FRAUNHOFER-CENTER FOR HIGH TEMPERATURE MATERIALS AND DESIGN HTL

FRAUNHOFER-INSTITUTE FOR SILICATE RESEARCH ISC

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CONTENT

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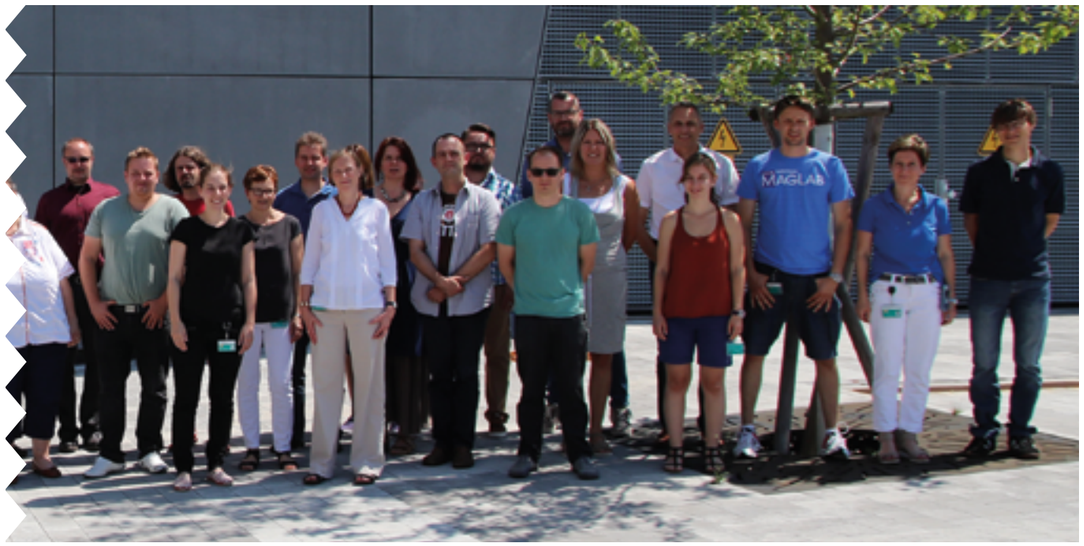


FRAUNHOFER-CENTER HTL IN PROFILE

HIGH TEMPERATURES – EFFICIENT SOLUTIONS

Fraunhofer-Center for High Temperature Materials and Design HTL develops materials and components as well as measuring and simulation methods for the use at high temperatures. Important applications are in energy, drive and thermal technology.

It currently has around 90 employees at its two locations in the German towns of Bayreuth and Würzburg. More than 2000 m² of high-quality laboratory and pilot plant space with state-of-the-art equipment are available for development projects and R&D services. In addition, HTL has the Application Center for Textile Fiber Ceramics TFK in Münchberg that emerged from a cooperation between Fraunhofer and the Hof University of Applied Sciences.

HTL has two business areas:

- Thermal Process Technology
- CMCs (Ceramic Matrix Composites)

The focus in the Thermal Process Technology business area is on improving quality as well as material and energy efficiency of industrial heating processes. In Germany, more than 10 % of primary energy is currently used for industrial heat treatments. There is significant potential for improvement with regard to saving costs and energy as well as for improving quality, which is identified with the systematic methods developed at HTL.

In the CMC business area, HTL has a complete manufacturing chain that ranges from fiber development to textile fiber processing and matrix construction to the finishing and coating of CMC components. The main application of CMC components is in high-temperature processes - e.g. gas turbines - where they also contribute to energy efficiency and the sustainability of processes.

