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FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

INDUSTRIAL SOLUTIONS

EXHAUST GAS PURIFICATION

1 Introduction
2 After-treatment of exhaust gases from engines
4 Industrial exhaust gas purification
6 Domestic application
8 Sensors
9 Material and process analytics
10 Equipment
12 Capabilities
13 Collaboration

COVER *Fraunhofer IKTS develops ceramic filters, adsorbents, catalytic converters and catalyst supports which help to remove carbon monoxide, hydrocarbons, nitrogen oxides and particulate matter from exhaust gases.*

1 *Heated foam ceramics in the hot-gas test stand.*

CERAMICS IN EXHAUST GAS PURIFICATION

Exhaust gases from various technical environments pollute our ambient air and can result in environmental and health damage. With regard to purifying exhaust gases and complying with emission and immission limit values, the available methods differ vastly from each other depending on type and origin of the pollution. In many of these methods of purification, ceramic filters, adsorbents, catalytic converters and catalyst supports enable efficient and cost-efficient results, in particular when it comes to high temperatures, chemical corrosion and longevity.

Ceramic catalyst supports and diesel particulate filters have become indispensable, in particular with regard to the purification of exhaust gases from internal combustion engines, such as gasoline or diesel engines. Every year approx. 20 million ceramic catalyst supports and particulate filters are integrated in Western European cars alone. Beyond this, ceramic components play an important role for the purification of exhaust gases from large-scale industrial processes, such as from power plants, waste incineration plants and chemical and thermal process engineering plants. Ceramic filters and catalytic converters are even used in many household applications.

Thanks to its many years of development in this area, Fraunhofer IKTS helps to optimize materials and manufacturing methods and opens up new applications. The institute also provides sophisticated analysis, modeling and simulation technologies, some of them newly developed, to support the optimization of materials, components and processes. The examination of ceramic components following field tests is also part of the portfolio. Furthermore, IKTS has extensive know-how in the development of ceramic gas sensors and complex sensor systems for use in exhaust gas purification.

CAPABILITIES	COMPONENTS	APPLICATIONS
Material development	Filters	**After-treatment of exhaust gases from engines** Cars, trucks, offroad, ships
Shaping	Adsorbents	**Industrial exhaust gas purification** Power plants, waste incineration, chemical and thermal processes
Coating	Catalytic converters	**Conditioning of room air** Small stoves and heating installations, interior cabins, air treatment systems
Simulation	Catalyst supports	
Testing	Sensors	
Post-mortem analyses		
Sample production		

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TREATMENT OF EXHAUST GASES FROM ENGINES

Exhaust gases from engines of passenger cars, trucks, offroad vehicles, stationary plants or vessels are among the main emission sources of air pollutants. Compliance with emission standards for carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO) and particulate matter (PM, PN) is therefore a major aspect in the development of internal combustion engines. While air pollution has been reduced in recent years to respond to stricter emission standards and thanks to improved exhaust gas treatment technologies, metropolitan areas still see immission limit values for nitrogen oxide and fine particulate matter exceeded on a frequent basis.

PARTICLE FILTRATION

Fine particulate matter from engine combustion is carcinogenic and thus especially dangerous for humans and the environment. Particulate filters allow to reduce fine particulate matter from engine exhaust gas safely and effectively. The method is already widely used in diesel particulate filters and has also been introduced in modern direct-injection gasoline engines in the form of gasoline particulate filters (GPF). The filters used for these applications need to meet the following requirements:

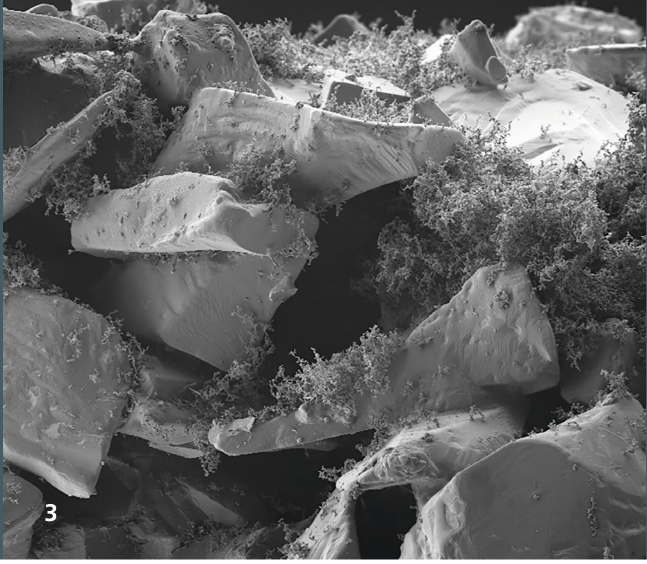
- Strong filtration effect for the efficient separation of extremely fine particles from the exhaust gas
- Low back pressure in the unloaded state and while the filter is being loaded with particles in operation
- High thermal resistance to withstand the high temperatures and temperature gradients found during regeneration

Ceramic wall-flow filters for soot particle filtration have already reached a high standard of development in recent years. At the same time, emission standards are becoming more stringent and more energy-efficient vehicles are required, meaning that further development is necessary in the future, focusing in particular on reducing back pressure and improving the separation performance of particulate filters, as well as combining particulate filtration with catalysis.

