FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS





Overview

- Fraunhofer in profile
- Fraunhofer IKTS in profile
- Ceramics a versatile material
- Cooperation with Fraunhofer
- Ceramic materials and technologies in application
 - Energy storage and transformation
 - Water and wastewater treatment
 - Mechanical and automotive engineering
 - Non-destructive testing
 - Environmental & Process engineering
 - Additive manufacturing



Additive manufacturing of SiC-Ceramics.



Fraunhofer-Gesellschaft in profile

Applied research to benefit private and public enterprise as an asset to society





What makes Fraunhofer stand out?

Know-how and partner at every stage of the value chain







Production



Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Profile

Institute Director: Prof. Dr. Alexander Michaelis



Usable area > 30.000 m^2 , 140 Labs © Fraunhofer







Fraunhofer IKTS

Coping with social challenges





Ceramics – a versatile material

Unique properties of high-performance ceramics





Ceramics – a versatile material

"enabling technologies" for 8 business divisions





Cooperation with Fraunhofer

Innovation and development as a building block for the company's future

Industrial projects

As a competence and knowledge provider, the Fraunhofer Gesellschaft is a reliable and discreet partner to industry. As a rule, companies appreciate the confidentiality and discretion of the Fraunhofer IKTS, which is why existing cooperations cannot be communicated explicitly.

Major projects with many partners

The aim is to work on complex problems with several industrial and research partners. Fraunhofer researchers have experience with the efficient and fair handling of large projects and also know which government grants are eligible.

International cooperation

Fraunhofer has a worldwide network of centres of excellence and branch offices, enabling it to serve international companies abroad as well. For example, the Fraunhofer IKTS has a strong cooperation with the Center for Energy Innovation (CEI) and the University of Connecticut.

Strategic partnerships

Fraunhofer wants to advance promising technologies. This preliminary research, which initially takes place independently of contracts, often results in long-term partnerships with companies.

Innovation clusters - networking promotes performance

The long-term cooperation of several research institutions and companies is a sensible strategy for dealing with future-oriented topics on a comprehensive basis. Long-term networks emerge from the proximity of research organisations, investors and companies.

Spin-offs

The Fraunhofer IKTS encourages researchers to put technological developments into practice. Spin-offs are a suitable means of actively promoting the commercialization of innovations.

Confidentiality and discretion with the challenges of our customers are a central prerequisite for our success.



Fraunhofer IKTS – Thinking in value chains

Example: from sensor development to certified NDT testing systems









Ceramic materials and technologies in application Energy storage and transformation

Integrated bipolar battery "embatt"







- Planar battery concept for compact, system-integrated batteries
- Stacked large-area electrodes in bipolar layer structure from many years of fuel cell experience





ThyssenKrupp System Engineering





Energy storage and transformation

100 Ah Sodium Nickel based high temperature battery cell

Sodium Nickel Battery Module

 Integration of 20 cerenergy®- battery cells in one Module with 5 kWh





Test rig for evaluation of the Battery Modules

- Lifetime-Tests
- Charge/ Discharge-Tests





Batteries – Why IKTS – What we can contribute?

- Materials from powders to slurries
- Powder processing technologies from lab to pilot line (1t / a)
- 25 years experiences in thick layer foil processing technologies
- Electrochemistry on advanced scientific level
- 20 years in advanced energy system development (SOFC, MCFC) from lab to industrial production
- Dedicated Li-Ion battery departement (Dr. Wolter)
- Joint Li-Ion battery manufacturing application center with TKSY in Pleissa since 2011
- Broad range of non-destructive inspection technologies and material diagnostics
- Center of Energy Storage Technologies together with Fraunhofer IFAM and TU BS in Braunschweig announced in 2017



Fuel cell systems developed at Fraunhofer IKTS





SOFC-Services along entire value chain at IKTS: Development example

Materials and processes

- Powders, pastes, foils
- Protective coatings
- Characterization



Production planning, pilot manufacturing

- Design to cost
- Production planning
- Pilot manufacturing
- Safety concept
- CE



Cell and stack components

- Electrodes, MEAs
- Contact layersGlas sealings



System engineering and demonstration

- Proof-of-concept
- System prototypes



SOFC and SOEC stacks

Test & characterization



Customized test-rigs and validation

- Customized test-rigs
- Assembly, commissioning and operation



Reactors and system components

- Reformer, burner, HEX
- Membrane reactors
- Sensors
- HotBox-Integration



CAD and simulation

- System concepts
- 3-D CAD drafting
- Process models
- Component models





Fuel cells – From research to application









Testing & validation



Systems & prototype manufacturing



- More than 20 years experience
- Closed value chains
- Successful implementation and commercialisation

mCHP system



Biogas fuel cell











Selected highlights: Water and wastewater treatment



Overview of water treatment topics

Industrial effluents

- Solvent cleaning
- Alkali recycling
- Textile waters
- Radioactive waste water
- Oil-water mixtures
- Whey refinement