The following core competencies of HTL contribute to the two business areas:

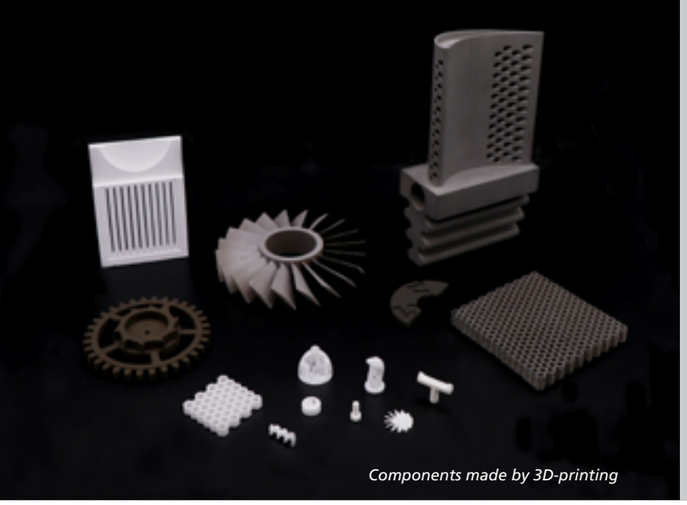
- High temperature characterization of materials and components with ThermoOptical Measuring systems (TOM)
- Optimization of high temperature processes using in-situ measurements and computer simulation
- Development of high temperature materials from ceramics, metal-ceramic composites and CMCs
- Development of high temperature components and systems

At Fraunhofer-Center HTL, various 3D printing processes are available for the production of metal and ceramic components with complex geometries. Materials and components can also be characterized with different non-destructive or mechanical and thermal testing methods. Numerous computer programs are used to design materials, components and processes – from in-house software through material databases to commercially available finite element simulation tools.

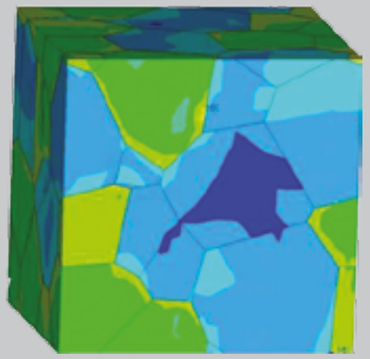
Fraunhofer-Center HTL
is certified acc. to ISO 9001:2015

Mission Statement

HTL designs energy-efficient heating processes and thus contributes to the sustainable technological progress of society. It develops high temperature materials, high temperature components as well as high temperature measuring methods, thereby optimizing thermal processes. HTL works with systematic methods on a high scientific-technical level. The primary goal is the implementation of its developments in the industry.



Components made by 3D-printing



Computer simulation of the thermal stresses in a zirconia/alumina ceramics

Spools with continuous non-oxide ceramic fibers

Fiber pilot plant with fiber drawing tower

HIGH TEMPERATURE MATERIALS

OUR EXPERTISE

Fraunhofer-Center HTL has the entire production chain to develop technical ceramics. From offset preparation to shaping and heat treatment to the finishing process, oxide and non-oxide and silicate ceramics can be produced. Likewise, metal-ceramic composites, carbon and metal components are manufactured. A special feature is additive manufacturing. It can be realized both based on slurries and as powder bed process. Thus, ceramic, metallic and metal-ceramic components can be produced with complex geometries.

Material development starts with the selection of suitable mineral phases. Extensive material- and thermodynamic databases are available. Using special developed in-house software, material properties of multiphase – also porous – ceramics or composites can precisely be predicted. Hereby the microstructure of materials is optimized. Component design is done by means of the finite element method. In particular, thermomechanical loads during the application of the components are minimized.

For forming – in addition to 3D-printing – customary methods as cold isostatic pressing, extrusion, slip casting or wet pressing are available. Raw materials can be milled, dispersed, mixed and homogenized with different techniques. Particle size- and zeta potential analyzers as well as rheometers are used for process related analyses. The quality of green bodies is examined by special in-house procedures. The heat treatment of the green body is carried out in various electric or gas-fired furnaces. For finishing, a computer controlled 5-axis machining center is provided. Components with complex geometries can be constructed with high temperature joining techniques from simple parts.

Fraunhofer-Center HTL develops customized coatings that can be applied using application techniques such as dipping, spraying and brushing. After the application process, the layers are baked for compression.

