# FGK – Research, Development, Testing and Consultancy in the Field of Inorganic Materials, Glass and Ceramics

**FGK (Forschungsinstitut für Anorganische Werkstoffe – Glas/Keramik – GmbH/DE), the new network partner of CERAMIC APPLICATIONS, is also in process to set-up a permanent exhibition for all partners at the institute in Höhr-Grenzhausen/DE to promote technical ceramic components for their wide range of applications.**

**Introduction**

FGK GmbH/DE was founded in 1986 by the state of Rhineland-Palatinate and the Westerwald District as an applied research institute and has continued to develop further in the three decades that followed. Whereas the main focus was initially on co-operating with regional companies in the raw materials and ceramics industry and companies involved in glass decoration in Höhr-Grenzhausen, the FGK project teams have now been working for many years not only on a national level but also throughout Europe. In this respect, the spectrum of activities has expanded from the classic silicate-based ceramics in the areas of functional and structural ceramic materials, and from natural mineral raw materials to synthetic raw materials for technical ceramics. Currently, 38 persons work in the three business fields Research + Development, Material Testing and Consultancy, which have developed in close collaboration with the industry over a number of years. The FGK R+D activities are reflected in the testing services according to ISO 17025 and divided in the three Working Groups: Optical Ceramics and Photocatalysis, Ceramics Applications and Process Technology as well as Raw Materials.

**Raw material research and analysis at FGK**

The opinion is often made in discussions that everything has already been done regarding research into the field of ceramic raw materials and that no further innovations are to be expected. Quite the opposite is true, and this is continually being confirmed in daily production practice – both equally in silicate ceramics as well as in technical ceramics. Production processes have continued to become increasingly automated, in combination with even higher requirements on process stability and the quality of the end products, and the solution approaches here are almost always in the development of suitable raw material concepts, which FGK has been intensively engaged to since its foundation.

Basic chemical-mineralogical testing is not only supported by the extensively equipped testing laboratory at FGK, but in particular regarding other intrinsic properties such as grain size distributions, mineralogy in the fine fractions, the specific surface, surface charge, cation exchange capacities as well as bound and soluble trace elements, which verifiably influence the processing and product characteristics. FGK expertise is in demand not only for R+D projects but also in the optimisation of the interface between raw material supplier and processor, for example, in the context of preparing quality assurance agreements and in the assessment of raw material product data sheets.

**Diverse raw material and material analytics in the FGK test laboratory**

Quality management at the FGK test laboratory which is accredited according to DIN EN ISO/IEC 17025 ensures the necessary high level of accuracy of investigational results, which are available for external clients as well as the in-house R+D department for a number of analytical tasks. Extensive laboratory equipment in the areas of chemical, physical-thermal and mechanical testing enable varied special analyses in particular for ceramic raw materials and other materials. For this reason, various companies utilise the FGK test laboratory for regular production controls or supplier assessments. In the area of analytical chemistry, methods of analysis are available such as X-ray fluorescence analysis (XRF), optical emission spectroscopy using inductively coupled plasma optical emission spectrometry (ICP-OES) and ICP mass spectrometry (ICP-MS), with which ceramic raw materials and other materials can be precisely chemically characterised. The particular significance of the application of physical-thermal analytical procedures in the field of ceramics is taken into account by the test laboratory with a broad spectrum of analysis. These include, above all, numerous instruments for simultaneous thermal analysis (STA) as well as for dilatometry. Different kinds of STA testing combinations are available

*Fig. 1*
*View of the division Thermoplastic Design at the FGK Technical Centre*

(DTA-TG, DSC-TG and STA-FTIR-coupling for gas analysis). In the area of dilatometry, the equipment enables the determination of thermal expansion coefficients in a temperature range of –190 °C up to 2400 °C.

For the analysis of powdered ceramic raw materials and other materials, test methods such as particle size analysis using laser light scattering and sedimentation procedures or the determination of the zeta potential are available and these are sensibly supplemented by qualitative and also quantitative phase analysis using X-ray diffraction analysis (XRD) as well as scanning electron microscopy (SEM/EDX) and light microscopy procedures.

The increasing significance of technical ceramics is reflected in the higher demand for corresponding specific analytical methods. For example, different chemical and physical tests are routinely carried out on $ZrO_2$ materials (DIN EN ISO 13356 Implants for Surgery) or materials in the field of dentistry (DIN EN ISO 6872).

