants. Absorption states realized by specific dopants are the base for ceramic laser components, optical filters and ceramic scintillators for lighting technology and medical technology. Figure 1 shows transparent spinel ceramics (thickness 3.9 mm) with cobalt doping (blue), chromium doping (red), and a cerium-doped cubic 8Y-ZrO_2 ceramics (orange, thickness 1.9 mm). The absorption bands of the different ceramics are displayed in the UV-VIS spectrum (Figure 3).

Figure 2 shows YAG ceramics (thickness 2.7 mm), doped with ytterbium (light blue) or with cerium (yellow). The spectrum of the in-line transmission (Figure 3) shows that for 8Y-ZrO_2 the absorption band with cerium dopant is shifted to shorter wavelength. Both mechanisms, incorporation of absorption centers or scattering centers, open new possibilities in contrast to the classical transparent materials, such as glass, crystals and transparent plastics to create materials with new optical properties and to combine the excellent mechanical and thermal properties of ceramics with new optical properties. Compared to single crystals, transparent ceramics provide advantages due to the isotropic structure of polycrystalline microstructure, such as simplified manufacturing processes and new dopant opportunities, e.g. in higher concentrations.

Potential applications of transparent ceramics include mechanically, thermally or chemically stable windows for ballistic protection or for thermally or chemically stressed reactors and IR-transparent domes. The specific optical properties of ceramics, such as high refractive index and low stress-induced birefringence, make transparent ceramics interesting for optical lens systems. The requirements for the optical quality of ceramics depend on the respective applications. The following table defines development goals in terms of the criteria: loss factor k, in-line transmission, optical homogeneity and the number of visible defects at the wavelength of 600 nm for ceramic windows, optical lenses made of ceramics and laser ceramics. Partially, these parameters are highly ambitious because they are ultimately based on the task of producing perfect, i.e. in volume, completely defect-free ceramics. The necessary technologies for each crystal system and any impurity have to be developed starting from the ceramic raw materials followed by shaping and sintering.

Fraunhofer IKTS in Dresden has successfully met this challenge for the past 15 years, as the good optical homogeneity of IKTS spinel ceramics (see Figure 4, measurement Zeiss-SMT), which exceed the requirements of laser-suitable sapphire single crystals in terms of homogeneity, demonstrates.

Optical requirements of different application fields for transparent ceramics

Application field	Loss factor k in-line ~ 600 nm	In-line transmission ~ 600 nm, 4 mm thickness	Optical homogeneity Δn	Number of visible defects > 20 µm
Window	≤ 0.05 cm^{-1}	> 0.95 T_{max}	-	< 100/cm^3
Optical lenses	< 0.01 cm^{-1}	> 0.99 T_{max}	< 0.05 ppm	< 10/cm^3
Laser ceramics	< 0.001 cm^{-1}	> 0.999 T_{max}	0.01–1 ppm	~ 0

For further progress, a systematic investigation of the basic relationships between properties of ceramic raw materials and their compaction behavior, as well as the sintering mechanisms of ceramics at densities > 99.9 % of the theoretical density is required.

Acknowledgements

Parts of the presented research were supported by King Abdulaziz City for Science and Technology (Riyadh, Saudi Arabia), Schott AG (Mainz, Germany) and Zeiss-SMT GmbH (Oberkochen, Germany).

1 Doped $MgAl_2O_4$ and 8Y-ZrO_2 ceramics with specific absorption.

2 Doped YAG ceramics with specific absorption .

3 In-line transmission spectra of the ceramics from Figure 1 and Figure 2.

4 Homogeneity measurement of IKTS spinel ceramics.

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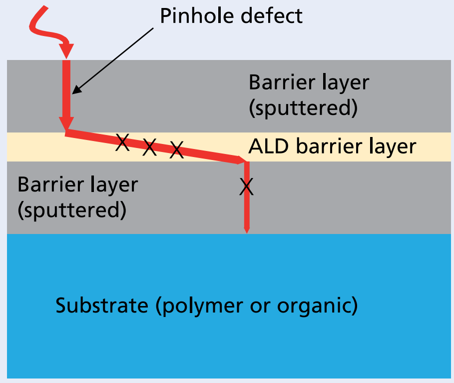


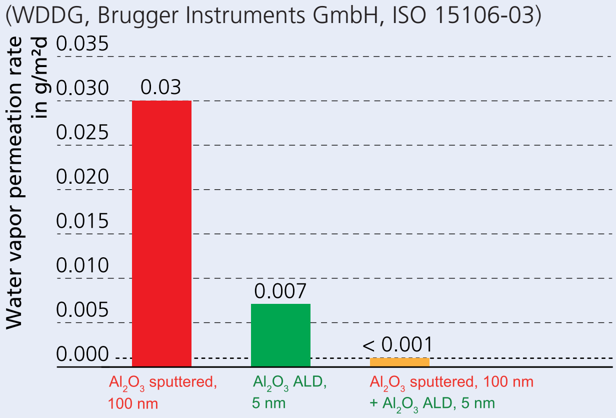
2

BARRIER LAYERS FOR THE ENCAPSULATION OF ORGANIC ELECTRONICS

Dipl.-Phys. Mario Krug, Dr. Ingolf Endler

Organic electronics, such as organic solar cells or organic light emitting diodes, rely on functional thin-film layers, which are very sensitive to moisture and oxygen. Desired substrates for the fabrication of these devices are polymers. However, these materials have an insufficiently high water vapor and oxygen permeation. Therefore, an excellent encapsulation and protection of the device against moisture and oxygen is necessary. The encapsulation has to limit the oxygen permeation rate to less than 10^{-3} $cm^3(m \cdot d \cdot bar)^{-1}$ and the water vapor permeation rate to less than 10^{-4} $g(m^2d)^{-1}$. Established encapsulation processes use, for example, layer stacks, in which an organic interlayer with a thickness of some micrometers is embedded in two inorganic barrier layers of a single layer thickness of approx. 100 nm. The inorganic barrier layers are deposited under vacuum by PVD whereas the interlayer is applied by lacquering. The interruption of the vacuum in the process chain hinders the development of overall concepts for encapsulation processes. The encapsulation process developed by IKTS in cooperation with the Fraunhofer FEP combines inorganic barrier layers, applied by magnetron sputtering, with a thin interlayer applied by atomic layer deposition (ALD). The thin ALD interlayer is also deposited in vacuum and covers or respectively seals defects of the sputtered layer (Figure 2) underneath.

Water vapor permeation rates of different barrier layer systems
(WDDG, Brugger Instruments GmbH, ISO 15106-03)



Substrate: PET, 75 µm

A comparison of different barrier layers (left diagram) shows a much better barrier performance of a 5 nm ALD-Al_2O_3 in relation to a sputtered 100 nm Al_2O_3 layer. A combination of these two layers enhances the barrier performance significantly so that the water vapor permeation rate falls below the detection limit of common barrier analyzers. For a better evaluation of the quality of encapsulation properties, a 20 nm ALD-Al_2O_3 layer was embedded in two sputtered Al_2O_3 layers with a single layer thickness of 100 nm on a plastic substrate. In this case, the water vapor permeation rate was determined by the help of an optical calcium test. The obtained value of $6 \cdot 10^{-5}$ $g(m^2d)^{-1}$ is comparable to other encapsulation processes. The use of ALD barrier layers opens new opportunities for continuous manufacturing techniques without vacuum interruption. Furthermore, these analyzes show that even very thin ALD layers are a promising component within overall encapsulation concepts for sensitive organic electronics.

Services offered

- Manufacturing and analysis of barrier layers
- Development of ALD processes
- Sample preparation for product development

1 *ALD lab-scale equipment of the IKTS.*
2 *Structure and mechanism of action of the new barrier layer system.*

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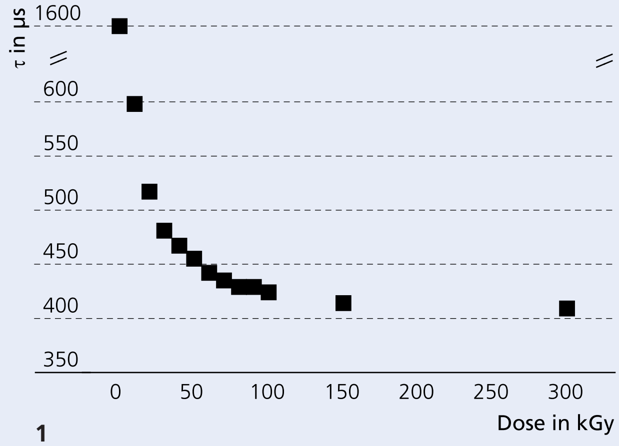

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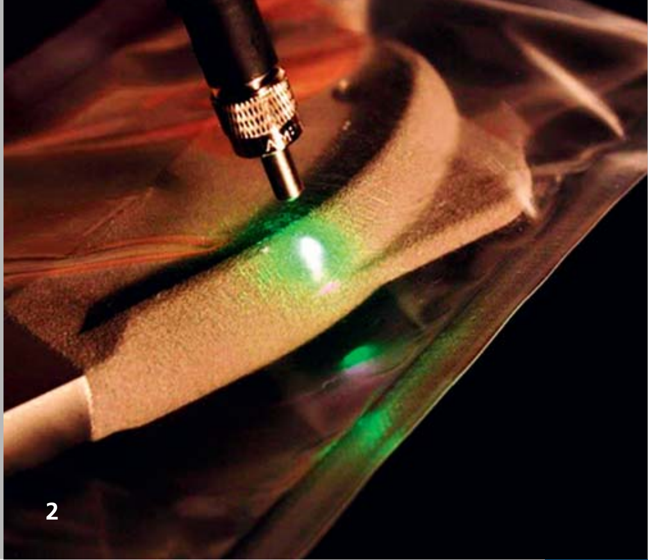


2

TAPE AND 3D DOSIMETRY FOR THE MONITORING OF ELECTRON BEAM PROCESSES

M. Sc. Manuela Reitzig, M. Sc. Jens Antons, Dr. Jörg Opitz, Dr. Christiane Schuster, Dr. Thomas Härtling

The sterilization of surfaces via electron e-beam in the low-energy range is important considering, for example, the aseptic packaging of products. Highly sensitive medical devices, surfaces of food packaging, thermolabile plastics, sensitive electronics or functional, biological materials can be sterilized with low-energy electrons. However, there is no in-situ method to verify a successful electron beam sterilization so far, which increases the cost for qualtiy assurance.

At Fraunhofer IKTS, a method was developed which allows to control the sterilization process reliably and with high lateral resolution. Powdery inorganic luminescent materials, which change their optical properties in the course of the electron irradiation, were used on that account. These luminescent materials react to optical stimulation, for example via infrared light, with distinct luminescence. For this purpose, so-called up-conversion materials are particularly interesting. In this material class, the electronic interaction of host crystal lattice and doping causes the emission of a high-energy quantum after the absorption of two low-energy light quanta (photons). Thus, infrared light (IR) is transformed into visible light in the crystal lattice.

The luminescence decay time of ceramic luminescent materials provides information about the incorporated radiation dose via electron beam. Figure 1 shows the optical response after stimulating the pigments with short light pulses. After the energy input through the sterilization process, a clear reduction of the luminescence lifetime τ can be observed, which is dependent on host lattice and doping regarding its distinctiveness. With increasingly applied radiation dose, the luminescence lifetime is further reduced.