Drinking water

- Disinfection
- Degradation of anthropogenic trace substances
- Flocculation and dewatering

Mine drainage

- Resource recovery
- Mining water treatment

Agricultur. waste water

- Degradation of Glyphosat
- Degradation of anthropogenic substances
- Water treatment and deodorisation of aquafarms

Process & Piloting

- Membrane filtration
- Photocatalysis
- Electrochemical processes
- Electrolysis
- Extraction process
- Combination procedures
- Schmalkalden
- Rainitza, Deep geothermal energy

Sensors & Analytics

- Rapid tests for raw and surface water
- Online analytics for anthropogenic trace substances

Plant monitoring

 Condition monitoring of plant components and production processes



Ceramic membrane – Fraunhofer IKTS as an R&D partner at all steps of value chain



Water/Wastewater treatment	Bioethanol	Biogas	O2 production and utilization	e. g. O2 Generator for O3 production		
				?	MATERIAL DIAGNOSIS dependability quality assurance	7
					TECHNOLOGY COMPETENCE	MATERIAL COMPETENCE



Water and wastewater treatment: application examples



Food and beverages



Chemical industry



Textile industry

Application examples

- Nutrient recovery
- Elimination of drug residues
- Partial current treatment
- Implementation of closed water cycles
- Strategic resource recycling

Collaborative projects

Technology leader in ceramic membranes for micro-(MF), ultra- (UF) and nanofiltration (NF)

- Long-term use in industrial separation processes (beverage, textile industry, water/waste water treatment)
- Established network of partners for turnkey solutions and maintenance/repairs

Industrial sectors

- Private / public water suppliers
- Pharmacy
- Chemical
- Textile
- Food & drink
- Energy

Selected cooperation partners





Detection and elimination of micropollutants







Selected highlights: Mechanical and automotive engineering



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Ceramic materials and technologies in application Superhard Wear-Resistant Materials

- Diamond coatings or polycrystalline diamond (PCD) materials for wear parts, cutting tools or rock drills
- Diamond-SiC material based on a graded composite with a SiSiC substrate and a 1- to 3-mm-thick SiCbonded diamond coating
- Improved service life (>10x)
- Effective production technology
- Comparable cost



Microstructure of SiCdiamond ceramics (dark diamond, grey SiC).

SiC/diamond materials for components subjectd in the mining industry.



Non-Oxide ceramics for high temperature applications

- Silicon Nitride with extraordinary stability at very high temperature
- Strength and creep resistance up to 1400°C
- ETB Environmental Barrier Coatings



Ceramic rotor for small gas turbine.



Rare earth-silicate layer for oxidation protection of CMC and monolithic ceramics.





Inline-Process monitoring

CeraCode: Product marking and process tracking

- Product marking for extreme process conditions (>1100°C)
- Dosimetric tracking of irradiation processes with electron beam sensitive color pigments (3D dosimeter)
- No interaction with surface
- Pilot testing with global automotive OEM





Selected highlights: Non-destructive testing





Non-destructive testing

Key competencies and applications

Optical Methods	Electromagnetic Methods	Micro- and Nano Analysis	
Ultrasonic Methods	Monitoring	Reliable Electronics	





Non-destructive testing – Ultrasonic testing methods Fields of application







Non-destructive testing – Ultrasonic testing methods

Ultrasonic testing systems: Hollow shaft test system

- Mobile, compact and robust system for testing hollow drilled wheelset shafts (ICE, TGV, Shinkansen etc.)
- Low maintenance
- High positioning accuracy
- Long service life, simple operation
- Adapter for docking to different shaft types
- Shaft with bore diameter between 30 mm and 90 mm testable
- Fast inspection from only one page
- Analysis & documentation of findings
- Approx. 200 systems in use at Deutsche Bahn and international customers



Hollow shaft testing system.



Test system in use.



Non-destructive testing – Ultrasonic testing methods

Ultrasonic testing systems: Phased-array test system for solid shafts for wheel sets

- Testing of coated railway wheelset shafts
- Simultaneous use of up to 8 phased array probes (32 elements)
- Display of test results in real time
- Cycle time less than 4 minutes
- Fully automatic operation, analysis mode
- 3 PCUS Pro Array US electronics in parallel operation
- PCUS Pro LAB Software in-house development
- Successful test acceptance by DB AG currently in trial operation







Non-destructive testing – Condition monitoring Fields of application





Non-destructive testing – Condition monitoring

Materials, structures and components: Monitoring of ferromagnetic components

Services

- Evaluation of the fatigue condition of large industrial plants and buildings
- On-site determination of the residual stress and material condition as well as the hardness of ferromagnetic materials
- Development of test systems for the evaluation of fatigue conditions







Non-destructive testing – Condition monitoring

Materials, structures and components: Corrosion and crack monitoring

CoMoRanger

Monitoring system for monitoring integral wall thickness changes consisting of:

- CoMoBase (Signal processing)
- CoMoSens (Converter element)

Application example (in the field)