Fraunhofer IKTS has been developing and analyzing particulate filters for 20 years. Research is focused on material development for substrates from various materials, such as SiC (RSiC, LPS-SiC and oxidically bound SiC) or cordierite, and on the design of the particulate filters and their extensive characterization. For this purpose IKTS covers the full process chain, from the selection of materials to mass preparation, shaping (e.g. extrusion) and heat treatment. Various characterization and test methods are used for the individual technological steps. This includes e.g. viscosity, tolerance and shrinkage analyses, as well as checks of the thermal degradation of ceramic additives using TG/DTG.

Another large field of activity of Fraunhofer IKTS is the characterization of particulate filters in new or post-mortem condition with regard to back pressure, separation performance, ash deposit, strength values, thermophysical properties, chemical composition and microscopic as well as macroscopic properties.

1 *Engine exhaust gases (source: ssuaphotos/shutterstock.com).*
2 *Large-scale SiC particulate filter for trucks and offroad vehicles.*



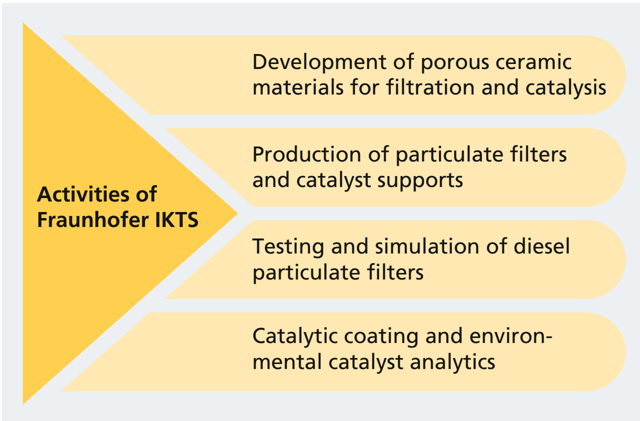
CATALYSIS

Catalytic converters are used in engine-related applications to reduce carbon monoxide, hydrocarbon and nitrogen oxide emissions, as these pollutants are particularly hazardous for the health of humans and for the environment on account of their irritant and toxic effects. The testing and development of catalytic converters for exhaust gas treatment is one of the main fields of activity at Fraunhofer IKTS. This includes the analysis of properties and operating behavior of conventional catalytic converters as well as the implementation of novel catalytic converter solutions. Among such solutions are diesel oxidation and DeNOx catalytic converters and functionalized particulate filters.

Various catalytic supports, such as highly porous honeycomb and filter segments or open-cell foam ceramics, are at the center of this work. Different catalytic structures are compared with each other, with the aim of assessing properties relevant for application, such as reactivity and back pressure, which are affected by different types of flow behavior. Optimized and innovative coating technologies are another focus of our work.

IKTS has two syngas test stands with modern analytical equipment at its disposal, allowing to examine and optimize catalytic converters and catalytically coated particulate filters. The test stands also enable us to determine light-off temperatures and conversion rates for oxidation and SCR catalytic converters in stationary or dynamic test cycles. Furthermore, transient switching between rich and lean gas compositions allows to determine the conversion behavior of three-way and NO_x catalytic converters. These analyses are dependent on the temperature (up to 900 °C with heating rates of up to 30 K/s), the exhaust gas composition (CO, CO_2, NO_x, O_2, HC, H_2O, NH_3, SOx) and the volume flow (up to 200 l/min). To achieve representative and meaningful results, we use specially produced test specimen geometries (catalyst segments or core samples) and adapt the sample volume to suit the flow conditions relevant for the application.

In addition to these reactivity analyses, special methods for characterizing material properties are also available. A better understanding of deactivation mechanisms is possible through the analysis of age-related changes of the catalyst composition, wash coat structure, specific surface and the mechanical and thermomechanical properties.



3 *Scanning electron microscopy image of a particulate filter loaded with soot.*

4 *Test stand for measuring back pressure and sooting.*

INDUSTRIAL EXHAUST GAS PURIFICATION

Various methods are available for the purification of hot exhaust gas, depending on the type of emission and application. Ceramics are used in particular for cases where more traditional solutions reach their limits due to the prevailing temperatures or the presence of very corrosive media. Ceramics can also be a cost-efficient alternative to expensive special alloys or other costly materials.

HOT GAS FILTRATION / DUST REMOVAL

To remove the dust and recover valuable materials from hot exhaust gas, ceramic filters with good backflushing capability are used in operating temperatures up to approx. 800 °C and above. For a long time, development efforts focused on applications in modern designs for coal-fired power stations (pressurized combined cycle plants). More recent projects, by contrast, investigate processes in biomass gasification, exhaust gas purification in the cement and glass industries, waste incineration, and in the production of ink pigments or metal powders.