By integrating the inorganic pigments directly into the packaging materials (e.g. plastic tapes) or applying them onto the surface of test bodies, quality control of the irradiation process is possible. During the development, it was apparent that the physical integration via compounding process is most suitable as it represents a ready-to-use procedure.

Tapes cast with inorganic luminescent materials are used as dosimetry tapes at Fraunhofer IKTS for the proof of electron and gamma radiation (Figure 2). Furthermore, the coating of three-dimensional test body surfaces with pigments is possible. This allows for the dosimetric analysis of complicated surfaces, for example screw threads on food packaging. So far, such surfaces with fine structures posed a major challenge for dosimetric strips.

Besides the high lateral dose resolution, the wide dynamic range of the reaction on the applied dose (up to > 100 kGy, highest sensitivity up to 25 kGy) is another major advantage of inorganic pigments. Moreover, the luminescence measurement can take place instantly, i.e. without further preparation of the dosimetric tape or the coated surface. For this reason, the method can be applied in-situ at irradiation facilities and used for process control. In special cases, a local repitition of the sterilization procedure is possible.

Hence, in respect of continuously increasing requirements regarding quality assurance, inorganic luminescent materials have considerable advantages in contrast to conventional dosimetric processes.

1 *Dependence of the luminescence decay time τ on the applied radiation dose.*

2 *Packaging material with integrated inorganic pigments under infrared stimulation.*

BUSINESS DIVISION

MATERIALS AND PROCESS ANALYSIS

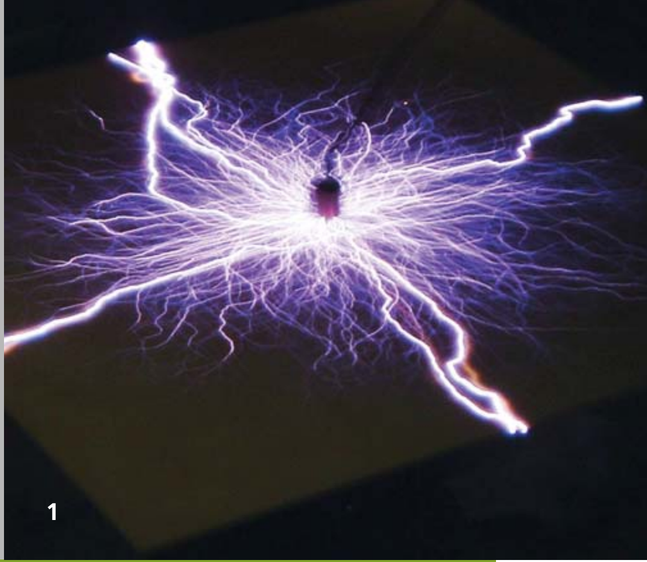
Project reports

Through its "Materials and Process Analysis" business division, Fraunhofer IKTS provides users and manufacturers of materials and components with a comprehensive portfolio of methods for testing, characterization, and analytical methods for material properties and production processes. The focus here is on ceramic materials, components, and processes for technical applications, including lightweight construction as well as materials for microelectronics, nanoelectronics, photonics and biomedicine.

How do microstructure and composition influence the macroscopic properties of a material, and hence the product itself? Can a less expensive material replace an existing one, without any loss to the quality of the product? How can production processes be configured to make them stable, cost-effective, efficient and sustainable? What quality standards must be observed and enforced? In order to respond to these and other questions associated with the application and production of materials, the complex interrelationships that exist among raw materials, production technology, material structures and properties, as well as the operating conditions must be considered as a whole. In this regard, not only are the key performance indicators identified – they are interpreted as well.

Fraunhofer IKTS sees itself as first contact for any issues that involve chemical, thermal, microstructural, mechanical, tribological, electrical and electrochemical analysis, assessment and optimization of materials and components, as well as the manufacturing processes involved. Aside from all of the necessary standard analytical methods, the institute also has the world's most exceptional tools at its disposal – especially to identify, define and quantify the properties at extreme temperatures. With its vast reservoir of expertise in processes, materials and analysis as its foundation, Fraunhofer IKTS consults with and assists clients with the development of new materials and products, clarification of complex failure mechanisms and achievement of legal and quality standards. With accredited laboratories for determining characteristic values for powders, suspensions, thermophysical and electrical/dielectrical materials, electrical components and component systems, the institute is in a position to perform a variety of quality assurance and certification tasks commissioned by the customer – from products and processes to the study and analysis of prototypes.

Fraunhofer IKTS is a reliable, manifold accredited and regularly audited service provider devoted to the investigation and evaluation of materials science principles, application-specific questions and metrological developments.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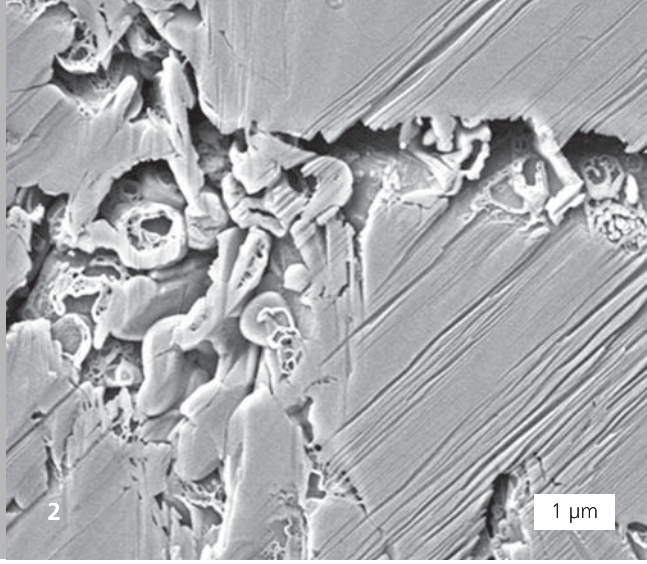


2

FAILURE ANALYSIS AND CORROSION BEHAVIOR OF CERAMIC COMPONENTS

Dr. Mathias Herrmann, Dr. Sören Höhn, Dipl.-Ing. Kerstin Sempf, Dipl.-Ing. Roy Torke

The urgent need of cost-efficient production components, which exhibit longer lifetimes both under abrasive tribological and corrosive conditions, exists in broad areas of the economy. This leads to the increasing strain of existing materials and components in various applications. Besides developing high-performance materials, a substantial, stress-suitable materials selection for different applications is necessary in order to avoid early component failure. For that, detailed knowledge of the material behavior under mechanical thermal, corrosive and tribological stress is required. This knowledge can be generated, on the one hand, via well-engineered measurement and analysis methods, which can map extreme stress conditions. On the other hand, conclusions regarding the failure cause can be drawn from a profound analysis and evaluation of failure or defect incidents. Therefore, a qualification of the materials is possible. For solving research questions, a unique combination of modern analysis devices and know-how for the characterization of microstructures and properties of the entire range of ceramic materials, hard metals and cermets is available at IKTS. Due to the close linkage of the characterization with the other departments of IKTS, a substantial interpretation of the results is possible.

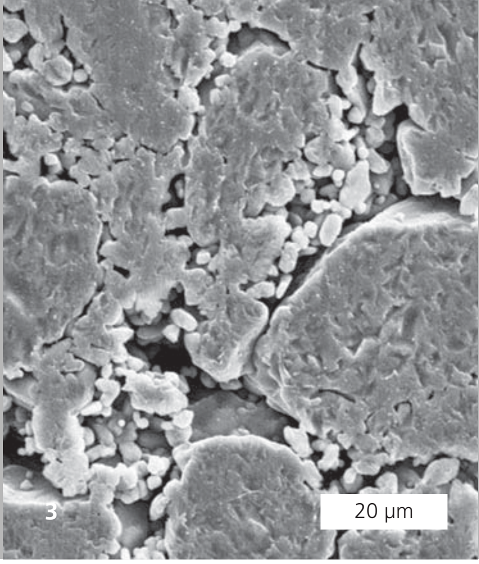
Regarding the analysis of both failure or defects incidents for customers and in-house developed components, extensive fractographic studies and changes in the microstructure and properties are performed. If necessary, accompanying simulations of stresses are possible to determine the failure causes. A fractographic analysis often clearly informs about the fracture source and fracture-causing defects. From the type and size, conclusions regarding stresses can be drawn and hence, possible failure causes. Non-destructively detetced defect in the component can be accurately prepared by mechanical or ion beam-based methods (BIB, FIB). These can be visualized with high-resolution imaging and analyzed. For this purpose, high-performance scanning electron microscopes and a transmission electron microscope are available at IKTS.

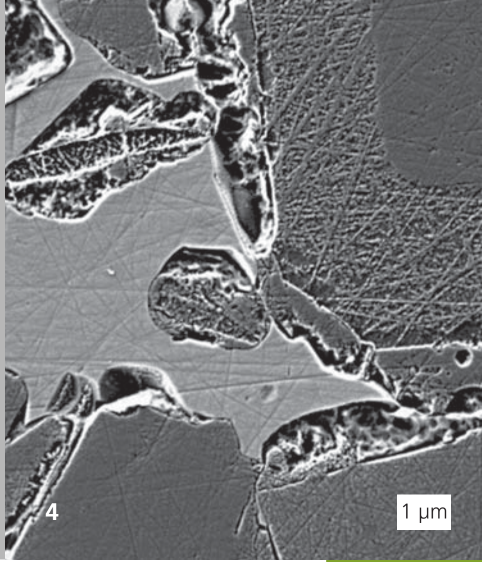
Via micro x-ray diffractometry or electron beam diffraction in the scanning electron microscope, information on the chemical analysis as well as crystalline structures of phases can be obtained.

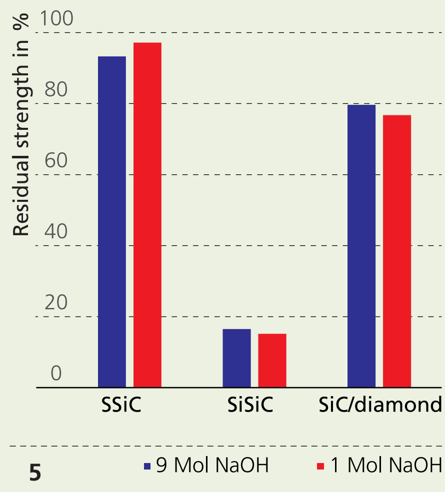
An example for such a target preparation is shown in Figure 1 and 2. After applying thin hBN discs with a field strength of up to 80 KV/mm, puncture can be observed. In Figure 2, the puncture channel prepared via ion beam cutting is depicted. Analyses show that oxidation and melting of the hBN partially occur [1]. In contrast to other analyzed materials, hBN exhibits no microcracks around the puncture channel, which indicates an excellent thermal shock behavior.

The failure analysis can be replicated by simulating mechanical, thermal stresses via adjusted test methods up to tests in the vibration test stand (acceleration < = 200 g) or by simulating thermal shock or climate fluctuation, or respectively nummerical simulation.