OUR SERVICES

Material Selection and Microstructure-/ Component Design

- Identifying suitable ceramics for customer-specific needs
- Design of components for complex thermomechanical stresses
- Identifying optimal microstructures for customer specific requirements

Material and prototype development

- Green body production as well as green body evaluation
- Optimization of heat treatment processes
- Materials and component testing

Ceramic

- Development of coating materials such as slips, sol-gel precursors, preceramic polymers
- Application methods such as dipping, brushing, spraying
- Utilization as corrosion protection, thermal insulation, gas-tight surface sealing, heating layers
- Characterization of coatings

CERAMIC FIBERS AND MATRICES

OUR EXPERTISE

Fraunhofer-Center HTL develops ceramic fibers, fiber coatings and matrices for ceramic fiber composites according to customer-specific requirements. The competencies of HTL cover the process chain from the synthesis of raw materials, through the processing methods to the material testing for individual components.

The raw materials used are pre-ceramic polymers, sol-gel precursors or slip. They are developed specifically for the particular application and the processing requirements. The raw materials are either developed completely at HTL or commercial raw materials are modified application-specific.

Fraunhofer-Center HTL develops oxide and non-oxide ceramic fibers. The melt and dry spinning technology are available for this. The fiber development is shown from laboratory to technical scale. As of 2019, a pilot research facility will be available which will enable the development and production of ceramic fibers down to the ton scale.

We develop fiber coatings for our customers. The coatings are applied by a wet-chemical process, which is fast, inexpensive and easy to implement industrially. The objective of the ceramic fiber coating is to set a fiber-matrix interface that enables damage-tolerant behavior of composites.

Fraunhofer-Center HTL develops matrices for ceramic composites. For this purpose, preceramic polymers, sols or slips are used. The raw materials are optimized for the processing methods. After processing, the materials are transferred to a ceramic via a thermal process. The experimental development of thermal processes can be supported by computer simulations.

OUR SERVICES

Ceramic fibers

Ceramic fiber sampling from laboratory scale to small-scale series:

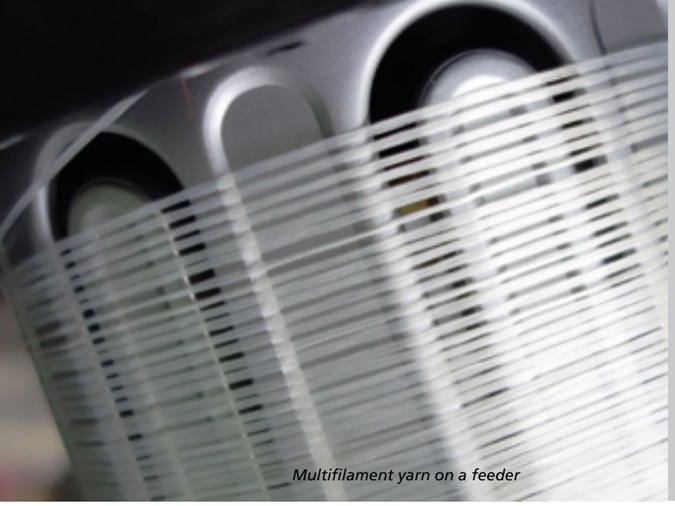
- Various spinning techniques such as melt spinning and dry spinning
- Oxide and non-oxide ceramic fibers
- As individual fibers or as roving with up to 1000 filaments

Ceramic coatings

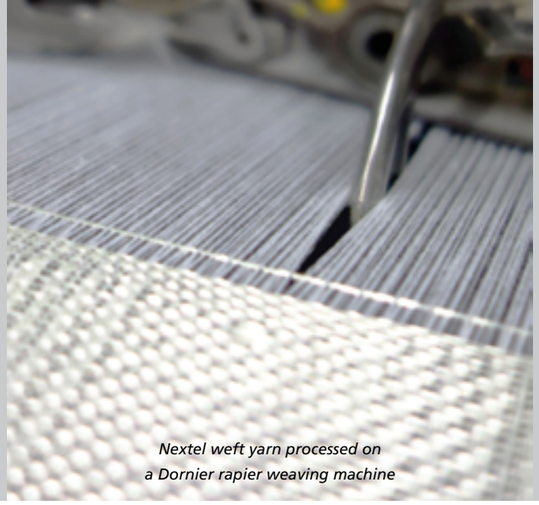
- On ceramic filaments
- As corrosion protection and oxidation protection and for setting the fiber/matrix interface when using CMCs
- Coatings applied primarily by low-cost wet chemical means