In this regard, Fraunhofer IKTS works to improve filter materials, technologies for the manufacture of innovative filter geometries and new applications for hot gas filters. A specialized test stand allows to test the separation performance of the filters and their reconditioning behavior for various types of dust.

CATALYTIC EXHAUST GAS PURIFICATION

Catalytic converters for the reduction of pollutant emissions from exhaust gas are used in a number of industrial processes. Among the most popular catalytic applications in exhaust gas purification is the oxidation of carbon monoxide, hydrocarbons and other volatile organic compounds, as well as the reduction of nitrogen oxides. The biggest advantages of catalytic exhaust gas treatment are their lower energy consumption and higher conversion rates as compared with thermal methods. Efficient catalytic converters, whose structure and material composition are adapted to the respective process conditions, are a prerequisite for realizing these advantages.

In this regard, structured catalytic converters, based on their large geometric surface and their favorable flow behavior, are highly suitable for use in heterogeneously catalyzed gas phase processes. Fraunhofer IKTS develops optimized catalytic converters based on highly porous ceramic structures, such as open-cell foam ceramics or ceramic honeycombs. The materials are functionalized by coating the support structures with selected catalytically active materials. Applying thin coats onto the support structure is usually sufficient to achieve catalytic conversion rates that are comparable with packing. It has already been possible to implement such solutions for oxidation and DeNOx catalytic converters.

1 *Industrial plants with exhaust gases (source: leungchopan/shutterstock.com).*

2 *Hot gas filtration test stand for honeycomb filters or filter tubes.*

ADSORPTION

Adsorption allows to purify gaseous pollutants, especially if they occur in low concentration. Loaded adsorbents are then disposed of or regenerated in desorption. Valuable substances, such as solvents from the exhaust air of printing works, can be recovered this way.

Typical adsorbents are activated charcoal and zeolites. They are used primarily as fixed bed packing. Using ceramic technologies, however, adsorbents can be also transformed into more specialized shapes and fixed to supports, e.g. as balls, pellets, honeycombs or other open-cell structures. This opens up new options in terms of handling and application, as well as innovative regeneration methods, such as microwave-based methods. Furthermore, Fraunhofer IKTS works to develop new or improved adsorbents in the form of modified activated charcoal, clay minerals, zeolites and MOFs (metal organic frameworks).

The combination of adsorbents with other materials allows to optimize specific properties. For instance, the sheathing of cylindric zeolite pellets with a metallic coating quadrupled the thermal conductivity of the fixed bed, which is very helpful for fast heating and cooling down during loading and regeneration processes.

GAS SEPARATION

Fraunhofer IKTS develops materials, components and processes for gas separation at high temperatures. Energy savings and easy integration in existing industrial processes (e.g. CO_2 separation, CCS) are the main advantages over traditional methods. With regard to the development of new power plant concepts with reduced emissions and higher efficiency, gas-separating membranes are more and more the center of attention. The advantages of membranes, when compared with cyclical processes such as adsorption and desorption, are their continuous operation and their simple, flexible plant design, ensuring low investment cost and low energy consumption.

For its valuable materials development, IKTS uses graphite, carbon-nanotube and polymer-derived ceramic membranes, based on silicon oxycarbide (SiOC), silicon carbonitride (SiCN) as well as silicon carbide (SiC). The targeted optimization of synthesis routes allows to produce thin membranes which act as molecular sieves. The separating characteristics can be adapted across a wide range of options by varying the membrane material. Thus, the membranes offer wide-ranging potential for the separation of gases of differing molecular sizes (e.g. H_2/CO_2), but also for the separation of gases of similar molecular sizes through adsorption (e.g. CO_2 separation from biogas).

3 *Open-cell, catalytically coated large-format foam ceramic components.*

4 *Fully ceramic pellets and metal-sheathed ceramic pellets with increased thermal conductivity.*

DOMESTIC APPLICATION

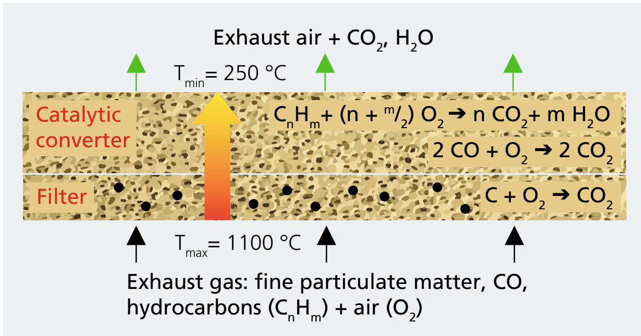
Most people spend considerable chunks of their day indoors – whether at home, in transit or at work. Room air quality therefore plays an important role. Dust, bacteria and odors pose a threat to air quality. Foam ceramic filters for dust removal or ceramically supported photocatalysts for odor filtration can contribute to healthy indoor air quality and a beneficial room climate.