Besides mechanical, thermal stresses, corrosion plays an important factor in the operating behavior of materials. At IKTS, manifold methods for corrosion testing of ceramic materials and components were established. Table 1 shows an overview of the most important methods. Furthermore, tests adjusted to specific applications (e.g. interaction with molten metal) can be generated and performed on the basis of extensive know-how. In addition to the testing of materials and components according to standardized tests, the testing of stability under various conditions is carried out in order to determine corrosion cinetics and mechanisms. The corrosion progress is characterized by various parameters, such as mass and geometry change, formation of corrosion layers, microstructure and phase change, as well as residual strength, and is then correlated with the microstructures and compositions of the materials.







Corrosion is a property of the system, which is why the detailed knowledge and control of the corrosion conditions is important. Figures 3 and 4 show the surfaces of SiSiC in a post-corrosion state in 1 M NaOH after 200 h at 70 °C (Figure 3) and after applying a voltage at room temperature. While SiC is stabil without the impact of the electric current and only the free silicon is dissolved by means of NaOH, SiC formed secondarily during the siliconization is attacked in the chemical corrosion. The freely available Si is not affected as much, which indicates different corrosion mechanisms [2]. Mostly, the simple measurement of the mass change or corrosion layer thickness is sufficient in order to understand the behavior of materials under application conditions. For this purpose, the measurement of the residual strength is additionally necessary. Figure 5 shows the change of the residual strength of SiSiC, SSiC and SiC diamond materials after the 200 hours of corrosion in NaOH at 90 °C. Although Si is dissolved out of both SiSiC and SiC diamond materials, the decrease of the residual strength is completely different. This phenomenon can be explained by the different formation of the SiC framework in both materials during the manufacturing [3].

Overview of the standard corrosion methods at IKTS

Method	Temperature	Media
Corrosion due to liquids under normal pressure	Up to boiling temperature	Acids, alkaline solutions, salt solutions
Electrochemical corrosion in various electrolytes	Near RT	Acids, alkaline solutions, salt solutions
Hydrothermal corrosion	< 250 °C	Pressure < 200 bar, water, salt solutions, diluted acids, water vapor
Gas corrosion	< 2000 °C	Gas with various compositions, flowing
Hot gas / burner test stand	< 1600 °C	Flow velocity v = 100 m/s, pressure 1 atm, up to 30 % water vapor
Salt spray test	35 °C	DIN EN ISO 9227 (NSS)
Humid heat	0–100 °C / 10–100 %rel.	Constant climate, also cycle tests possible
Resistance against tracking and erosion	Standard climate	Standard and aggravated requirements, DIN EN 60112; DIN IEC 60587
Electric arc reliability	Standard climate	Low voltage – high current High voltage – low current

Services offered

- Consultation regarding the application-oriented selection of materials and the component design
- Analysis of failure or defect incidents and mechanisms
- Analysis of the composition and microstructure of ceramic materials
- Different tests according to national and international standards
- Determination of the corrosion behavior and corrosion mechanisms of ceramic materials
- Determination of thermophysical, electrical, mechanical and chemically corrosive material and component parameters
- Factory calibrations according to VDI, VDE, DGQ guidelines

Sources

[1] C. Steinborn, M. Herrmann, u. a., J. Europ. Ceram. Soc., 34, 2014, 1703.
[2] M. Herrmann, K. Sempf, u.a., Ceram. Inter., 41, 2015, 4422.
[3] M. Herrmann, B. Matthey, S. Kunze u. a. cfi/Ber. DKG 2015,10; E39.

1 *Voltage puncture through a ceramic material.*
2 *FESEM image of a puncture channel in hBN ceramics.*
3 *Surface of a SiSiC material corroded in NaOH.*
4 *FESEM image of the same SiSiC material corroded under electrochemical conditions.*
5 *Residual strength after 200 h of corrosion at 90 °C in NaOH.*

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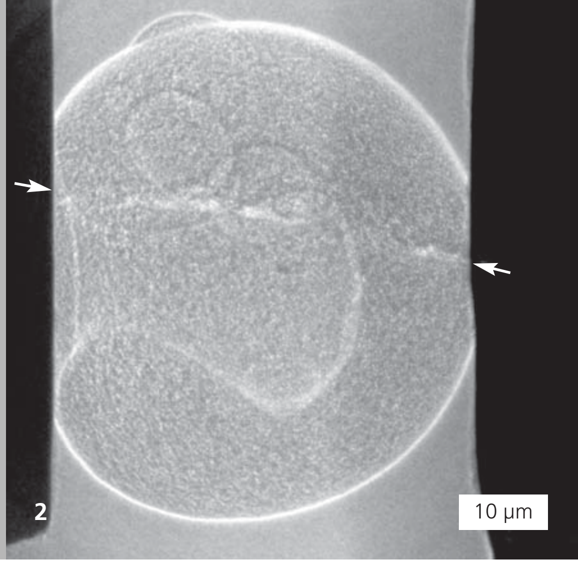


X-RAY MICROSCOPY FOR MATERIALS RESEARCH, ENERGY MANAGEMENT, MICROELECTRONICS

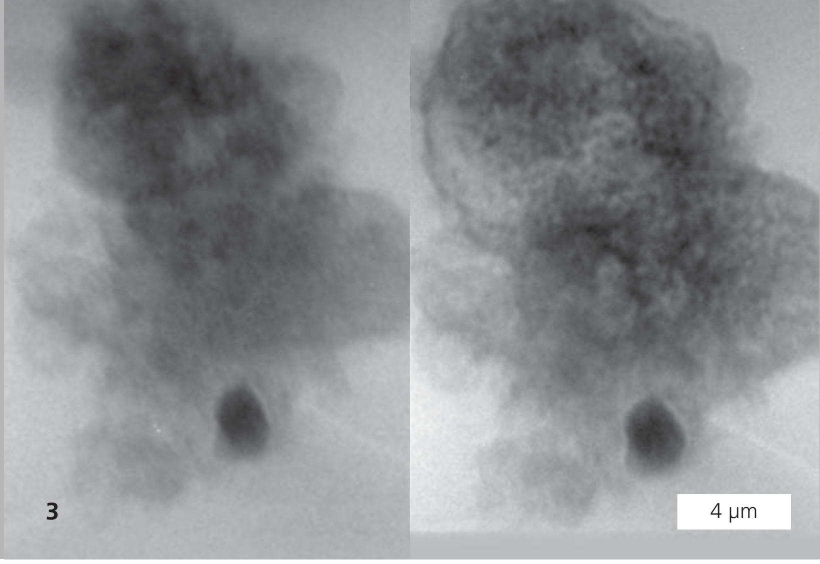
Dr. Jürgen Gluch, Prof. Ehrenfried Zschech

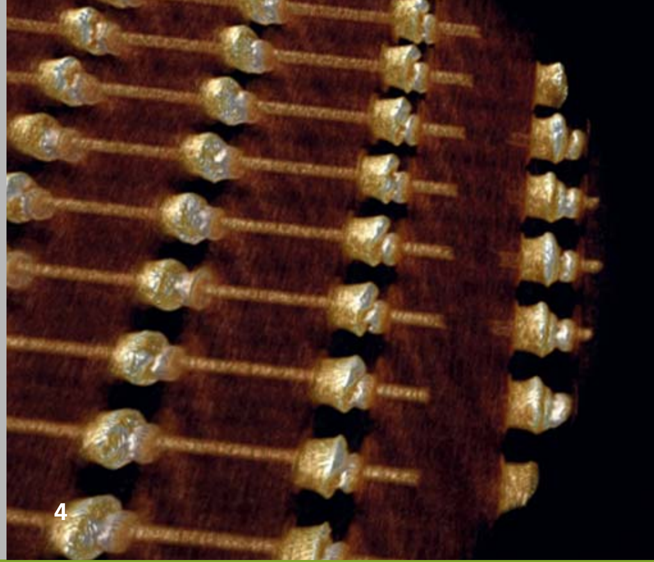
X-ray microscopy is a modern and non-destructive method, which is increasingly used for high-resolution analysis of structures and defects in materials as well as biological objects. The applications range from materials science, energy management, geological science and microelectronics to biology and medicine.

Today's laboratory-based x-ray microscopes (Figure 1) mostly use Fresnel zone plates as focusing optics, reaching a resolution of approximately 50 nm. Thereby, the x-ray microscopy fills the gap between visible light microscopy and electron microscopy. The x-ray computed tomography (CT) reconstructs a three-dimensional representation of an object from multiple projection images taken from different directions. Virtual cross sections through the reconstructed volume are applicable to show buried structures and material components (e.g. in composite materials), as well as to discover defects in materials and devices, like inclusions, pores and cracks. Furthermore, it is possible to analyze the sub-structure of biological tissue.

In materials science, x-ray microscopy is used for both the investigation of structural as well as functional materials. The three-dimensional microstructure, the morphology and topology of microstructure components, such as precipitations, pores and – in the case of composite materials – fibers and particles are analyzed by nano x-ray CT. If the x-ray absorption contrast or the differences between structural constituents is marginal, it is possible to capture high-contrast images by utilizing the so-called Zernike phase contrast. It emphasizes not only interfaces and surfaces, but also delamination and cracks. This contrast mechanism allows to image, for example, high-strength oxide ceramic fibers inside a matrix of the same material. With the help of nano x-ray CT, it is possible to visualize the arrangement of fibers inside the digital volume model of the sample matrix. These data are used as input for simulations to model mechanical properties of modern high-performance ceramics and optimize them through improved materials design. Likewise, the method enables the localization of cracks and delaminations after loading composite materials mechanically. By using in-situ test devices, experiments can be carried out inside the x-ray microscope under observation in order to extract 4D information in addition to 3D data sets. A miniaturized double cantilever beam (DCB) test, i.e. a piezo-driven mechanical test device, which is positioned inside the beam path, allows to adjust defined small values of mechanical strain and observe the effects. Figure 2 shows a spray-dried ceramic granule, made of aluminum oxide, between the two flat jaws of the DCB device under mechanical load, simulating the process of compacting a green body. If a certain load is reached, the granule fractures and gets compressed. Radiography with phase contrast does not only show the inner structure – e.g. in Figure 2 this granule is hollow – but also the cracks (arrows) and inclusions of impurities if present.

Among others, representative applications for x-ray microscopy are found in the research and development of energy storage materials and processes. To study kinetic processes, it is necessary to place and operate miniaturized reaction chambers inside the x-ray microscope. Such a microreaction chamber is able to run chemical processes at temperatures of up to 700 °C and under inert or reactive atmosphere at standard pressure, so that innovative processes for hydrogen storage can be analyzed. The steam iron process stores hydrogen, operates at low pressure and does not require rare noble metals. Therefore, it is a potential technology for decentralized energy storage management. The morphological change in the iron/iron oxide powder during the cyclic oxidation and reduction reaction influence the lifetime and the storage capacity of the storage material. If nanosized iron powders are used, the process temperature can be lowered due to the high surface area and therefore, the high reactivity. The oxidation reaction of very fine iron powders with particle sizes below 100 nm was investigated by in-situ experiments with temperatures of up to 500 °C in an inert atmosphere laden with water vapor. The formation



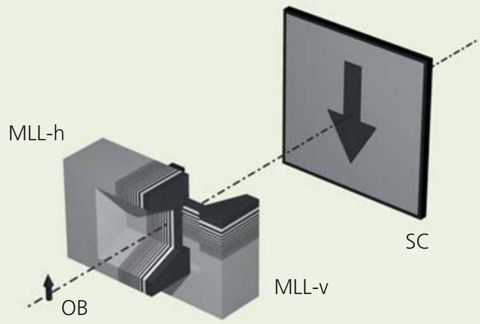


of a dense oxide layer hampers the gas exchange – i.e. release of hydrogen and entry of water vapor – and leads to the expansion of the powder agglomerates (Figure 3). The formation of such an oxide layer has to be prevented by material and process parameter selection. The in-situ x-ray microscopy is a suitable method for the characterization of processes on a microscopic scale within the development of new storage technologies.

