Laboratory for
High Performance Ceramics

Materials development
Process optimization
Component prototyping
Materials testing
Failure analysis
Expertise

Empa
Materials Science and Technology

Laboratory for High Performance Ceramics

Methods and equipment available for competent customer service

Characterisation of ceramic materials

Microstructure/raw materials

- **Parameters**
  phase content, particle size, size distribution and shape of grains and porosity, crack type, crack path, density, specific surface, chemical composition.

- **Equipment/methods**
  - light microscopy
  - field emission scanning electron microscopy with EDS
  - environmental scanning-electron microscope, ESEM
  - scanning electron microprobe analysis by WDS
  - quantitative microstructural analysis
  - time of flight secondaryion mass spectrometry, TOFSIMS
  - x-ray diffraction analysis XRD
  - mercury intrusion porosimetry
  - adsorption, desorption and chemisorption, BET
  - laser scattering particle size analysis and dynamic light scattering
  - laboratory for ceramography
  - He-pycnometry
  - IR-dryer

Mechanical properties

- **Parameters**
  strength, fracture toughness, Young's modulus, shear modulus, Poisson's ratio, hardness, fracture mode, topography of fracture surface, fractography, residual stress

- **Equipment/methods**
  - universal test equipment for tensile and bending strength with the following setups: 3-point, 4-point, ring on ring, piston on three balls, tensile test together, single fibre tensile test, stress- strain test, IF, IS, SEVNB, SCF, SEPB and CNV test for fracture toughness. T_{max}: 1500 °C with automatic specimen feeding
  - pneumatic tensile creep tester for temperatures up to 1600 °C
  - test facilities for subcritical crack growth under static load at temperatures up to 100 °C in nonreactive liquids or corrosive media or up to 1200 °C in air
  - laser interferometry for the measurement of fracture surfaces
  - micro-hardness tester
  - equipment for static and dynamic fatigue
  - impulse excitation apparatus to measure elastic properties

Design

- **Parameters**
  design aspects, materials, material combinations, load, geometry

- **Methods**
  - stress analysis, theoretical and experimental
  - boundary element and finite element calculations
  - mechanical proof testing for components

Thermal properties

- **Parameters**
  coefficient of thermal expansion, thermal conductivity, thermal shock behaviour, high temperature corrosion, thermal fatigue

- **Equipment/methods**
  - dilatometer up to 2200 °C
  - microthermography
  - thermal analysis
  - chemisorption
  - exposure to air, corrosive or inert gases
  - thermal shock test

Ceramic process technology

Processing, compounding

- **Slips**
  - agitators, mixers
  - ultrasonic disintegrator
  - attrition mill, continuous/discontinuous
  - rotating rheometer
  - surface potential measurement
  - mobility measurement

- **Granulates**
  - fluidized bed granulator
  - spray dryer up to 3 kg/h

- **Plastic blends**
  - sigma blade mixer
  - instrumented torque rheometer for temperatures up to 400 °C

- **Milling**
  - vibration mill
  - ball mills
  - attrition mills, blunger mill
  - disc mill

Shaping

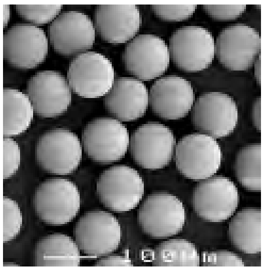
– slip casting and tape casting
– stereolithography
– cold isostatic pressing (dia: 100 mm, l: 300 mm, p: 2000 bar)
– uniaxial pressing, load up to 2000 kN
– extrusion rheometer
– screw extruder
– ram extruder
– machining of green bodies

Thermal processing

– furnace for vacuum and inert gas (graphite) with dilatometer for rate controlled sintering (T_{max} 2400 °C, dia: 280 x h 300 mm)
– brazing furnace high vacuum (molybdenum T_{max} 1400 °C)
– high temperature furnace for air or oxidising conditions (T_{max} 1750 °C, 300 x 300 x 300 mm)
– various other furnaces for temperatures up to 1350 °C with different atmospheres
– various tube furnaces with temperatures up to 1600 °C for different atmospheres (also corrosive)
– high temperature dilatometer for sintering and rate controlled sintering investigations at temperatures up to 2200 °C in vacuum or inert gas and up to 1650 °C in air.

Final machining

– grinding, drilling, honing, lapping, polishing
– contacts to machine shops for any machining, including laser cutting, erosive water jet cutting, ultrasonic milling and electrical discharge machining.