HEATING

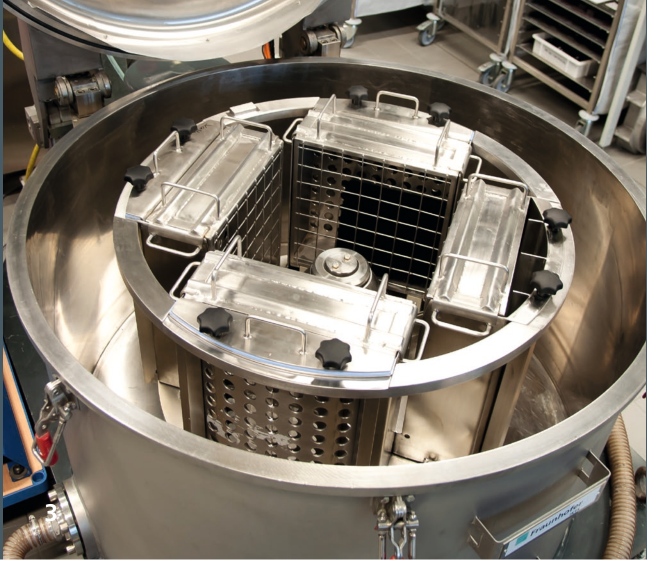
Fireplaces and small stoves used with wood or wood pellets or other renewable raw materials are legitimate alternatives to heaters running on conventional energy sources, such as oil or gas. Phase 2 of the 1st Federal Immissions Protection Ordinance came into effect in Germany on January 1, 2015. It limits the admissible emissions of fireplaces for single rooms (wood-burning stoves and tiled stoves) to 40 mg/m^3 for dust and 1250 mg/m^3 for carbon monoxide.

The use of foam ceramic filters allows to reduce the fine particulate matter emissions of fireplaces. The web-like, highly porous ceramic structure absorbs particles and pollutants without becoming clogged up. This works, above all, during firing up, when a lot of soot and hydrocarbons is emitted. Once a higher temperature is reached these pollutants are safely combusted in the filter. The installation of a foam ceramic filter directly in the stove above the flames ensures a self-cleaning effect without the need for interventions from the user, and without costly additional equipment.

An additional reduction of gaseous pollutants, such as hydrocarbons (HC) and carbon monoxide (CO) beyond this point can be achieved through the use of catalytic converters. These must be particularly well-suited for the operating conditions of the fireplace in order to achieve optimal results in reducing pollution. The temperature conditions occurring during the use of a fireplace are of particular importance for catalytic activity and aging resistance.



1 *Wood burning stove (source: XXLPhoto/shutterstock.com).*
2 *Stereomicroscopic image of a foam ceramic filter loaded with ash.*



FILTRATION OF ODORS

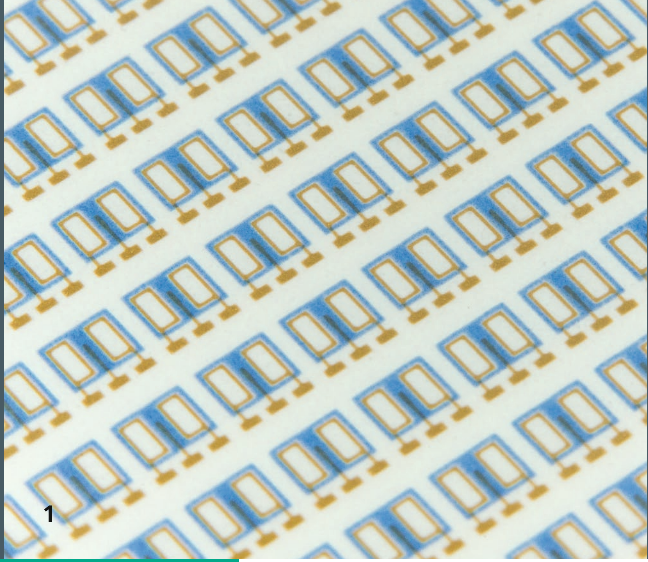
Emissions of gaseous odorous substances occur in many industrial processes and in private households. Above a certain, mostly very low threshold, they are perceived as a nuisance in the room and ambient air. In order to reduce odors effectively, and to safely remove and bind many types of contamination, adsorbents such as activated charcoal are frequently used in packing or fabrics. Using ceramic technologies, these can also be transformed into cellular formed components or applied to suitable ceramic substrates. This makes handling easier and improves specific application properties, such as the back pressure or regeneration behavior in high temperatures. In addition to activated charcoal, IKTS also develops and processes adsorbents that are similar to ceramics, such as zeolites or metal organic frameworks (MOFs). They provide better performance and more stable regeneration in specific applications.

Photocatalytic converters are an alternative to adsorbents. When irradiated with natural or artificial UV light, radicals are produced on their surface which decompose organic substances and oxidize gaseous substances. Fraunhofer IKTS has the suitable technologies at its disposal to apply TiO_2-based photocatalytic converters as layers onto cellular structures such as Al_2O_3, cordierite or SiC foam ceramics, or onto flat ceramic elements. The fact that this solution provides a large effective surface, in addition to its low back pressure, boosts the air-purifying effect. This means that frequent indoor pollutants, such as formaldehyde and acetaldehyde, can be converted into harmless compounds. Photocatalytic layers can also contribute to cleaner air in the interior cabins of vehicles and aircraft, or in private household applications, e.g. extractor hoods in kitchens. Furthermore, they have an antibacterial and antimicrobial effect and help prevent fungal growth.