Matrix materials

- For building up oxide and non-oxide CMCs
- Available for non-oxide CMCs based on preceramic precursors and as thermoplastic polymer or polymer solution
- For oxide CMCs based on aqueous sol-gel precursors or on aqueous suspensions of ceramic powders



Multifilament yarn on a feeder



Nextel weft yarn processed on a Dornier rapier weaving machine

TEXTILE FIBER PROCESSING

OUR EXPERTISE

In Münchberg, Fraunhofer-Center HTL has the Application Center for Textile Fiber Ceramics TFK. The Application Center TFK arose from a cooperation between Fraunhofer and the University of Applied Sciences Hof. Machines for traditional textile production processes such as weaving, braiding, warp and weft knitting as well as fleece production are available on site for development projects.

The Application Center TFK applies textile processing techniques to ceramic fibers. Thus, it produces semi-finished textile products and end products. Together with the other working groups of Fraunhofer-Center HTL, projects and services are possible for the development of ceramic fiber composites covering all process steps from the fiber to the finished CMC component.

The processing of textile fibers into 2D and 3D structures has progressed rapidly in the last decade with the introduction of new technologies. These innovative production processes are now being transferred to inorganic fibers to open up new applications. For ceramic reinforcing fibers , the biggest challenges to commercial success are the high costs of fibers and processing steps. The Application Center TFK is working on the development of cost-effective methods that are suitable for series production for processing inorganic fibers into load-adapted 2D and 3D structures.

OUR SERVICES

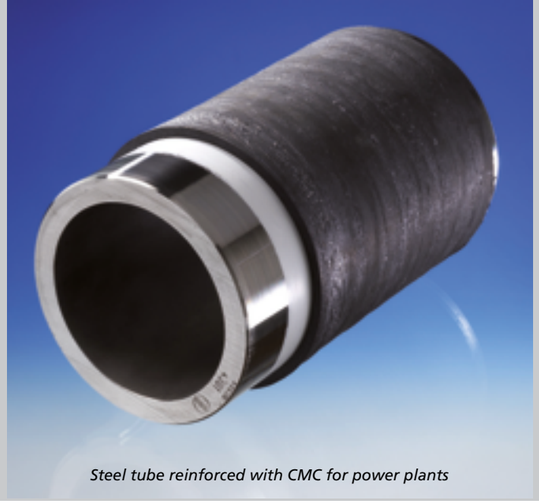
The Application Center TFK is able to examine, test or process ceramic fibers such as SiC- and Al_2O_3- as well as carbon-, glass- and basalt fibers for a huge variety of purposes.

Focused dialogues identify the customers' requirements and objectives and define the common approach. Upon request, the customer receives an examination report and / or a presentation of the results including its interpretation. If required, customer-specific solutions are developed and joint research and development projects are initiated.

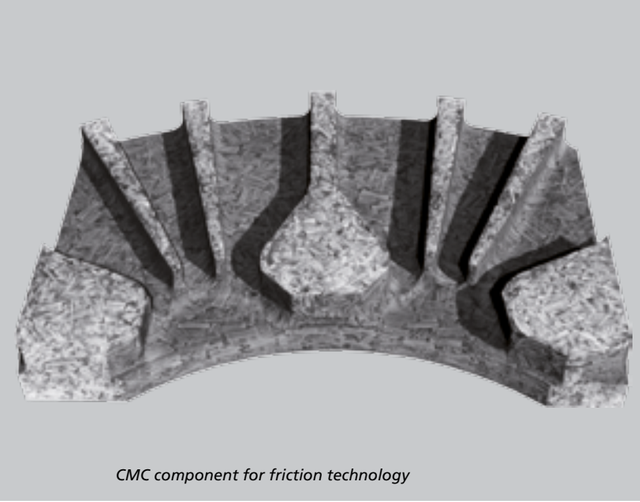
In addition, we provide training courses and seminars on textile processing methods.