The imaging of buried structures and defects becomes more important in the microelectronics industry, both for process control and quality assurance. For novel techniques in the packaging of integrated circuits, e.g. the 3D stacking of dies or the application of interposer structures, x-ray tomography is a convenient method to localize and measure defects regarding the electrochemical filling of metal vias in the die (through-silicon via – TSV). Conventional micro-CT provides informative overview data, e.g. on microelectronic products (Figure 4). The region of interest can be identified and subsequently investigated in detail by nano x-ray tomography. The nano x-ray CT is able to detect pores with less than 100 nm dimension in copper TSV structures (several micrometers in diameter and several 10 micrometers in height). Furthermore, irregularities in the formation of intermetallic phases and possible cracks in micro solder bonds can be identified (e.g. silver tin alloys that connect the vertically stacked dies).

A further improvement of the resolution in the x-ray microscopy will be achievable with novel x-ray optics, Multilayer Laue Lenses (MLL), that replace the Fresnel zone plates as focusing optics. A resolution of 10 nm and below seems possible. The successful integration of crossed MLLs into a laboratory-based x-ray microscope for full-field imaging and the proof of an undistorted projection are the basis for future applications of high-resolution x-ray microscopy, also regarding the analysis of modern microelectronic devices with dimensions of less than 100 nm on the wiring level. An investigation of defects in those pathways requires a resolution of 10 nm. Another field of application is the analysis of biological structures, e.g. the imaging of sub-structures in cells.

Schematic representation of crossed Multilayer Laue Lenses for full field imaging



Services offered

- High-resolution x-ray microscopy: 2D and 3D imaging in x-ray microscope
- Characterization of kinetic processes, in-situ experiments: thermal treatment chamber, chemical reaction chamber, mechanical test (micro-DCB)
- Imaging in absorption and Zernike phase contrast mode
- Highest resolution, smallest pixel width 32 nm
- Recording and reconstruction of 3D and 4D data sets (tomography, laminography, temporally resolved tomography, image series)
- Data analysis, segmentation

1 *Inner view of the x-ray microscope.*
2 *Ceramic spray-dried granule under mechanical load in the moment of fracture.*
3 *In-situ oxidation of iron powder during hydrogen release.*
4 *3D interconnect structure of a microelectronic chip with TSVs and solder bonds.*

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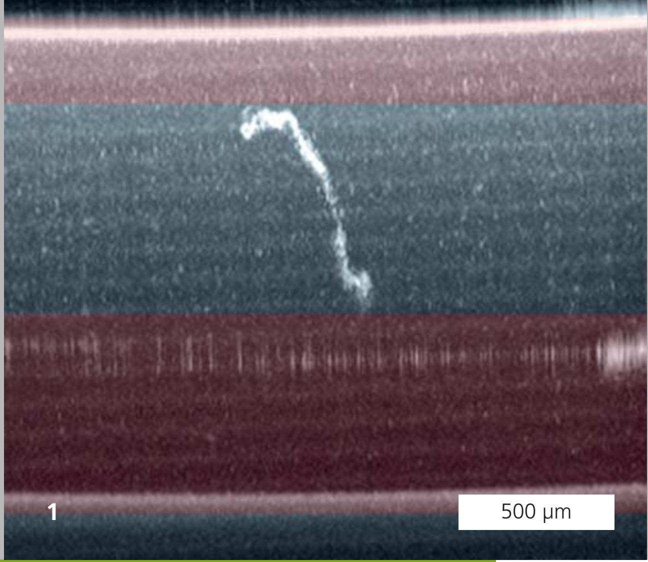

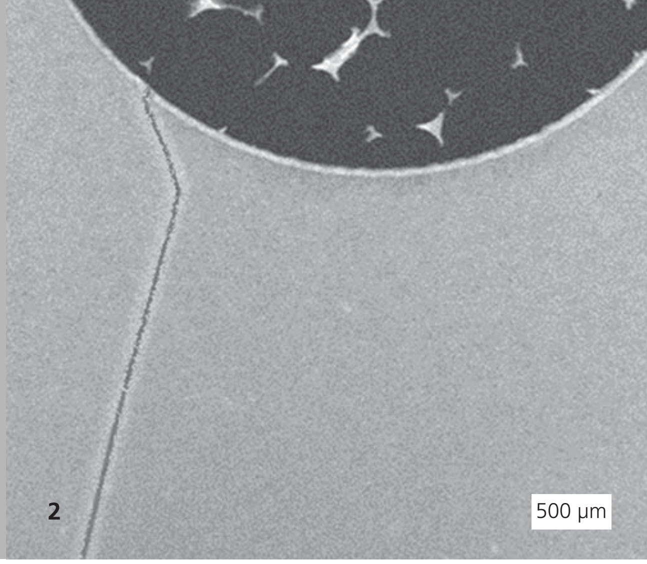

3D INSPECTION OF TRANSLUCENT CERAMIC COMPONENTS USING OCT

Dipl.-Ing. (FH) Christian Wolf, Dipl.-Ing. (FH) Christian Jürgens, Dipl.-Ing. Uta Oberbach, Dr. Thomas Härtling, Dr. Isabel Kinski

The optical coherence tomography (OCT) is well-established in medical diagnostics and life science (e.g. ophthalmology, dermatology). Current OCT developments of Fraunhofer IKTS expand the field of application to non-destructive testing of translucent ceramic components. Developing an automatic test solution for process control in the production of ceramic components is the aim in order to discard defective components before particularly costly processing steps follow.

When light penetrates ceramic components, it is strongly scattered during the passage. For this reason, the detection of defects und material inhomogeneity is normally very limited for optical imaging methods. Fraunhofer IKTS is capable of using optical coherence tomography (OCT) for structural analysis of porous and dense ceramics (such as foams and Al_2O_3 components).

By using near-infrared light, semi-transparent media can be analyzed non-destructively. Applying a special test probe, the investigated surface is irradiated with light of appropriate wavelength. For this contact-free method, no coupling medium is necessary. The backscattered light produces the desired information on scattering intensity in the medium and is processed by interferometry (A-scan). When assembling a number of A-scans, a cross-sectional image is created, also referred to as a B-scan in analogy to the term used in ultrasound imaging. By additional displacement of the test probe or the test specimen, a series of cross-sectional images (B-Scan) can be recorded. This batch of images (tomogram) provides high-resolution geometric information from the interior of the specimen.

The OCT, used for optical 3D inspection, provides high-resolution information about the scattering intensities in various ceramics. From the visualization of these signals, major quality parameters can be extracted. The versatile OCT measurement method can be used throughout the whole production chain. In this example, pore sizes and web widths of foams are determined or structural defects, such as cracks, pores or notches in dense ceramics, automatically detected.

At the Fraunhofer IKTS, a system for evaluating planar high-performance ceramics, such as electrolytes for solid oxide fuel cells (SOFC) and high-strength functional components, is currently under development. In contrast to projective methods, the defect type and spatial defect position in the material can be specified by the cross-sectional analysis of the OCT image (Figure 1). While the defects in the red area are uncritical, the central part must not contain any defects. Consequentially, the component can be declared "defect" already before progressing to the next costly process step (especially hard machining). The rejection of defective parts in advance leads to a great increase in efficiency of the ceramic industry.

In the thermally separating processing of ceramic electrolytes, crack formation might occur on the edges. In Figure 2, a thermally induced fracture is shown, starting from the cutting edge into the volume of the ceramic material. In the case of ceramic carrier substrate with such defects, the robustness of the whole SOFC stack is significantly reduced, also decreasing the service life. So far, only a time-consuming manual quality check was possible, which also required a lot of expertise. The 3D inspection with OCT enables an automated quality assurance of electrolytes increasing the robustness of SOFC stacks and gaining a higher added value in the chain of production.

1 *Cross-sectional image of inhomogeneous ceramics with a filamentous inclusion.*

2 *OCT image of a crack in laser-cut ceramics.*

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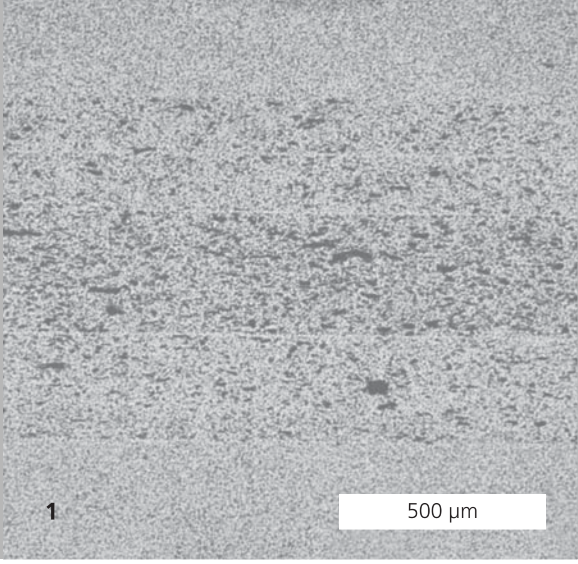
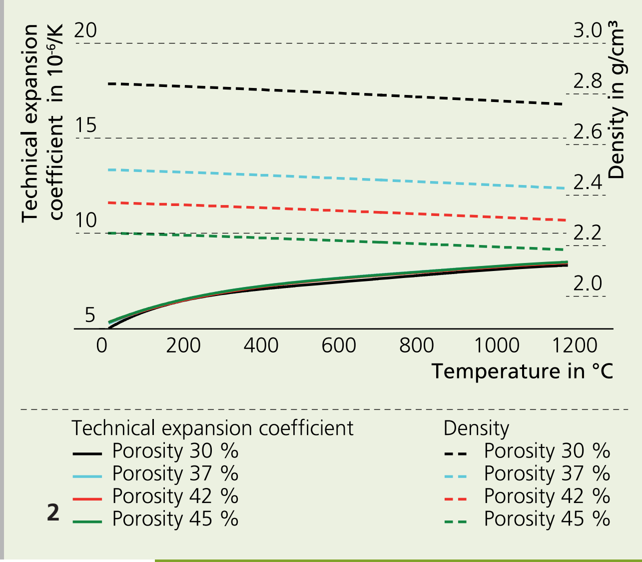