DISINFECTION

Under certain conditions (depending on temperature and humidity), filters and air conditioning systems can contaminate the air with germs due to the number of bacteria and viruses in the air flow. Ceramic components with adsorbents and antibacterially effective surfaces can play a decisive role in disinfecting room air. Photocatalytically effective surfaces do not just help eliminate odors. They also contribute to a reduction of the bacterial load and boost the efficiency of UVC systems.

3 *Large centrifuge used to coat open-cell foam ceramics.*
4 *Open-cell foam ceramic pellets for catalytic packing.*



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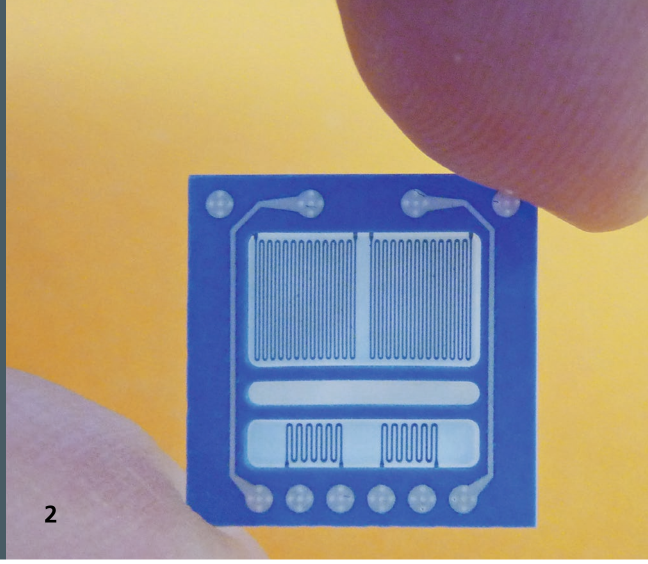

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SENSOR SYSTEMS

Thanks to the chemical resistance of ceramic materials, even in high temperatures, ceramic-based sensors are particularly suitable for use in tough environments, such as exhaust gas treatment and purification. Fraunhofer IKTS offers sophisticated sensor elements and sensor integration solutions from one single source. Based on the synthesis of functional ceramics or the processing of commercial materials, IKTS develops soot, mass flow, temperature and gas sensors for the most varied operating conditions. When it comes to producing sensor elements based on thick-film and multilayer technology, IKTS can boast many years' worth of know-how in the field of ceramic pastes and inks, which are deposited onto ceramic, metallic and polymeric substrates using various printing methods. Using packaging and joining methods suitable for high temperatures, these components can then be reliably integrated in measuring systems.

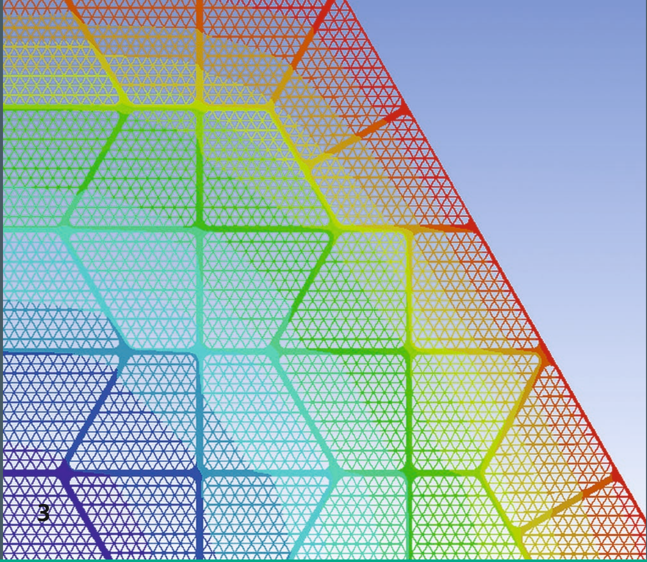
To achieve reliable diagnostic functionality in automotive exhaust gas treatment applications, soot sensors must be robust and able to withstand the occurring aggressive atmospheres and the stress from high temperatures and strong vibrations. To ensure this, Fraunhofer IKTS has brought resistive soot sensors to maturity after optimizing their resistor and heating conductor structures, layer properties and packaging techniques.

