PRECURSOR CERAMICS

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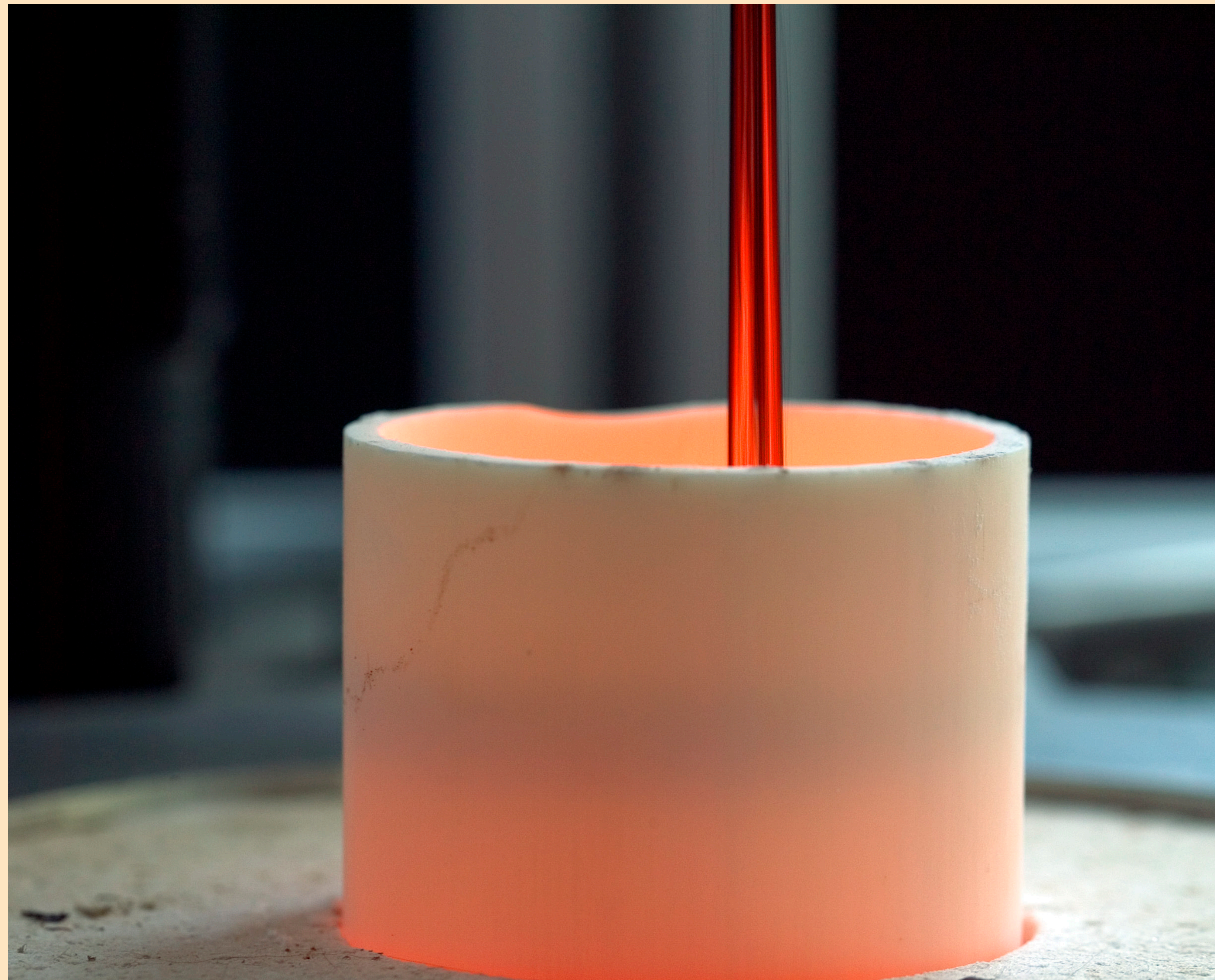
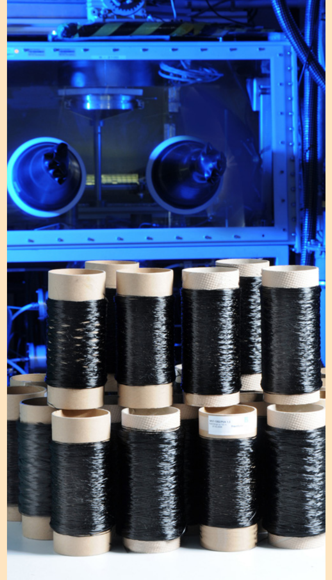
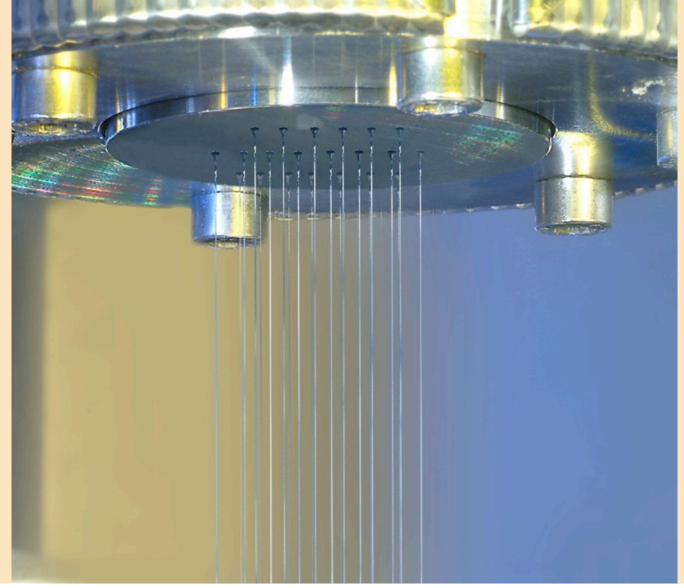
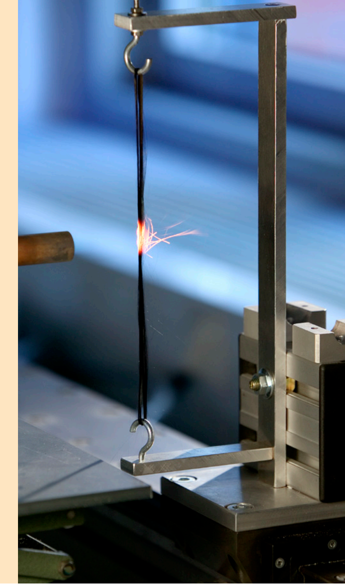
CERAMIC FIBER DEVELOPMENT