THERMOPHYSICAL PROPERTIES: BASIS FOR SIMULATION AND FURNACE DESIGN

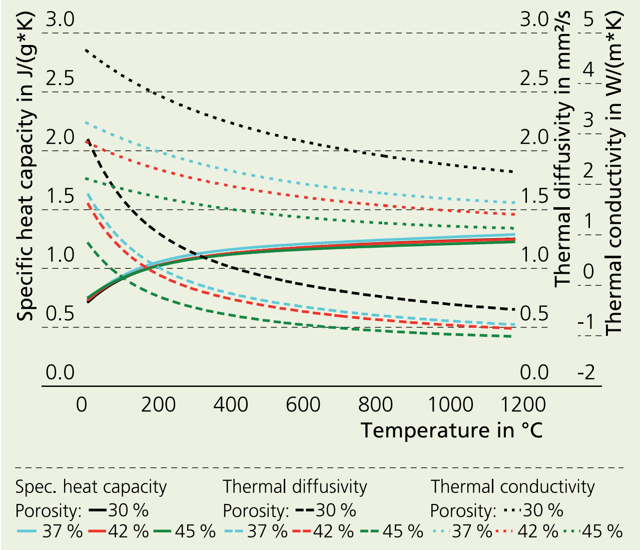
Dr. Tim Gestrich, Dr. Arno Kaiser, Dipl.-Ing. Uwe Scheithauer

Refractories play a key role in all high-temperature applications in different industries, like steel, glass, cement, energy plants etc. At the Fraunhofer IKTS, the principles of manufacturing of refractories with graded properties are investigated. Because of the possibility to adjust properties, the material system Ca-aluminate/alumina is selected. It is produced by a combination of alumina powder and calcium-carbonate in a mass ratio of 11:1. To increase the porosity, cellulose fibers were added in amounts of 0 to 12 wt.-% with regard to the ceramic powder [1]. A microstructure with porosity gradient shall result in improved thermal shock properties of the materials and is realized by the lamination of ceramic green tapes with different contents of pore-forming agents. In order to determine the optimal arrangement of these different tapes by simulation, it is necessary to know the influence of the porosity on the thermophysical properties.

The following methods are used for the determination of the thermal dependence of these properties: Thermal Mechanical Analysis/Thermodilatometry (TMA, TDil) for thermal expansion coefficient $\alpha(T)$ and density $\rho(T)$, Differential Scanning Calorimetry (DSC) for heat capacity $c_p(T)$, and Laser Flash Analysis (LFA) for thermal diffusivity (a). The thermal conductivity $\lambda(T)$ is calculated by means of the following equation:
$\lambda(T)=\rho(T)*c_p(T)*a(T)$.
The measured coefficients of thermal expansion and the heat capacity of the four samples are independent of the porosities and increase with the temperature. Density, thermal diffusivity and thermal conductivity strongly depend on porosity. Higher porosity leads to lower density as well as lower thermal conductivity and thermal diffusivity. The parameters determined are going to optimize this material by simulation for application as refractory material.

The presented results are part of the DFG project SPP1418 "FIRE II". We thank the German Research Foundation for the financial support.

Specific heat capacity, thermal conductivity of multilayered Ca-aluminate/alumina



Services offered

- Determination of thermophysical properties (thermal conductivity, heat capacity, coefficient of thermal expansion)
- Thermodynamic calculations

Sources

[1] Scheithauer, U.; Slawik, T.; Haderk, K.; Moritz, T.; Michaelis, A.: Development of planar and cylindrical refractories with graded microstructure, proceedings of UNITECR 13th, 2013.

1 *Cross-section of multilayer components with graded microstructure.*
2 *Thermal expansion coefficient and density of multi-layered Ca-aluminate/alumina .*

COOPERATION IN GROUPS, ALLIANCES AND NETWORKS

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

Membership in Fraunhofer Groups, Alliances, Networks and Demonstration Center

AMA Association for Sensors and Measurement

American Ceramic Society (ACerS)

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)

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

Deutsche Glastechnische Gesellschaft (DGG)

DIN – German Institute for Standardization

DKG/DGM Community Committee

DRESDEN-concept

Dresden Fraunhofer Cluster Nanoanalysis

Dresdner Gesprächskreis der Wirtschaft und der Wissenschaft

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 Cluster 3D Integration

Fraunhofer Energy Alliance

Fraunhofer Group for Materials and Components – MATERIALS

Fraunhofer Group for Microelectronics

Fraunhofer Lightweight Design Alliance

Fraunhofer Nanotechnology Alliance

Fraunhofer Numerical Simulation of Products and Processes Alliance

Fraunhofer Sensor Network

Fraunhofer Vision Alliance

Fraunhofer Water Systems Alliance (SysWasser)

German Acoustical Society (DEGA)

German Association for Small and Medium-sized Businesses (BVMW)

German Biogas Association

German Ceramic Society (DKG)

German Electroplating and Surface Treatment Association (DGO)

German Energy Storage Association (BVES)

German Engineering Association (VDMA)

German Society for Materials Research (DGM)

German Society for Non-Destructive Testing (DGZfP)

German Thermoelectric Society

Hydrogen Power Storage & Solutions East Germany

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

International Zeolite Association

KMM-VIN (European Virtual Institute on Knowledge-based Multifunctional Materials AISBL)

Materials Research Network Dresden (MFD)

medways

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

smart³

Society for Corrosion Protection (GfKORR)

Wasserwirtschaftliches Energiezentrum Dresden

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 and Environment, Mobility, Health, Machinery and Plant Engineering, Construction and 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 microsystems 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
- Wind Energy and Energy System Technology IWES

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 Institute for Chemical Technology 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 engineering, mechanical and plant engineering, and medical technology. Well-known examples are highly efficient tools and coatings, new material 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

Dr. Michael Zins
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Fraunhofer Institute for Ceramic Technologies and Systems IKTS
www.advancer.fraunhofer.de

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

GROUPS, ALLIANCES, NETWORKS

CERAMICS MEETING POINT – CERAMIC APPLICATIONS

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, the Goeller Verlag and its currently 26 members forms the basis for new project ideas. Prospectively, new issues in the area of materials diagnostics will be offered here. The opportunity to see the latest research topics in one room and to get in contact with possible suppliers is a unique capability of Fraunhofer IKTS. The members of the Fraunhofer AdvanCer Alliance also benefit from this infrastructure. The meeting point is a suitable platform to acquire, for example, industry partners for research-accompanying committees of AiF projects.

The newly developed magazine "Ceramic Applications" is a key element to inform potential users of advanced ceramics. Joint trade fair activites regarding the Hannover Messe and the Ceramics Expo form strategic marketing alliances.

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 1650 visitors informed about ceramic product innovations and manufacturers in 2014.

One highlight in 2015 will certainly be the "Technical Ceramics Day" at the Ceramitec in Munich, Germany. As part of a joint presentation, the Technical Ceramics with approx. 30 partners are displayed on more than 400 m². The AdvanCer Alliance is responsible for the scientific organization of the lecture program.

Members of the Ceramics Meeting Point

TREFFPUNKT KERAMIK
CERAMIC APPLICATIONS

1 Hannover Messe 2015: presentation of the Ceramics Meeting Point at the Ceramic Applications Booth.

NAMES, DATES, EVENTS

Granted patents 2014

Adler, J.; Heymer, H.
Method for recycling powdery silicon carbide waste products
DE 10 2013 218 450 B3

Ahlhelm, M.; Moritz, T.
Synthetic bone substitute material and method for producing the same
DE 10 2012 211 390 B4

Bednarz, M.; Paulus-Rodatz, U.
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Stockmann, J.
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Verbindungstechnik
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17. Werkstofftechnisches Kolloquium an der TU Chemnitz, Chemnitz (11.–12.9.2014), Presentation

Voigt, I.; Richter, H.; Kriegel, R.
Anorganische Membranen für die Gastrennung
19. Sitzung DKG Fachausschuss Werkstoffanwendung, Darmstadt (29.1.2014), Presentation

Voigt, I.
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Voigt, I.
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erties of Ce:YAG ceramics for white LEDs
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Wätzig, K.; Koszyk, S.; Kinski, I.; Jahn, M.
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Weyd, M.
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Wolfrum, A.-K.; Herrmann, M.
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Wufka, A.
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6. Hohen Luckower Bioenergieseminar, Hohen Luckow (2.4.2014), Presentation

Wufka, A.
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DBFZ Jahrestagung, Workshop "Best-Practise-Beispiele in der energetischen Biomassenutzung", Leipzig (1.–2.10.2014), Presentation

Wufka, A.
Vergärung von Stroh
Energetische Nutzung von Stroh und Schilf, Gülzow (3.4.14), Presentation

Wunderlich, C.
Aktuelle und zukünftige Märkte für Hochtemperaturbrennstoffzellen (SOFC)
Vision Keramik: Werkstoffe – Technologien – Systeme: Symposium & Ausstellung, Dresden (16.–17.1.2014), Presentation

Wunderlich, C.; Pfeifer, T.; Freund, S.; Kunath, M.

Green technology innovations at Fraunhofer IKTS
International Green Energy Expo & Conference 2014, Daegu, Südkorea (2.–4.4.2014), Presentation

Zins, M.
Anwendungen und Lieferanten keramischer Hochleistungskomponenten
Advancer-Schulungsprogramm Hochleistungskeramik Teil I: Werkstoffe, Verfahren, Anwendungen, Dresden (5.–6.3.2014), Presentation

Zschech, E.; Niese, S.; Gluch, J.; Löffler, M.; Röntzsch, L.; Wolf, J.
Anwendung der Röntgenmikroskopie in der Werkstoffwissenschaft
5. Dresdner Werkstoffsymposium "Werkstoffoberflächen für Mensch und Technik", Dresden (8.–9.11.2014), Presentation

Zschech, E.
Materialdiagnostik am Fraunhofer IKTS-MD
Vision Keramik: Werkstoffe – Technologien – Systeme: Symposium & Ausstellung, Dresden (16.–17.1.2014), Presentation

Zschech, E.
Survey of analysis techniques for multiscale materials characterization
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Zschippang, E.
Strukturkeramik für elektrische Anwendungen
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Zschippang, E.; Wolfrum, A.-K.; Herrmann, M.; Michaelis, A.; Haas, D.; Berroth, K.
Preparation and characterization of Si_3N_4-diamond composites
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Zschippang, E.
Siliziumnitrid und siliziumcarbidbasierte Komposite – Einstellung von elektrischen Eigenschaften
Industrietag "Keramische Werkstoffe für elektrische Anwendungen" – ELCERAM, Dresden (5.–6.6.2014), Presentation

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Tailoring the electrical resistivity of Si_3N_4-SiC-based composites
4th International Symposium on SiAlONs and Non-oxides – ISSNOX4, Nagahama, Japan (25.–28.5.2014), Presentation

Teaching activities of IKTS employees

Dr. Barth, S.
Lecture
"Keramische Verfahrenstechnik"
Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec (WS 14/15)

Dr. Eberstein, M.
Lecture
"Dickschichttechnik"
TU Bergakademie Freiberg, Institut für Keramik, Glas- und Baustofftechnik (SS 14)

Dr. Fries, M.
Lecture
"Granulationsverfahren und Granulatcharakterisierung in der keramischen Industrie"
TU Bergakademie Freiberg (5.6.2014)