**Working group "Ceramics Applications and Process Technology"**

***Ceramics process technology***

The properties of ceramic materials essentially depend on the chemical composition and their microstructural characteristics which are mainly influenced by process technology. At FGK there are a multitude of aggregates available for processing (grinding technology, mixers, spray granulation, amongst other things), shaping (uniaxial and isostatic pressing, extrusion, thermoplastic shaping, amongst other things) and thermal process control (kiln technology up to 2000 °C in different atmospheres as well as hot isostatic pressing up to 2000 °C and 3000 bar). In this way, almost the entire process chain used in ceramic processing can be matched at FGK. The area of material systems to be processed ranges from silicate ceramics, oxide and non-oxide ceramics to modern composite material systems. In the area of applied research and development, FGK develops optimal process technology in close collaboration with industry, starting with the choice of raw materials, processing, moulding and other types of shaping up to sintering, as well as material conforming design. In numerous R+D projects, material systems and components are developed according to the target applications and the requirement profiles defined by the customer and project partner (Fig. 2).

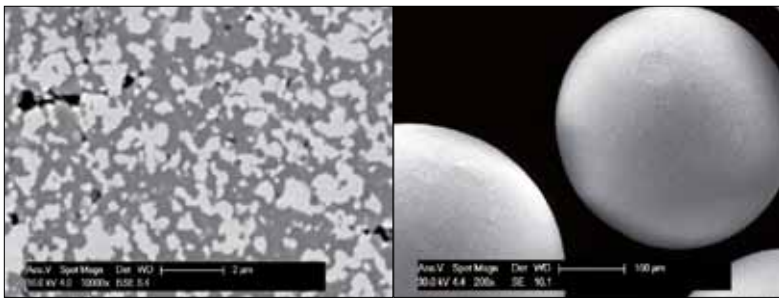

*Fig. 2*
*$ZrO_2$-WC composite materials and sintered milling beads*

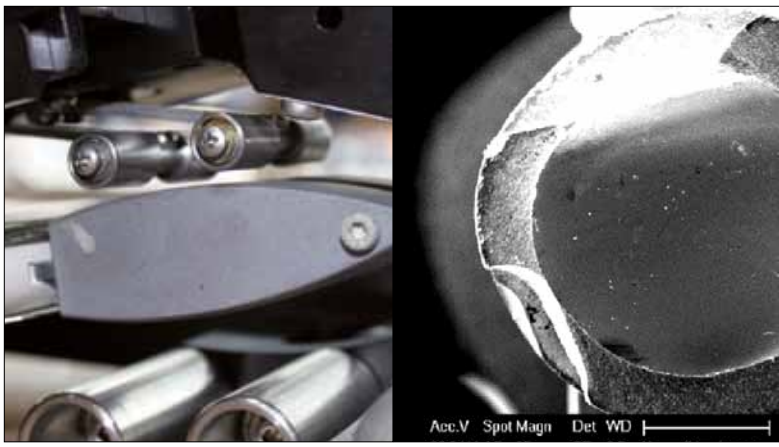


*Fig. 3*
*Heating wedge made of SiSiC for welding highly abrasive plastic waterproofing membranes in civil engineering (Source: Herz GmbH)*

*Fig. 4*
*Fractured surface of a dental implant, caused by bending loads during implantation*

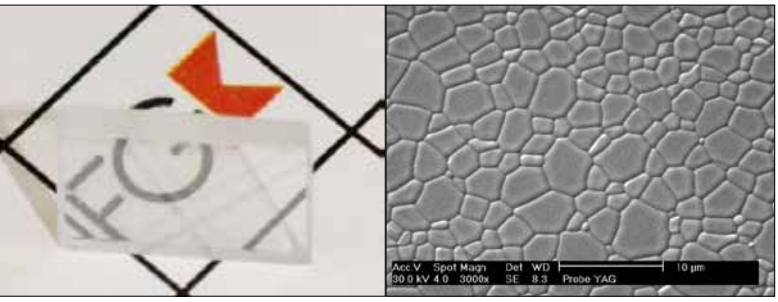


*Fig. 5*
*Highly transparent YAG ceramics with pore-free microstructures, no defects and no detectable secondary phases*

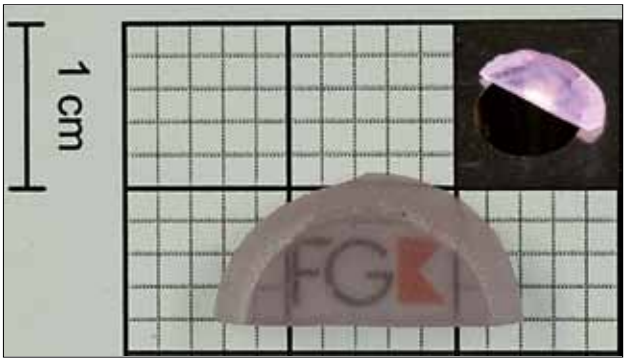


*Fig. 6*
*Example of a neodymium-doped YAG ceramic based on FGK powder synthesis using a micro-jet reactor*