Textile Testing Methods

- Determination of the sizing content according to DIN EN 1007-1
- Determination of the linear density according to DIN EN 1007-2
- Determination of the fiber diameter and cross-section according to DIN EN 1007-3
- Determination of tensile properties of filaments at room temperature according to DIN EN 1007-4
- Determination of the tensile properties of fibers within a multifilament tow at room temperature according to DIN EN 1007-5



Steel tube reinforced with CMC for power plants



CMC component for friction technology

CMC COMPONENTS

OUR EXPERTISE

At Fraunhofer-Center HTL, components made of ceramic matrix composites (CMCs) are developed in a closed process chain: from component design and material design to pilot-scale production. CMC materials are distinguished from monolithic ceramics by virtue of their significantly higher fracture toughness, which results in damage-tolerant component behavior.

At the component design stage, we carry out the simulation and dimensioning of structures made from fiber-reinforced ceramics. We develop a low-strain design by simulating mechanical and thermal loading conditions. When using hybrid constructions, ceramic components can be combined with metallic components. Using FE modeling, the different expansion behaviors of the materials at high temperatures are taken into account.

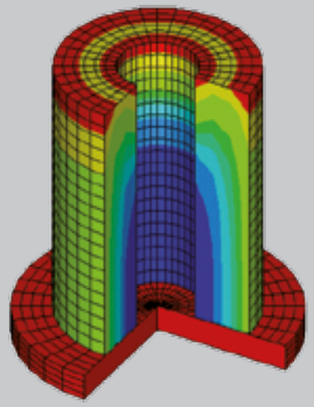
On customer's request, we develop application-specific CMCs. This material group comprises carbon-fiber-reinforced carbon, carbon-fiber reinforced SiC (C/SiC), silicon-carbide-fiber-reinforced SiC (SiC/SiC) and oxide-fiber-reinforced oxide ceramics (O-CMCs). The desired material properties are attained by selecting suitable starting materials – fibers, matrices and additives – and their spatial arrangement. We possess the full range of technologies for the manufacture and ceramization of fiber-reinforced green bodies. Statistically reliable characteristic data are obtained from laboratory samples. For manufacturing prototypes, pilot plant facilities are available that permit upscaling to component dimensions up to approx. 700 mm. This makes it possible to elaborate concepts for the series production of components made of CMCs. Manufacturing can be expanded to incorporate customer-specific quality assurance measures, allowing the results and technology to be subsequently transferred to production scale.

OUR SERVICES

We'll provide you with samples of fiber-reinforced ceramic composite components and advise you on making the right choice for your applications. The initial orientation tests permit experimental investigation of whether the application properties can be obtained with available materials. Experience has shown that materials have to be adapted to the specific application and optimized in the course of R&D projects.

- Advice on selecting appropriate CMC materials
- Providing material samples made of carbon-fiber reinforced carbon (C/C) and oxide and non-oxide CMCs for new applications
- Testing application properties
- Coating rovings and fabrics including thermal processing / ceramization
- Cost analysis for the manufacture and quality assurance of CMC components in different amounts and quantities

ThermoOptical Measuring device TOM_air



Computer simulation of temperature distribution of magnetic rings during sintering

Three-point bending test

Furnace system for heat treatments up to 2400 °C

THERMAL PROCESSES

OUR EXPERTISE

We optimize the heat treatment processes used in manufacturing ceramics, metals and metal-ceramic composites, such as drying, binder burnout / pyrolysis and sintering or melt infiltration. Thus, time-temperature cycles can be improved as well as the furnace atmosphere or the set-up of the charge in the industrial furnace. Our aim is to receive high and reproducible quality with good material-, energy- and cost efficiency of thermal processes.