Dr. Gall, M.
4th Lecturing at TU Dresden
Prof. Dr. Zschech, E.; Dr. Gall, M.; Dr. Aubel, O.
Master's Program Nanoelectronic Systems
Module "Semiconductor Industry Challenges: Market Dynamics – Technology Innovations – Yield and Reliability Engineering"
LECTURE: "Reliability Engineering and Kinetics of Degradation Processes in Advanced Electronics"
TU Dresden, Fakultät Elektrotechnik und Informationstechnik (WS 14/15)

Dr. Gall, M.
Lecture and practical training
"Introduction to Nanobiotechnology"
TU Dresden, Fakultät Maschinenwesen, Institut für Materialwissenschaften (WS 14/15)

Dr. habil. Herrmann, M.
Lecture and student affairs
"Technische Keramische Werkstoffe"
University of Witwatersrand, Johannesburg, Südafrika (09/2014)

Dipl.-Ing. Höhn, S.
Lecture
"Keramografie", im Rahmen der Lehrveranstaltung "Metallografie"
TU Dresden, Institut für Werkstoffwissenschaft (13.01.2014)

Dr. Jahn, M.
Presentation
"Heterogeneous Catalysis with Ceramics"
Katalyseverbund Mitteldeutschland (15.7.2014)
"Mitteldeutscher Katalyse-Lehrverbund" Kurs 2014, Leipzig (14.-18.7.2014)

Dr. Jahn, M.
Lecture
"Synthesegaserzeugung aus Biogas – Reaktordesign und Integration in ein Festoxidbrennstoffzellensystem"
Brennstoffchemisches Seminar am Engler-Bunte-Institut des KIT, Karlsruhe (3.2.2014)

Dr. Jahn, M.
Presentation
"Heterogeneous Catalysis with Ceramics"
Winterschool/compact course "Characterization of micro- and nano-materials", BTU Cottbus-Senftenberg (11.2.2014)

Dr. Jahn, M.
Presentation
"Neuartige keramische Trägerstrukturen für den Einsatz in der heterogenen Katalyse"
Institutsseminar, Universität Leipzig, Technische Chemie (16.4.2014)

Dr. Kinski, I.
Lecture
"Hydrothermalsynthese und Solvothermalsynthesen"
Friedrich Schiller Universität Jena, Institut für Technische Chemie und Umweltchemie (20.1.2014)

Dr. Kinski, I.
Lecture
"Precursorsynthese"
TU Dresden, Institut für Werkstoffwissenschaft (28.1.2014)

Dr. Kinski, I.
Lecture
"Oxidkeramik – ZrO_2 und Al_2O_3"
TU Dresden, Institut für Werkstoffwissenschaft (7.11.2014)

Dr. Kriegel, R.
Lecture
"Keramische Verfahrenstechnik"
Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec (WS 14/15)

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 14)

Prof. Dr. Michaelis, A.
Lecture and practical training
"Keramische Werkstoffe"
TU Dresden, Institut für Werkstoffwissenschaft (SS 14)

Prof. Dr. Michaelis, A.; Dr. Kinski, I.; Dr. Herrmann, M.; Dr. Klemm, H.; Dr. Moritz, T.; Dr. Potthoff, A.; Dr. Gestrich, T.; Dr. Kusnezoff, M.; Dr. Neumeister, P.
Lecture
"Prozesse – Gefüge – Eigenschaften keramischer Werkstoffe"

TU Dresden, Institut für Werkstoffwissenschaft (WS 14/15)

Dr. Moritz, T.
Lecture
Vertiefung Keramik "Spritzgießen"
TU Dresden, Institut für Werkstoffwissenschaft (WS 14/15)

Dr. Moritz, T.
Lecture
Vertiefung Keramik "Additive Fertigung"
TU Dresden, Institut für Werkstoffwissenschaft (WS 14/15)

Dr. Moritz, T.
Lecture
"Keramikspritzgießen"
TU Bergakademie Freiberg (3.7.2014)

Dr. Moritz, T.
Lecture series
"Grundlagen der Technischen Keramik"
Kunsthochschule Halle, Burg Griebichenstein (WS 13/14)

Dr. Neumeister, P.
Lecture
"Bruchkriterien und Bruchmechanik"
TU Dresden, Institut für Festkörpermechanik (SS 14)

Dr. Rebenklau, L.
Lecture
"Dickschichttechnik" und "Multilayerkeramik"
in der Vorlesung von Prof. Michaelis "Funktionskeramik"
TU Dresden, Institut für Werkstoffwissenschaft (SS 14)

Prof. Dr. Stelter, M.
Lecture
"Technische Chemie I / II"
Friedrich-Schiller-Universität Jena (SS 14; WS 14/15)

Prof. Dr. Stelter, M.
Lecture
"Technische Umweltchemie"
Friedrich-Schiller-Universität Jena (SS 14; WS 14/15)

Prof. Dr. Stelter, M.
Lecture
"Energiesysteme – Materialien und Design"
Friedrich-Schiller-Universität Jena (WS 14/15)

Dr. Voigt, I.
Lecture
"Keramische Verfahrenstechnik"
Ernst-Abbe-Fachhochschule Jena, Fachbereich SciTec (WS 14/15)

Dr. Weyd, M.
Lecture
"Filtern mit keramischen Membranen"
TU Dresden, Institut für Werkstoffwissenschaft (26.11.2014)

Dr. Zins, M.
Lecture
"Metalle, Kunststoffe, Keramiken – Technische Keramik als Leichtbaustoff"
TU Dresden, Institut für Werkstoffwissenschaft (WS 13/14, WS 14/15)

Participation in bodies and technical committees

Bodies

Dr. Krell, A.
- Associate Editor of the "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, Scientific Advisory Committee Member
- European Fuel Cell Forum -EFCF-, Scientific Advisory Committee

Dr. Gall, M.
- IEEE Transactions on Device and Materials Reliability (TDMR), Editor

Prof. Dr. Michaelis, A.
- Editorial Board of the "International Journal of Materials Research", Hanser Verlag
- Editorial Board of the "Journal of Ceramic Science and Technology", Göller Verlag
- Publication Series "Competencies in Ceramics", Michaelis, A.(Hrsg.), Stuttgart: Fraunhofer Verlag, Start 2006
- Publication series "Kompetenzen in Keramik und Umweltverfahrenstechnik", Michaelis, A.(Hrsg.), Stuttgart: Fraunhofer Verlag, Start 2008
- Publication series "Applied Electrochemistry in Material Science", Michaelis, A.(Hrsg.); Schneider, M.(Hrsg.), Stuttgart: Fraunhofer Verlag, Start 2009
- AGEF e.V. Institute at Heinrich-Heine-Universität, Arbeitsgemeinschaft Elektrochemischer Forschungsinstitutionen e.V., Member
- American Ceramic Society, Member
- DECHEMA Society for Chemical Engineering and Biotechnology, Member
- DECHEMA working group "Angewandte Anorganische Chemie"
- Deutscher Hochschul-Verband, Member
- DGM German Society for Materials Research, Member
- DKG Member of executive board and chairman of Forschungsgemeinschaft der Deutschen Keramischen Gesellschaft, Research advisory board, Director of the scientific works
- DPG-Deutsche Physikalische Gesellschaft
- Dresden-concept e.V.
- Dresdner Gesprächskreis der Wirtschaft und der Wissenschaft e.V.
- Energy advisory council of Wirtschaftsministeriums Sachsen
- EPMA European Powder Metallurgy Association, Member
- Fraunhofer AdvanCer Alliance, Spokesperson
- Fraunhofer USA, Board of directors
- Company Roth & Rau, Member of supervisory board
- Evaluation team "Interne Programme" of Fraunhofer Gesellschaft, Chairman
- GreenTec Awards, Member of the jury
- Helmholtz-Zentrum Dresden-Rossendorf, Member
- IFW Dresden e.V., Member
- Materialforschungsverbund Dresden e.V. MFD, Member and executive board
- NOW GmbH, Member of advisory board
- Silicon Saxony e.V., Member
- Solarvalley Mitteldeutschland e.V., Member and executive board
- "World Academy of Ceramics" WAC, Member

Dr. Schneider, M.
- Publication series "Applied Electrochemistry in Material Science", Michaelis, A.(Hrsg.); Schneider, M.(Hrsg.), Stuttgart: Fraunhofer Verlag, Start 2009
- DGO-Bezirksgruppe Sachsen der Deutschen Gesellschaft für Galvano- und Oberflächentechnik, Chairman
- Fachbeirat der Gesellschaft für Korrosionsschutz, GfKORR, Member

Prof. Dr. Stelter, M.
- Center for Energy and Environmental Chemistry CEEC, Jena, Member of directorate
- MNT Mikro-Nano-Technologie Thüringen e.V., Member of the executive board
- RIS3 working group "Nachhaltige Energie und Ressourcenverwendung", Free State of Thuringia
- VDMA, working group Research and Innovation in Medical Technology

Dr. Richter, H.
- International Zeolite Association

Dr. Voigt, I.
- BVMW German Association for Small and Medium-sized Businesses
- DKG Member of the executive

board
- DECHEMA Society for Chemical Engineering and Biotechnology, Member
- American Ceramic Society – AcerS, Member

Dr. Voigtsberger, B.
- DKG Member of the presidential council and executive board
- DGM/DKG joint committee "Hochleistungskeramik", working group "Koordinierung"
- University council of Ernst-Abbe-Fachhochschule Jena
- IHK Ostthüringen zu Gera, Ausschuss für Industrie und Forschung

Dr. Wunderlich, C.
- Fuel Cell Energy Solutions GmbH, Member of advisory board
- Energy Saxony e.V., Deputy chairman
- European Fuel Cell Forum, International board of advisors

Dr. Zins, M.
- Fraunhofer AdvanCer Alliance, Spokesperson
- Editorial Board of "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 Numerical Simulation of Products and Processes Alliance NUSIM

Dipl.-Math. Brand, M.
- Technical committee "Schallemissionsprüfung (SEP)" of the German Society for Non-Destructive Testing DGZfP

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

Freund, S.
- Fraunhofer AdvanCer Alliance, Central office

Dr. Fries, M.
- DGM/DKG working group "Verarbeitungseigenschaften synthetischer keramischer Rohstoffe", Director
- DKG technical committee FA III "Verfahrenstechnik"
- ProcessNet-Fachgruppe "Agglomerations- und Schüttguttechnik«, Beiratsmitglied
- ProcessNet technical group "Trocknungstechnik", Member of advisory board

Dr. Gall, M.
- Fraunhofer Nanotechnology Alliance
- Europäische Forschungsgemeinschaft Dünne Schichten e.V. (EFDS)

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

Dipl.-Ing. Gronde, B.
- Community "Thermisches Spritzen e.V."
- DVS working group "Thermisches Spritzen"

Dr. Herrmann, M.
- DGM technical committee "Field Assisted Sintering Technique / Spark Plasma Sintering"

Dr. Kaiser, A.
- GEFTA working group "Thermophysik"
- DGM technical committee "Thermodynamik, Kinetik und Konstitution der Werkstoffe"

Dr. Kinski, I.
- American Ceramic Society – AcerS, Member

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"
- DIN/VDE, Referat K 384, DKE Deutsche Kommission, "Brennstoffzellen"
- DGM working group "Aufbau- und Verbindungstechnik für Hochtemperatursensoren", Director of working group AVT

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
- InfectoGnostics Forschungscampus Jena/Förderinitiative "Forschungscampus – öffentlich-private Partnerschaft für Innovationen" of the BMBF

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

Dr. Moritz, T.
- Management committee of COST action MP0701 "Nanocomposite Materials"
- DECHEMA technical committee "Nanotechnologie"
- DKG expert group "Keramikspritzguss", Chairman of executive board
- Editorial board of the cfi, Ber. DKG, Chairman
- Management committee of COST action MP1105 "Flameretardant Materials"
- Member of technical committee III "Verfahrenstechnik" of DKG
- Member of Additive Manufacturing Group of EPMA

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."