CERAMIC FIBERS –

FROM MATERIAL SYNTHESIS TO APPLICATION

Fraunhofer-Center for High Temperature Materials and Design HTL develops and characterizes materials, components, and processes for high-temperature applications, primarily in the fields of energy and heating technology. Regarding materials, the main focus of its activities is on ceramics and composites such as ceramic matrix composites (CMC).

HTL has two business areas: Thermal Process Technology and CMCs (Ceramic Matrix Composites). It currently has around 100 employees at its three locations in the German towns of Bayreuth, Würzburg and Münchberg, along with over 2400 m^2 of high-quality laboratory and pilot plant space with state-of-the-art equipment for development projects and R&D services.

The primary area of research is improving the energy efficiency of industrial thermal processes. In Germany, more than 10 % of primary energy is currently used for industrial heat treatments. There is significant potential for saving energy.

FIBER TYPES AND APPLICATIONS

One core area of Fraunhofer-Center HTL's expertise is ceramic fibers, which are developed and manufactured on pilot plant scale from precursor synthesis and the spinning process to pyrolysis and coating of the filaments. Various types of oxide and non-oxide fibers can be produced. They can be manufactured in porous or non-porous, hollow or solid form. The fibers are required for use in CMCs or MMCs (metal matrix composites) as well as for high-temperature applications, e.g. as insulation material. Precursor synthesis is also used in developing matrix materials for CMCs and high-temperature coatings.

Our offer

- Fabrication of oxide and non-oxide fiber types
- Variation of filament diameters from about 5 to 150 µm
- Fibers with controlled porosity
- Development of hollow fibers

PRECURSOR SYNTHESIS

We develop and adapt precursor materials for the fabrication of ceramic fibers. This includes Si-polymers like polycarbosilanes and polyborosilazanes which are used for the fabrication of SiC or SiBNC fibers, and sol-gel precursors which are processed to oxide fibers like Al_2O_3 or $3Al_2O_3$-$2SiO_2$ fibers. We develop the precursors in the laboratory and have the possibility to upscale the precursor synthesis to pilot plant scale. The precursor development is accompanied by extensive characterization, especially in terms of the rheological properties.

Our offer

- Development of precursor materials for ceramic fibers
- Precursor synthesis from laboratory scale to pilot plant scale
- Production capacities up to 50 kg/batch
- Characterization of spinning dopes including rheological studies

FIBER SPINNING

We develop spinning processes for the fabrication of ceramic fibers with the focus on dry- and melt-spinning technology. For new fiber types, the studies start with monofilament spinning. Through various development stages, the spinning process is upscaled up to 1000 filaments. The upscaling process can be supported by computer simulations which enable faster development cycles and improve cost-efficiency.

Our offer

- Development of the spinning process for long and endless ceramic fibers
- Upscaling from laboratory to pilot plant scale (1 to 1000 filaments)
- Dry-spinning and melt-spinning technology
- Spinning of Si-polymers and sol-gel precursors
- Spinning under inert conditions (O_2: < 10 ppm; H_2O: < 1 ppm)

FIBER PYROLYSIS

The spun green fibers are transformed to ceramic fibers by pyrolysis at temperatures of up to 1700 °C. Typically, the fibers are pyrolyzed in a continuous process by drawing the filament bundle through a vertical tube furnace. The fiber pyrolysis is studied in detail to identify critical stages within the process. These findings are taken into account for the design of continuous pyrolysis processes.

Our offer

- Development of pyrolysis and sintering processes
- Continuous and batch pyrolysis of ceramic fibers
- Tube furnaces for pyrolysis up to 1800 °C
- Pyrolysis under inert conditions up to 2100 °C

FIBER COATING

Fiber coatings are needed for realizing a damage-tolerant fracture behavior in CMCs or for adding functionality to ceramic filaments. The coating process can be controlled to either coat the fiber bundle or the single filaments within the fiber bundle. Various precursors have been developed, so that oxide and non-oxide coatings can be applied.

Our offer

- Fiber coating by wet-chemical route
- Coating of fiber bundles and single filaments within bundle
- Development of new coating materials
- Characterization of fiber coatings
- Application of multi-layer coatings
- Oxide and non-oxide compositions

FIBER CHARACTERIZATION

We characterize fibers according to DIN EN standards, if applicable. This includes for example the determination of the mechanical properties like tensile strength, tensile modulus, etc. Beside the mechanical characterization, we offer chemical and microstructural analysis of fibers with state-of-the-art equipment.

Our offer

- Testing of the mechanical properties of single filaments according to DIN EN standards
- Determination of fiber diameters
- Chemical characterization, e.g. composition, surface analysis
- Microstructural characterization, e.g. scanning and transmission electron microscopy