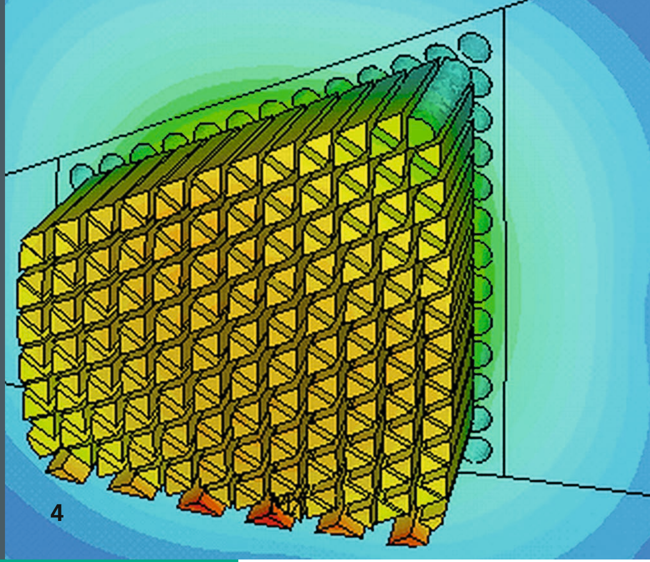
Fraunhofer IKTS is developing pulsation-capable mass flow sensors with the aim of reducing the particle, nitrogen oxide and carbon dioxide emissions in combustion processes. This makes it possible to improve exhaust gas control, in particular with regard to exhaust gas recirculation. The mass flow sensors are designed for determining the exhaust gas mass flow rates of diesel engine and biogas plants, as well as for use in portable emission monitoring systems (PEMS). The hybrid material approach consisting of a miniaturized, highly robust sensor element and a thermally uncoupled housing as well as an adapted high-temperature-capable packaging and joining technology enables use in rough ambient conditions.

Process temperature is an important factor in exhaust gas treatment and purification as it provides information on the system's efficiency and condition. Measuring process temperature in as many spots as possible requires compact solutions that can be easily integrated. Fraunhofer IKTS offers HTCC-based temperature sensors for this purpose. They allow highly precise measurements in areas with up to 1000 °C. In conjunction with a specially developed housing, these elements can be used without any additional encapsulation, ensuring the fastest possible response times.

Fraunhofer IKTS also provides various gas sensors for the detection of O_2, CO_2, H_2, CH_4 or NH_3. They can be adapted to the most varied operating conditions by selecting the right measuring approach, sensor design and operating parameters. Amperometric oxygen sensors based on Yttrium-stabilized zirconium oxide, for instance, can be used in temperatures of up to 700 °C and in a measuring range of 0 to 100 vol %. Multiple test stands are available at IKTS to characterize the interaction with gases, as well as other specific material properties.

1 *CO_2 sensor elements on a multiple panel.*
2 *Pulsation-capable air mass sensor for use in the exhaust gas of combustion engines.*





MATERIAL CHARACTERIZATION

As an accredited and audited service provider, Fraunhofer IKTS offers numerous characterization techniques and extensive equipment for the development of ceramic filters, adsorbents, catalytic converters and catalyst supports. This includes the analysis, assessment and optimization of materials and components as well as the associated production methods. Permeability, specific surface, strength, thermal conductivity and flow behavior are important parameters in this regard.

In addition to standard methods, we have specialized analytical methods at our disposal, some of which are unique worldwide. These methods cover the characterization of particles and suspensions, ceramographic microstructure preparation as well as quantitative phase and microstructure analysis. Furthermore, there is a wide range of mechanical, thermoanalytical and thermophysical characterization techniques. The mastery of these methods and techniques is connected with detailed process know-how and knowledge in materials engineering, providing a sound basis for the interpretation of measuring results.

Another focus is on non-destructive testing, used across the complete product life cycle, from development to tests performed in the production process. Traditional methods, such as ultrasonic, eddy current and radiographic testing or acoustic diagnostics, can be combined with and completed by novel methods, such as laser speckle photometry or optical coherence tomography. Furthermore, the data collected in a test can be linked to dynamic simulation models of the component or system, allowing forecasts of the expected service life.

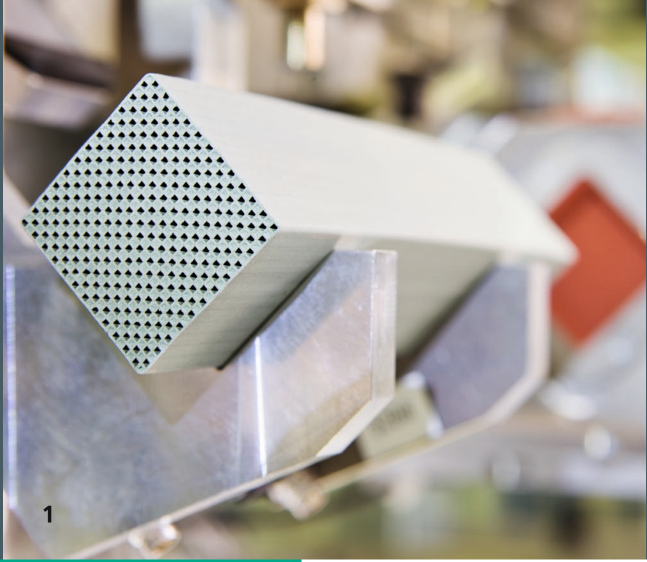
SIMULATION AND MODELING

The simulation of material properties, components, manufacturing technologies and system environments allows to minimize development risks and significantly reduce product cycles. For this reason Fraunhofer IKTS uses software equipment (FEM, CFD, system simulation) even in early development stages to simulate thermal, mechanical and flow processes as well as chemical reactions in components and systems. Based on many years of experience and the use of versatile program tools, we can prepare and analyze user-specific model descriptions for novel applications, in particular those with coupled mechanisms (network complex analyses, multiphysics).