Dr. 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.
- VDE/VDI Gesellschaft Mikroelektronik, Mikro- und Feinwerktechnik, GMM technical committee 5.5 "Aufbau- und Verbindungstechnik"
- Working group "Aufbau- und Verbindungstechnik für Hochtemperatursensoren"
- DVS working group A 2.4 – Bonden im DVS

Dr. Reichel, U.
- DKG technical committee 6 "Werkstoffanwendungen"
- DKG working group "Verar-

beitungseigenschaften synthetischer keramischer Rohstoffe“
- DGM technical committee “Field Assisted Sintering Technique / Spark Plasma Sintering“

Dr. Richter, H.-J.
- DGM/DKG joint committee “Hochleistungskeramik“, working group “Biokeramik“
- DGM technical committee “Additive Fertigung“

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, A.
- DVS-Ausschuss für Technik, working group W3 “Fügen von Metall, Keramik und Glas“
- DKG/DGG working group “Glasigkristalline Multifunktionswerkstoffe“

Dr. Schilm, J.
- DGG technical committee 1 “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

Dr.-Ing. Schubert, F.
- DGZfP technical committee “Ultraschall“, Unterausschuss “Modellierung und Bildgebung“, Member
- DGZfP technical committee “Ultraschall“, Unterausschuss “Phased Array“, Deputy director
- DGZfP working group Dresden, Director

Dipl.-Chem. Schubert, R.
- DKG expert group “Keramikspritzguss“

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

Standke, G.
- DGM technical committee “Zellulare Werkstoffe“

Prof. Dr. Stelter, M.
- DGM/DKG joint committee “Hochleistungskeramik“, working group “Energie“
- DGM technical committee “Werkstoffe der Energietechnik“
- medways e.V.
- Optonet e.V.

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

Dr. Voigt, I.
- ProcessNet technical group “Produktionsintegrierte Wasser- und Abwassertechnik“
- ProcessNet technical group “Membrantechnik“
- DGM/DKG joint committee “Hochleistungskeramik“, working group “Keramische Membranen“, Director
- DGM/DKG joint committee “Hochleistungskeramik“, working group “Koordinierung“

Dr. Weidl, R.
- EFDS Europäische Forschungsgesellschaft Dünne Schichten e.V.
- BVES German Energy Storage Association, working group 2 “Roadmap der Energiewende und Rolle der Energiespeicher“

Dr. Weyd, M.
- DGMT Deutsche Gesellschaft für Membrantechnik e.V.

Dr. Wunderlich, C.
- VDI technical committee “Brennstoffzellen“

Dr. Zins, M.
- DKG coordination group “Strukturwerkstoffe Fachausschüsse“
- DKG technical committee “Keramikanwendungen“
- DKG technical committee “FA 6: Werkstoffanwendung“, Director
- Technical committee “Pulvermetallurgie“
- Deutsche Messe AG, Advisory board “Industrial Supply“
- Messe Munich, Advisory board “Ceramitec“
- Institut für Prozess- und Anwendungstechnik Keramik, RWTH Aachen, Executive board

Advisory board for symposia and conferences

Prof. Dr. Michaelis, A.
- DKG-Jahrestagung 2014 / Symposium Hochleistungskeramik DKG/DGM 2014, Clausthal-Zellerfeld (24.–26.3.2014)
- 13th International Ceramics Congress and 6th Forum on New Materials – 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
- 5. Dresdner Werkstoffsymposium “Verbundwerkstoffe und Werkstoffverbunde“, Dresden, TU Dresden IfWW (8.–9.12.2014)
- Symposium Vision Keramik 2015, IKTS Dresden (15.1.2015), Organizer
- IMAPS/ACerS/DKG 11th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies – CICMT 2015, Dresden (20.–23.4.2015), Conference committee, Chair
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Vancouver, Canada (14.–19.6.2015), Co-chair
- 6th International Congress on Ceramics – From Lab to Fab – ICC6, Dresden (21.–25.8.2016), Conference committee, Chair

Dr. Eberstein, M.
- IMAPS/ACerS/DKG 11th International Conference and Exhibtion on Ceramic Interconnect and Ceramic Microsystems Technologies – CICMT 2015, Dresden (20.–23.4.2015), Local organizing committee

Freund, S.
- Advancer-Schulungsprogramm Hochleistungskeramik Teil I: Werkstoffe, Verfahren, Anwendungen, Dresden (5.–6.3.2014), Organization

Dr. Fries, M.
- 19. DKG-Fortbildungsseminar – Technologische Grundlagen der Granulierung und Granulatverarbeitung, IKTS Dresden/ TU Dresden (9.–10.04.2014), Program organizer
- 7. DKG-Fortbildungsseminar – Sprühtrocknung: Technologie – Statistische Versuchsplanung – Produkt- und Prozessoptimierung, IKTS Dresden/TU Dresden (12.–13.11.2014), Program organizer
- 7. DKG/DGM-Arbeitskreissitzung “Verarbeitungseigenschaften synthetischer Rohstoffe“, in Kooperation mit der TK des VKI e.V. und der Nabaltec AG, Dresden (16.10.2014), Program organizer
- DKG-Symposium “Verfahren zur Herstellung keramischer Schichten“, Erlangen (26.–27.11.2014), Member program committee

Dr. Gall, M.
- 18th IEEE International Interconnect Technology Conference – IITC/24th Materials for Advanced Metallization Conference –

MAM, Grenoble, France (18.–21.5.2015), Technical committee
- 2015 IEEE International Reliability Physics Symposium – IRPS, Monterey, CA, USA (19.–23.4.2015), Technical committee

Dr. Gestrich, T.
- 33. Hagener Symposium Pulvermetallurgie "Neue Horizonte in der Pulvermetallurgie – Werkzeuge, Produkte und Verfahren", Hagen (27.–28.11.2014), Program committee

Dr. Härtling, T.
- Second International Symposium on Optical Coherence Tomography for Non-Destructive Testing – OCT4NDT, Fraunhofer IKTS Dresden (25.–26.3.2015), Organizer

Dr. Herrmann, M.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T4S3 "Novel, Green, and Strategic Processing and Manufacturing Technologies" and Session T4S11 "Materials Diagnostics and Structural Health Monitoring of Ceramic Components and Systems", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Klemm, H.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T2S2 "Advanced Ceramic Coatings for Power Systems", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Köhler, B.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T4S11 "Materials Diagnostics and Structural Health Monitoring of Ceramic Components and Systems", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Krell, A.
- Symposium Vision Keramik 2015, IKTS Dresden (15.–16.1.2015), Organizer

Dr. Kusnezoff, M.
- 11th European SOFC & SOE Forum 2014, Luzern, Schweiz (1.–4.7.2014), Scientific advisory committee
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T1S1 "High-temperature Fuel Cells and Electrolysis", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Moritz, T.
- IMAPS/ACerS/DKG 11th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies – CICMT 2015, Dresden (20.–23.4.2015), Chair

Dr. Opitz, J.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T4S11 "Materials Diagnostics and Structural Health Monitoring of Ceramic Components and Systems", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Partsch, U.
- IMAPS/ACerS/DKG 11th International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies – CICMT 2015, Dresden (20.–23.4.2015), Local organizing committee

Pfeifer, T.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T1S1 "High-temperature Fuel Cells and Electrolysis", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Richter, H.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T3S4 "Porous and Cellular Ceramics for Filter and Membrane Applications", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Richter, H.-J.
- Workshop "Additive Fertigung von keramischen Werkstoffen", Dresden (20.–21.5.2014), Organizer

Dr. Schneider, M.
- 7th International Workshop on Impedance Spectroscopy – IWIS 2014, Chemnitz (24.-26.9.2014), Program committee
- 10th International Symposium on Electrochemical Machining Technology – INSECT 2014, Saarbrücken (13.–14.11.2014), Advisory board
- Symposium Industrieausstellung "Angewandte Elektrochemie in der Materialforschung", Dresden (4.–5.12.2014), Organizer

Dr. Schönecker, A.
- Symposium Vision Keramik 2015, IKTS Dresden (15.–16.1.2015), Organizer
- International Symposium on Piezocomposite Applications – ISPA 2015, Fraunhofer Institute Center Dresden, Germany (17.–18.9.2015), Conference organizer

Prof. Dr. Stelter, M.
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T4S3 "Novel, Green, and Strategic Processing and Manufacturing Technologies", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Voigt, I.
- 13th International Conference on Inorganic Membranes, Brisbane, Australia (6.–9.7.2014), International scientific committee
- 11th International Symposium on Ceramic Materials and Components for Energy and Environmental Applications – CMCee, Session T3S4 "Porous and Cellular Ceramics for Filter and Membrane Applications", Vancouver, Canada (14.–19.6.2015), Session organizer

Dr. Wunderlich, C.
- ASME 12th Fuel Cell Science, Engineering and Technology Conference, Boston, MA (30.6.–2.7.2014), Track co-organizer

Dr. Zins, M.
- 90. DKG-Jahrestagung 2015 & Symposium Hochleistungskeramik 2015 / 90th DKG Annual Conference & Symposium on High-Performance Ceramics 2015, Bayreuth (15.–19.3.2015), Member program committee

Prof. Dr. Zschech, E.
- 3rd Dresden Nanoanalysis Symposium, Dresden (17.4.2015), Scientific coordinator
- 2015 International Conference on Frontiers of Characterization and Metrology for Nanoelectronics – FCMN, Dresden, Germany (14.–16.4.2015)

Dissertations

Derenko, Susan
Sensors for Environmental Monitoring based on Localized Surface Plasmons
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Mathematik und Naturwissenschaften

Günther, Christiane
Entwicklung von Sodalithmembranen für die Gastrennung unter industriellen Bedingungen
Dissertation 2014
Fraunhofer IKTS – Friedrich-Schiller-Universität Jena, Otto-Schott-Institut für Materialforschung – TU Dresden, Fakultät Maschinenwesen, Institut für Verfahrenstechnik und Umwelttechnik

Han, Tae-Young
Phased Array Ultrasonic Testing of Dissimilar Metal Welds using Geometric based Referencing Delay Law Technique
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Elektrotechnik und Informationstechnik

Joedecke, Christian Bernd
Wolfram-Dickschichtmetallisierungen im Simultaneinbrand mit Aluminiumnitrid
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Köhler, Bernd
Scannende Erfassung von Ultraschall-Wellenfeldern für die Zerstörungsfreie Prüfung, die Zerstörungsfreie Materialcharakteriesierung und die Strukturüberwachung
Habilitation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Elektrotechnik und Informationstechnik