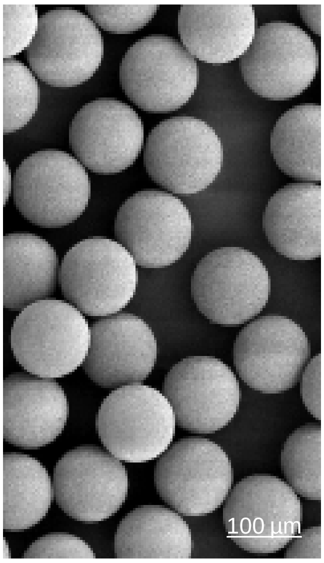
Ceramics and Ceramic Processing

The economical and reliable performance of ceramics in engineering systems requires that optimized materials be developed using sound process engineering methods and that the resulting components be integrated intelligently into their applications. Our specialization lies in the process engineering used to produce an optimized ceramic for a given application.

Ceramic powders

The powders we use are either commercially available grades or powders produced in-house by spray pyrolysis and other methods. These powders are refined by milling, sieving, and spray drying. Our specialty is generating narrow particle size distributions.

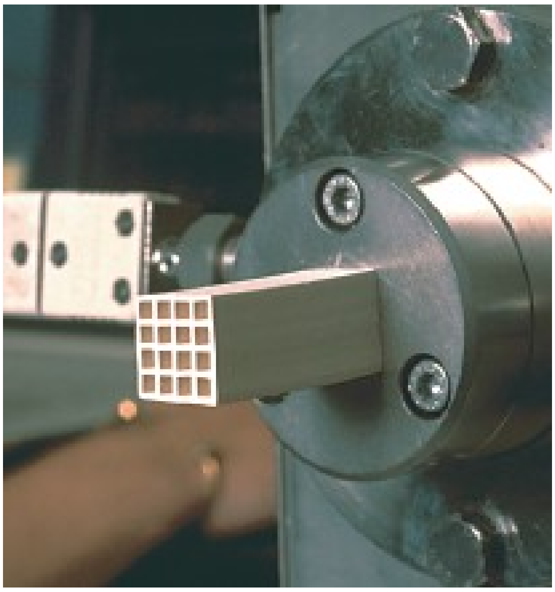
- pyrolysis methods
- milling
- sieving
- spray drying
- flame synthesis



Forming

The conditioned ceramic powders are formed into green parts by uniaxial pressing, isostatic pressing, slip casting, low-pressure injection molding, and extrusion. We specialize in extrusion, producing extrudates with minor dimensions on the scale of microns to centimeters with either thermoplastic or water-based binder systems.

- uniaxial pressing
- cold isostatic pressing
- slip casting
- extrusion
- low pressure injection molding
- tape casting
- sterolithography



are our focus

Characterization of raw materials, densified materials, components

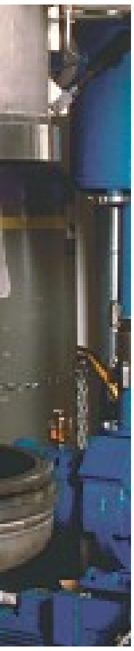
A wide spectrum of characterization methods is at our disposal to analyze raw materials and densified bulk materials. This analysis provides feedback with which we optimize our processing procedures and ensure reproducibility.

- powder properties
- rheology
- chemical composition
- phase composition
- microstructure
- pore size distribution
- density

We stringently test materials and components at temperatures up to 1650 °C according to accepted procedures and norms. New test methods can be developed and standardized if necessary.

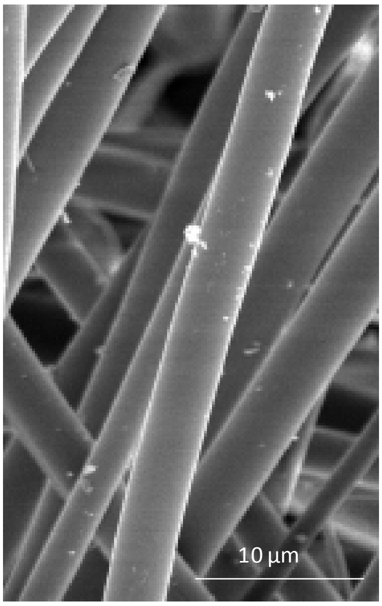
- strength and Young's Modulus
- fracture toughness
- hardness
- creep behavior
- subcritical crack growth
- fatigue testing
- fractography
- proof testing
- ionic and electronic conductivity
- impedance spectroscopy

Sintering



To develop optimal bulk properties in the sintered components we employ furnaces with maximum operating temperatures up to 2400 °C under diverse atmospheres and vacuum. Dilatometers in conjunction with rate controlled sintering routines are used to opti- mize sintering parameters.

- dilatometers
- high temperature furnaces
- vacuum furnaces
- fast sintering methods
- diverse atmospheres



Novel processes

We are also actively involved in fiber reinforced and particle reinforced composite materials. Extruded fibers, and suitably refined powders are used to generate preforms which are subsequently transformed into composites.

Furthermore we have at our disposal flame and thermal spraying processes to generate diverse ceramic coatings.

- customized properties
- fiber and particle reinforcement
- electrically conductive ceramics
- joining of ceramics with metals
- ceramic coatings

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