For instance, it is possible to simulate the flow behavior in filter elements in order to compare different support structures and layers with regard to permeate capacity. Beyond this, the influence of structural properties of ceramic foams, such as cell size and rib dimension, on filter performance can also be examined. We have developed and verified numerical models based on these characteristic values, which in future will allow a realistic estimation of the performance of filter foams, thus enabling the optimal selection and design of foam structures.

3 *Simulation of thermomechanical loads of a diesel particulate filter.*

4 *Simulation of die deformation when extruding honeycomb structures.*



EQUIPMENT

Extrusion of honeycomb and tube geometries

- Preparation with Eirich mixer and double-Z kneader
- Ram extruder and various screw extruders
- Various dies for honeycomb and tube geometries, individual dies are possible

Manufacture of open-cell foam ceramics following the Schwartzwalder method

- Semiautomatic impregnating unit for foam
- Single- and multi-step rolling unit for foam coating
- Centrifuges for foam coating

Calcination / heat treatment

- Air sintering furnaces, up to 1700 °C
- Inert gas furnaces, up to 2500 °C (Ar, N_2, vacuum)
- Fast firing continuous furnace, up to 1100 °C (air)
- Hydrothermal aging unit, up to 650 °C, 10% H_2O

Coating

- Immersion coating for individual segments and fine filter substrates
- Centrifuges of various sizes

Filtration test stands

- Sooting, back pressure and particle test stand for segments and filter discs (RT)
- Sooting, back pressure and particle test stand for filters up to 12’’ or industrial hot gas filtration up to 1000 °C (hot gas test stand), also for the endurance testing of filters or cyclical analyses of service life, drop-to-idle
- Back pressure measurements, up to 12 bar on small sample geometries (porometer)
- Pressure drop test stand for foam ceramics, up to 20 m/s
- Determination of cell width for cellular systems

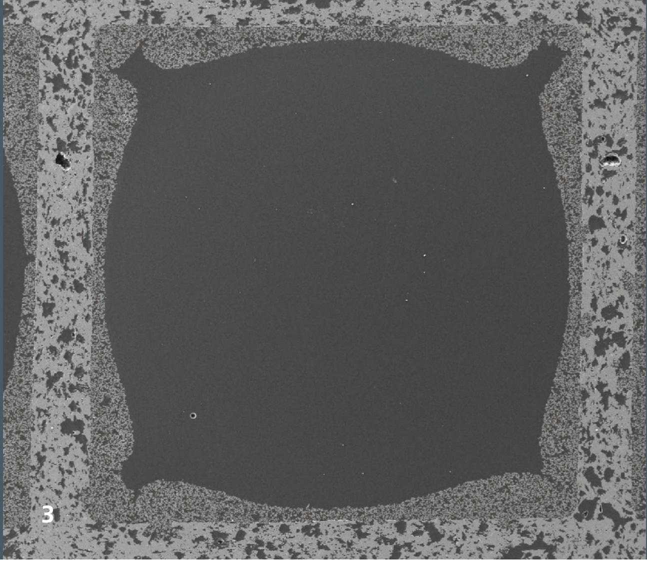
Catalysis test stands

- Fully automatic chemisorption analysis unit (Autochem) for chemical and temperature-programmed reactions on powder samples
- Syngas test stands for the analysis and aging of honeycombs and core samples, static and highly dynamic heating and gas dosing regimes, synthetic gaseous mixtures (N_2, O_2, CO, NO/NO_2, NH_3, HC, H_2O, SO_2, CH_4+C_3H_6, C_3H_8)

Testing of mechanical properties

- Compressive strength testing on filters, up to 10 bar
- Compressive strength testing for foam ceramics
- Compressive strength testing for honeycomb geometries in A, B or C direction
- Strength testing for honeycomb geometries according to ASTM C1674-08 at RT and < 1600 °C in air
- Determination of Young’s modulus
- Thermal stability and thermal shock resistance

1 *Semiautomatic plugging unit for filter segments.*
2 *Autochem test bench for chemisorption analyses of catalytic converters.*



Chemical composition

- Elemental analysis (EDX)
- X-ray fluorescent analysis (XRF)
- Inductively coupled plasma atomic emission spectroscopy (ICP-AES)
- Qualitative and quantitative phase analysis (XRD) also with grazing incidence, from RT to 1400 °C

Characterization of particulate matter and suspensions

- Particle size distribution, particle shape
- Specific surface BET (N_2/Kr adsorption and desorption)
- Pore distribution (Hg porosimetry, permeation porosimetry)
- Surface charge, zeta potential
- Rheology, viscosity
- Determination of density (bulk density, true density, pyknometry)
- Sedimentation stability

Microstructure and material characterization

- Materialographic preparation of samples (mechanical preparation, chemical and physical etching techniques, ion beam preparation)
- Microscopy (light microscopy, stereo light microscopy, scanning electron microscopy [REM/FESEM], transmission electron microscopy [TEM], etc.)
- Coat thickness analysis
- Precious metal crystallites and particle size
- X-ray computer tomography