Kovalenko, Daria
Micro-Raman Spectroscopy of Nano- and Micro-Structured Materials
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Lankau, Volkmar
Untersuchung technischer Einflussgrößen auf die elektrische Leitfähigkeit von festphasen-gesintertem Siliciumcarbid
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Peschel, Maik
Frontseitenkontaktierung polykristalliner Siliziumsolarzellen mittels bleifreier ZnO-haltiger Gläser in Silberpasten
Dissertation 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec – TU Dresden, Institut für Festkörpermechanik

Reuber, Sebastian
Ein systemtechnischer Ansatz zur ein- und multikriteriellen Optimierung von Energiesystemen am Beispiel der SOFC-Prozesssynthese
Dissertation 2014
Fraunhofer IKTS – TH Mittelhessen – TU Dresden, Fakultät Maschinenwesen

Rödel, Conny
Beitrag zur Aufklärung molekularer Wechselwirkungen von organischen Additiven in technischen Korund-Suspensionen
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Rödig, Thomas
Eignung piezoelektrischer Werkstoffe für mechanoelektrische Festkörpergeneratoren
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Elektrotechnik und Informationstechnik

Thiele, Maik
Superharte Werkstoffe auf der Basis von Borsuboxid (B6O)
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

Zschippang, Eveline
Elektrisch leitfähige Komposite auf Basis von Siliciumnitrid-Siliciumcarbid
Dissertation 2014
Fraunhofer IKTS – TU Dresden, Fakultät Mathematik und Naturwissenschaften

Diploma theses

Albrecht, Thomas
Untersuchungen zum Betriebsverhalten eines mit realem Biogas betriebenen SOFC-Systems mit Anodenabgasrezirkulation
Bachelorarbeit 2014
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Almeroth, Philipp
Präparation und Charakterisierung von edelmetallhaltigen Trägerkatalysatoren für die partielle Oxidation von Ethanol
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Antons, Jens
Structural and Sensitivity Optimization of Gold Nanohole Arrays Used for Molecular Sensing
Masterarbeit 2014
Fraunhofer IKTS – TU Dresden, Biotechnologisches Zentrum

Fogel, Stefan
Untersuchung von Scale-up-Kriterien durch Quantifizierung des Mischverhaltens disperser Mehrphasensysteme in Biogasreaktoren mit ovaler Reaktorgeometrie im Labor- und Technikumsmaßstab
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Gleichner, Benjamin
Modellgestützte Analyse von SOFC/Batterie-Hybridsystemen zur Haushaltsstromversorgung in Indien
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Grünberg, Ivo
Reaktionstechnische Untersuchungen an verschieden strukturierten perowskitischen Katalysatoren
Bachelorarbeit 2014
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Heng, Chang Win
Entwicklung von 1-3 Piezokompositen für Hochtemperatur-Ultraschallprüfköpfe
Bachelorarbeit 2014
Fraunhofer IKTS – HTW Dresden, Fakultät Elektrotechnik

Hipp, Raffael Luca Maria
Quantitative Charakterisierung von Punktschweißungen mittels Ultraschallmikroskopie unter besonderer Berücksichtigung von Oberflächenbeschaffenheit und Gefügedämpfung
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Hochmuth, Robert
Experimentelle Charakterisierung und Modellierung von regenerativen Wärmespeichern für Hochtemperatur-Separationsprozesse
Masterarbeit 2014
Fraunhofer IKTS – TU Ilmenau, Fakultät Maschinenwesen

Knüpfer, Paul
Mess- und Auswertungsroutinen zum Granulat-Füllverhalten beim uniaxialen Trockenpressen
Bachelorarbeit 2014
Fraunhofer IKTS – TU Bergakademie Freiberg, Fakultät Maschinenbau, Verfahrens- und Energietechnik

Münch, Stefan
Systematische Untersuchung biomechanischer und geometrischer Einflussgrößen auf das Verformungsverhalten einer Cornea während der Luftpulstonometrie
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen, Institut für Luft- und Raumfahrttechnik

Neubeck, Robert
Wellenmodenselektive Migrationsverfahren für Ultraschalldaten und ihre Anwendung an Plattenstrukturen
Masterarbeit 2014
Fraunhofer IKTS –

TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik

Oertel, Tobias
Entwicklung stabiler hydrophober Mixed-Matrix-Membranen für die Ethanolabtrennung
Bachelorarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Ostrikow, Alexander
Wirtschaftlichkeitsbewertung der Sauerstoffproduktion über keramische Membranen im Vergleich zu konventionellen Technologien
Bachelorarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Safonow, Elena
Elektrochemische Untersuchungen an flexiblen integrierten Multielektrodenarrays für Retina-Implantate
Bachelorarbeit 2014
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Schlotza, Stephanie
Untersuchungen zur thermochemischen Modifikation von Klärschlammaschen mit dem Ziel der Anwendung in Heißgasfiltrationsprozessen
Diplomarbeit 2014
Fraunhofer IKTS – Hochschule Fresenius, Fachbereich Chemie und Biologie

Scholz, Matthias
Charakterisierung der Prozesszustände eines Hochtemperatur-Brennstoffzellenmoduls (SOFC)
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Schreck, Marvin
Entwicklung modularer, automatisierter Sicherheitstechnik für Katalyse- und Permeations-Messplätze
Masterarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Schwab, Olga
Untersuchungen zu Einbrennverhalten und Haftmechanismen von Ag-Dickschichten auf AlN-Keramik
Masterarbeit 2014
Fraunhofer IKTS – HTW Dresden, Fakultät Maschinenbau/Verfahrenstechnik

Sendler, Thomas
Polymerabgeleitete Membranen zur Hochtemperaturanwendung – Überführung von Verfahrensparametern auf kreiszylindrische Substrate
Bachelorarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Steinke, Nadja
Funktionalisierung von nanostrukturierten Goldoberflächen für die Detektion von Biomolekülen mittels Oberflächenplasmonenresonanzsensorik
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Stelzig, Thomas
Entwicklung grundlegender Verfahrensparameter zur Abscheidung von CNTs auf porösen keramischen ZrO_2-Trägern mittels CVD-Verfahren
Masterarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Stier, Konstantin
Untersuchung des Einflusses der Pulveraufarbeitung auf die Gastrennung von schwefelmodifiziertem Sodalith
Bachelorarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Trümper, Stephan
Elektrochemische Untersuchung von dispersionsverfestigten Schichten mittels elektrochemischer Quarzmikrowaage
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Tschirpke, Caroline
Einfluss der Korngröße und hydrothermalen Alterung auf die mikrostrukturellen und mechanischen Oberflächeneigenschaften von Y-TZP/Al_2O_3-Dispersionskeramiken
Masterarbeit 2014
Fraunhofer IKTS – Friedrich-Schiller-Universität Jena, Physikalisch-Astronomische Fakultät, Institut für Materialwirtschaft und Werkstofftechnologie

Uhlig, Elias
Beständigkeitsuntersuchungen von keramischen Nanofiltrationsmembranen
Bachelorarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

Wagner, Lisabeth
Experimentelle Bestimmung notwendiger Parameter für die Simulation des thermisch- elektrochemischen Verhaltens von Elektrodenmaterialien
Diplomarbeit 2014
Fraunhofer IKTS – TU Dresden, Fakultät Maschinenwesen

Winkler, Mathias
Herstellung und Charakterisierung eines Komposites aus einer elektronenleitenden $MgFe_2O_4$- und einer ionisch leitfähigen $Ce_{0,8}Gd_{0,2}O_{2-\delta}$-Phase zur Herstellung von dichten mischleitenden Membranen für die Anwendung unter CO_2-Bedingungen im Kraftwerk
Masterarbeit 2014
Fraunhofer IKTS – Ernst-Abbe Fachhochschule Jena, Fachbereich SciTec

EVENTS AND TRADE FAIRS – PROSPECTS

Conferences and events

International Conference and Exhibition on Ceramic Interconnect & Ceramic Microsystems Technologies – CICMT 2015
April 20–23, 2015, Fraunhofer IKTS, Dresden

Meeting of the Fraunhofer Lightweight Design Alliance
April 22, 2015, Fraunhofer IKTS, Dresden

AMZ-Campus
June 9, 2015, Fraunhofer IKTS, Dresden

International Symposium on Piezocomposite Applications ISPA
Joint event of Smart Material GmbH and NASA Langley Research Center
September 17–18, 2015, Fraunhofer IKTS, Dresden

Dresden Battery Days 2015
In cooperation with the Graz Battery Days
September 22–24, 2015, Fraunhofer IKTS, Dresden

CoolTransferDay by Cool Silicon
November 2015, Fraunhofer IKTS, Dresden

6th International Congress on Ceramics (ICC6), Conference and Exhibition
August 21–25, 2016
International Congress Center Dresden
http://www.icc-6.com/

Please find further information at
www.ikts.fraunhofer.de/en/Events.html

Seminars and workshops

AdvanCer training program: Introduction into advanced ceramics

Part II / 2015: Machining
May 6–7, 2015, Berlin

Part I / 2015: Materials, technologies, applications
June 11–12, 2015, Dresden

Part III / 2015: Design, testing
November 12–13, 2015, Freiburg

Please find further information at
www.advancer.fraunhofer.de/en.html

Participation in trade fairs

Ceramics Expo
Cleveland, April 28–30, 2015

SMT Hybrid Packaging
Nuremberg, May 5–7, 2015
Joint booth Future Packaging

Wind & Maritime
Rostock, May 6–7, 2015

DGZfP DACH-Tagung
Salzburg, May 11–13, 2015

PCIM Europe
Nuremberg, May 19–21, 2015
Joint booth ECPE European Cluster for Power Electronics

Sensor + Test
Nuremberg, May 19–21, 2015
Joint booth "Forschung für die Zukunft"

ees electrical energy storage
Munich, June 10–12, 2015
Joint booth with ThyssenKrupp System Engineering

ACHEMA
Frankfurt a.M., June 15–19, 2015

CARBON
Dresden, July 12–16, 2015

LASER World of PHOTONICS
Munich, July 22–25, 2015
Joint Fraunhofer booth

Materialsweek
Dresden, September 14–17, 2015

Euromat
Warsaw, September 20–24, 2015
Joint booth DFCNA

ISPA 2015
Dresden, September 17–18, 2015

EuroPM
Reims, October 4–7, 2015

World of Energy Solutions
Stuttgart, October 12–14, 2015
Joint booth Fraunhofer Battery Alliance

SEMICON Europa
Dresden, October 20–22, 2015
Joint booth Silicon Saxony

ceramitec
Munich, October 20–23, 2015
Joint booth Goeller-Verlag

productronica
Munich, November 10–13, 2015
Joint Fraunhofer booth

PRORA Symposium "Prozessnahe Röntgenanalytik"
Adlershof, November 12–13, 2015

Hagener Symposium
Hagen, November 25–27, 2015

FAD Conference
Dresden, November 2015

Dresdner Sensor-Symposium
Dresden, December 2015

Please find further information at
www.ikts.fraunhofer.de/en/tradefairs.html

HOW TO REACH US AT FRAUNHOFER IKTS

Please find further information and direction sketches at
www.ikts.fraunhofer.de/en/contact.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
- Please sign in at the entrance gate

By public transport

- 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 in Dresden-Klotzsche

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 public transport

- 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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