Non-destructive testing – Condition monitoring

Processes: Machine and process diagnostics

Machine calibration and optimization of plant management by analysis of operational vibration problems:

- 3D Laser Vibrometer
- Optical measurement technology (FBG)
- Simulation

Permanent monitoring of heavily stressed machine/process parts:

- Wireless or wired
- Expansion-, vibration- and structure-borne sound based







Non-destructive testing – Condition monitoring Processes: Machine and process diagnostics

Process analysis/ structure-borne noise diagnosis for monitoring:

- Rivet and punching processes
- Pumps and hydraulic test benches

Monitoring of valves for compressors:

Monitoring with pressure, acceleration, temperature and acoustic emission sensors

Customer benefits

- Reduced downtime
- Reduced maintenance
- Increased mileage
- Cost and time savings





Non-destructive testing – Condition monitoring Processes: Monitoring of textile machines

Universally applicable diagnostic system for monitoring highly stressed components

Basic vibration and structure-borne noise analysis:

- Mobile sensor group
- Wireless data transmission
- Coupling of several sensor groups possible
- Database based detection and classification of error patterns
- Data interface to commercially available hardware





Non-destructive testing – Optical Methods

Optical coherence tomography: Processes

Method

3D imaging for semitransparent materials

- High penetration depth (1-3mm),
- High axial resolution (0,5–15 μm)
- High speed

Fields of application

- Material sciences
- Biomedicine
- Plastics/ packaging industry
- Photovoltaics





Core components



Complete systems





Non-destructive testing – Optical Methods

Optical coherence tomography: Possible applications



Bone replacement matrix, GtV45alpha.





Air entrapment in a foil welding seam.

Foreign object detection



OCT-B image, glass particles in calcium chloride powder.





Surface representation of coated particles.



Micro and nanoanalytics

Competencies

High-resolution electron and ion microscopy



- Transmission Electron Microscopy (TEM)
- Scanning Electron Microscopy (SEM)
- Focused Ion Beam (FIB)

High-resolution X-ray technology



- Nanoradiographic tomography (XCT)
- Nanoradiography (TXM)
- µ-Computer
 Tomography (µ-CT)

High resolution nanomechanical properties



- Atomic Force Microscopy (AFM/AFAM)
- Acoustic Microscopy (SAM)
- Nanoindentation
- Four-point bending technology
- Double beam bending technology







Process engineering: Fraunhofer technologies for structural change in the Lausitz region





Process engineering: Lab topics at IKTS





Competence for Filter Ceramics at Fraunhofer IKTS: Exhaust Gas Purification





Gas filtration (DPF, dedusting of hot gases)



Exhaust Gas Purification



Exhaust gas purification: Development and tests of catalysts

References

- Long-standing R&D partner of a German and US automotive OEM for the characterization of diesel particulate filters and DeNOx catalysts
- Material development (support and active material) for four noted international materials manufacturers and two users
- Development and commercialization of off-road DPFs made from silicon carbide with CleanDieselCeramics GmbH





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Selected highlights: Additive Manufacturing



Ceramic materials and technologies

Overview shaping technologies technologies

Pressing	Plastic shaping	Casting	Additive Manufacturing	Functionalization
Uniaxial pressingIsostatic pressing	ExtrusionInjection moldingHot molding	Slip castingTape castingGelcasting	 3D printing Laminated object manuf. Lithography based manuf. Fused deposition modelling 	CoatingThick-/Thin-FilmDirect writingMultilayer



Ceramic materials and technologies in application Overview additive manufacturing of ceramics

Layerwise (additive) material deposition for:

- Complex designs > New design freedom
- Reduced material consumption
- Fast design iterations > Rapid product development
- Tool-free production > reduced costs
- Functionalized parts

Manufacturing Point Line Layer 3DP SLS EFF SLA **SLA** LOM Powder Powder Paste Suspension Suspension Sheet, paper

Additive

Materials

Mixed Oxides, SiN, Hard Metals, Bioglass, HAP, Silica Glasses







3DP – 3D Printing SLS – Selective Laser Sintering EFF – Extrusion Freeforming

SLA – Stereolithography LOM – Laminated Object Manufacturing



Ceramic materials and technologies in application Additive manufacturing offers new possibilities



- Previously impossible structures become feasible
- Additional functionalities can be integrated (heater, cooler, sensors)
- Microreactors can be customized and optimized for the corresponding process



Heatable mixer structure made of Al2O3, manufactured via LCM and ink jetting.



Flow optimized fluidic connection system for microreactors.



Miniaturized instruments and implants through additive manufacturing und functional printing





- Production of completely new structural components for surgery and medical technology
- Process combination of additive manufacturing and functionalization by means of sensors/actuators
- Vision: Theranostatic implants with sensory and therapeutic functions



Development of patient-specific bone substitutes



Natural bone

- Rel. dense, outer layer Substantia corticalis
- Porous inner structure, framework of fine trabecula Substantia spongiosa
- Material: hydroxyapatite





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