Thermal analytics and thermal physics

- Thermogravimetry (TG)
- Thermomechanical analysis (TMA)
- Thermodilatometry (TD)
- Thermal conductivity at RT
- Heat capacity

Modeling and simulation

- Finite element analysis (FEM), ANSYS (Emag/Mech), COMSOL Multiphysics, FlexPDE, Atila
- Flow simulation (Fluent)
- System simulation (Matlab/Simulink, Simulation X, Dymola/Modelica)
- Thermodynamic simulation (Factsage)

Accredited laboratories (DIN EN ISO/EC 17025)

- Thermal analytics and thermal physics
- Characterization of particulate matter and suspensions
- Laboratory for quality assurance and reliability

3 *Scanning electron microscopic image of a catalytically coated substrate at the polished section.*
4 *Continuous multi-step system for foam coating.*

CAPABILITIES

Development of particulate filters and catalyst supports, sample production

Material and technology development for the production of ceramic particulate filters and catalytic coatings on ceramic substrates (highly porous honeycombs and filter segments, open-cell foams, foam and catalyst pellets), design and optimization of particulate filters, sample and small-batch production

Selection of materials for substrates

- Silicon carbide (SSiC, LPS-SiC, RSiC, SiSiC clay-bonded SiC, glass-bonded SiC)
- Cordierite
- Alumina
- Zeolite
- Mullite
- Metal foams (steel, non-ferrous metal)

Catalytic and adsorptive coatings

Homogeneous, slip-based coatings and coating methods with defined coat thickness/loading through development and application of suspensions with adapted rheological properties

- Inner and outer coating
- Single- or multi-stage coating
- Immersion coating

Post-mortem analyses

- Soot load, soot analysis (physical)
- Ash load, ash deposits, ash analysis (chemical and physical)
- Post-mortem analysis of components and discrete samples (performance, mechanical, chemical)

Material and component testing

Analytics for DeNOx catalytic converters (SCR, LNT, sDPF) and oxidizing catalytic converters (DOC, cDPF, TWC)

- Specific surface
- Macro- and microstructure
- Chemical composition
- Thermal stability
- Soot oxidation activity
- Catalyst dispersion (chemisorption)
- Catalytic activity (various syngas test stands, up to 900 °C, temperature-programmed desorption TPD, reaction TPR, oxidation TPO, NO_x reduction)
- Life cycle assessment, forecast (hot gas test stand)
- Hydrothermal aging

Filter analytics

- Back pressure and filtration efficiency up to 1000 °C
- Pore size and pore size distribution
- Sooting, filter regeneration
- Particle separation capability
- Endurance testing at the hot gas test stand

Sensors

- Materials: Oxide and non-oxide ceramics, functional ceramics, polymer ceramics as powders, films, pastes and inks
- Technologies: Thin-film and thick-film technologies, packaging and joining technologies
- System integration

1 *Syngas test stand for exhaust gas catalytic converters.*

2 *Material analysis at the field emission scanning electron microscope.*

COOPERATION MODELS

Innovation and development are the cornerstones of a promising corporate future. In order to create a competitive edge, Fraunhofer offers tailored options for cooperation, so that companies can work together in the best possible way. This also allows to utilize development skills at short notice and as needed.

One-off contracts

The classic cooperation model is the one-off contract. A company perceives a need for research or development. A discussion with Fraunhofer IKTS identifies possible solutions and clarifies the form the partnership could take and the estimated cost.

Large-scale projects

Some challenges are so complex that they require multiple partners to develop a solution. Clients in this situation have access to the full range of Fraunhofer Institutes. It is possible to incorporate external partners and additional companies.

Strategic partnerships and innovation clusters

Pre-competitive research which starts off without any ties to specific development contracts often results in long-term partnerships with companies on a regional and international level.

Spin-offs

Fraunhofer researchers often take the step towards independence by founding their own company. Fraunhofer itself only participates in these kinds of start-ups up to a certain extent. Sometimes the customer who commissioned the new development is interested in taking a stake in the spin-off company.

Licensing models

Licenses grant third parties the right to use industrial property rights under defined conditions. They provide an option for making use of an innovation in cases where in-house development is prohibitively expensive, capacities are not sufficient for market introduction, or the innovation does not fit into the company's existing range. Fraunhofer IKTS offers flexible licensing models for companywide use, supplementation of the range of offers, or marketing to end customers.

FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden (Saxony) and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics, microscopy and laser technology contribute substantially to the quality assurance of products and plants.

The Fraunhofer IKTS has set itself the task of considering ceramic materials and technologies not only singularly, but also in the context of their application along the entire value-added chain. As a result, developments such as diesel particulate filters for off-road and small engines, filters for wood-burning stoves or high-temperature-resistant hot-gas dedusting filters and catalytic converters from the raw materials to complex components have already been successfully implemented in various areas of exhaust gas purification.

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Industrial Solutions
Exhaust gas purification

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