*Fig. 7 Translucent luminescent ceramics with colour emission under special optical excitation*

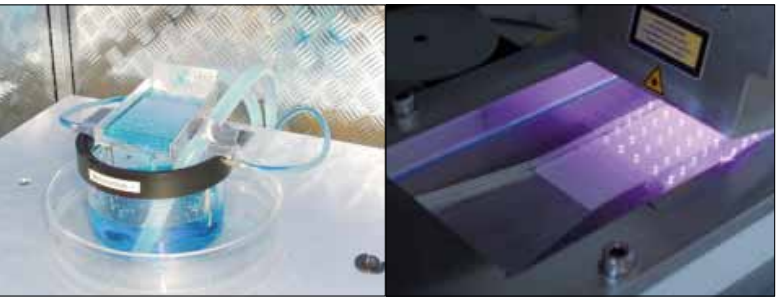

*Fig. 8*
*Modified measurement of photocatalytic activity on surfaces according to DIN 52980 : 2008 by methylene blue degradation (l.) and determination of air purification capacity of semi-conducting photocatalytic surfaces according to DIN ISO 22197-1 : 2007, test procedure for photocatalytic removal of nitrogen oxides (r.)*

***Ceramics applications***

The group of ceramic materials additionally excels through its enormous variety of properties and the resulting high potential in many areas of use. For the successful implementation of this potential for different applications, this requires knowledge about the respective material characteristics and in particular the construction and utilisation with these materials. In this respect, FGK profits from the many years of cooperation with ceramic manufacturers and users. These applied developments cover all areas from fundamental design, selection of materials and processes to realisation of the product.

Application of ceramics is also concerned with damage analysis as a consequence. An important point in the case of damage is to establish the cause of failure and to initiate specific countermeasures. This already starts in the area of material development and continues later on to the application. FGK has many analytical possibilities available as well as experienced employees, who are able to detect the cause of damage and to deduce sensible and necessary measures from this knowledge together with the customer, in order to sustainably improve the reliability of materials, construction parts and systems.

**Working group "Optical Ceramics and Photocatalysis"**

***Optical ceramics***

About 8 years ago, the cornerstone was laid at FGK for a special field in technical ceramics which is still very young: transparent or optical ceramics. Transparent ceramics show a typical ceramic, polycrystalline micro-structure after firing, which gives a very high optical quality due to its chemical purity, in the absence of even the slightest traces of secondary phases and pores (Fig. 5). The structural quality determines the optical characteristics.

Transparent ceramics represent an attractive, new group of materials with optimal properties for optical applications. Optical glass available today has limitations regarding refractive index and optical dispersion, as well as other physical properties, which limits their use in certain areas. With the properties of transparent ceramics (such as e.g. significantly higher refractive indices), there arise new innovative approaches for particular small-formatted and high-resolution optics with potential applications in the area of consumer optics (ultra-flat cameras, mobile phone cameras). Also, interesting approaches are seen and followed in the area of military and civil aerial photographic observation as well in microlithography for the semiconductor industry.

Transparent ceramics not only possess remarkable advantages compared to other inorganic transparent materials, such as e.g. glass. Also, the ceramic production approach promises economic advantages, such as e.g. in comparison to single-crystal growth processes.

Translucent ceramics are well-known as permanent highly resistant components in the field of high-performance lamps, thanks to their excellent chemical, mechanical and thermal properties. Their use in high-pressure sodium vapour lamps and halogen metal vapour lamps gave the motivation to develop optical ceramics with high transmission for a multitude of further applications. For example, a current field of application of optical ceramics lies in the area of modern LEDs, in which inorganic luminescent ceramics are used as light converters and offer advantages over other materials due to their intrinsic properties. The range of attractive applications in

the research field of transparent ceramics and optical materials has not yet been exhausted and also extends to highly refractive lenses, LASER media or electrooptical elements, which change their refractive index when an electric field is applied. The activities of FGK not only include known material systems and applications, but are continually being expanded to involve new materials and innovative applications.

**Photocatalysis**

FGK is involved with developing and testing photocatalytic active surfaces, whose efficacy is based on the special material properties of semi-conducting titanium dioxide under exposure to UV radiation. In numerous applied projects with renowned industrial and institutional partners, practical solutions for utilising this effect have been and will be successfully worked out and implemented for different branches of industry (construction, food, the environment).
Since 2010, FGK is also member of the Working Committee for Photocatalysis of the Standardisation Committee for Material Testing (NMP) of the German Institute for Standardisation (DIN e.V.) and the CEN/TC 386/WG 7 (New Technologies), and participates, amongst other things, in the further development of analytical methods and application of photocatalysis.

FGK

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