Fraunhofer-Center HTL develops ThermoOptical Measuring furnaces (TOM), in which the industrial heat process is simulated in the laboratory. TOM-devices are able to simulate all relevant industrial furnace atmospheres: gas burner atmosphere, air, inert gases, forming gas, hydrogen, vacuum, overpressure, etc. They are equipped with detectors monitoring material changes with high accuracy during the heat treatment. For example dimensional changes can be measured during sintering with extremely good reproducibility or acoustic emission signals can be detected during debinding with sensitive microphones. Also high temperature properties of materials can be measured with TOM-devices.

The data measured are parameterized – in particular the kinetics of thermally activated reactions are described with robust models – and then used in FE simulations to optimize the heat treatment on the computer. In the FE models, the interaction between the industrial furnace and the charge is taken into account so that the laboratory results can be transferred to the production scale.

In addition, we offer methods for investigating temperature distribution, furnace atmosphere and heat balance of production furnaces. These data can be displayed in the FE models and used for process optimization as well.

For further information visit: www.htl-enertherm.eu/en

OUR SERVICES

- In-situ characterization of the behavior of solids and melts during heat treatment
- Analyzing drying, sintering, debinding, melting and infiltration processes
- Measuring dimensional changes (sintering, distortion, expansion)
- Measuring gas-phase reactions (changes in weight, gas emission)
- Thermophysical characterization: Thermal conductivity, creep resistance, emissivity, high temperature strength, high temperature elastic modulus, thermal shock properties
- Characterization of melting: wetting, viscosity
- Simulating heat flow and temperature field during heat treatment
- Developing time-temperature cycles with shorter overall duration (cold/cold)
- Developing heat treatment processes with fewer rejects and output that requires less finishing work
- Developing time-temperature cycles conditions that consume less energy
- Customer specific development of high temperature measuring methods
- Measuring of industrial furnaces: temperature distribution, furnace atmosphere, heat balance

CHARACTERIZATION

OUR EXPERTISE

We measure the composition, microstructure and properties of high-performance ceramics and composites. If required, we develop application-specific characterization methods and give customers advice on potential improvements to processes.

The focus of testing at Fraunhofer-Center HTL lies in non-destructive as well as mechanical and thermal testing methods. Samples and components are examined non-destructively by means of computerized tomography (CT) measuring up to 700 mm in diameter or achieving resolutions down to 3 µm. CT is completed by ultrasound and terahertz wave imaging and thermography. For mechanical testing all common test methods are available. The thermal tests are carried out by means of standard methods or with TOM-furnaces (see section „Thermal Processes“). Our cooperation with the Center for Applied Analytics at Fraunhofer ISC in the German town of Würzburg gives us access to numerous other measurement techniques in addition to the methods we have on site. This allows us to take a problem-centered approach, whereby we use the most suitable characterization methods for the job at hand.

OUR SERVICES

- Non-destructive testing of materials and components
- Measuring thermal and mechanical material properties
- Qualitative and quantitative microstructural analysis
- Chemical and elementary analyses
- Density measurements
- Dimensional and damage analyses of components
- Consulting, carrying out studies

TEST FIRING

OUR EXPERTISE

For the heat treatment of oxide and non-oxide ceramic materials and components, about 40 different furnaces are available in our pilot plant facilities. The following processes can be carried out in a controlled atmosphere and optimized in close cooperation with the customer: debinding, pyrolysis, graphitization, melt infiltration and sintering. Various furnaces are connected to a thermal afterburner system, making it possible to carry out processes that produce large volumes of condensates.

OUR SERVICES

- Assessing and carrying out test and contract firing according to customer specifications from room temperature to 2400°C
- Defined atmospheres such as vacuum, inert gas, hydrogen and air
- Furnace utilization volumes from 1 liter up to 385 liters; suitable for manufacturing large individual components or small-scale series
- Possible to manufacture components up to a maximum size of 800 x 800 x 600 mm³ via sintering and pyrolysis
- Optimizing manufacturing processes to obtain ideal material properties
- Test firings in a rotary kiln up to 1100°C
- Process documentation and final inspection of components according to the customer’s request