# Competence Center for Additive Manufacturing of Inorganic-Nonmetallic Materials – 3DK

**A project group at Forschungsinstitut für Glas | Keramik (FGK/DE), supported by funding of the Ministry of the Economy of Rhineland-Palatinate (MWVLW/DE) and the European Regional Development Fund (ERDF/DE), is currently working on the establishment of an infrastructure and the development of know-how for Additive Manufacturing (AM) of inorganic-nonmetallic materials, which will result in the first competence center for AM of the aforementioned material group in Rhineland-Palatinate, named 3DK.**


*Fig. 1*
*Thematic focus of 3DK*


*Fig. 2*
*Equipment of 3DK along the entire process chain*

Additive Manufacturing (AM) processes are regarded as future-oriented cross-sectional and key technologies for almost all industries. The market potential is estimated to be correspondingly large. A major advantage of these processes is that they can be manufactured individually according to customer requirements and at the same time economically. The product properties allow an almost unlimited variety of geometries and designs and thus offer countless possible applications, for example in the engineering and design sector or in medicine for bone and tooth replacements, implants and prostheses.

Over a period of three and a half years, the three partners – Forschungsinstitut für Glas | Keramik (FGK), Koblenz University of Applied Sciences/DE and the University of Koblenz-Landau/DE – are pooling their proven expertise in working with inorganic non-metallic and, in particular, ceramic materials in order to better adapt existing printing processes to the wide range of material types. At 3DK, these range across the entire spectrum of ceramic materials – from silicate ceramics, refractory ceramics, technical ceramics, including transparent ceramics, to multi-material printing (Fig. 1).

The main location of 3DK is the CeraTechCenter in Höhr-Grenzhausen in the Kannenbäckerland/DE, a cultural landscape with the largest clay deposit in Europe. In addition to traditional ceramic crafts, the ceramics industry and numerous educational and research institutions related to glass and ceramics have also established themselves here.

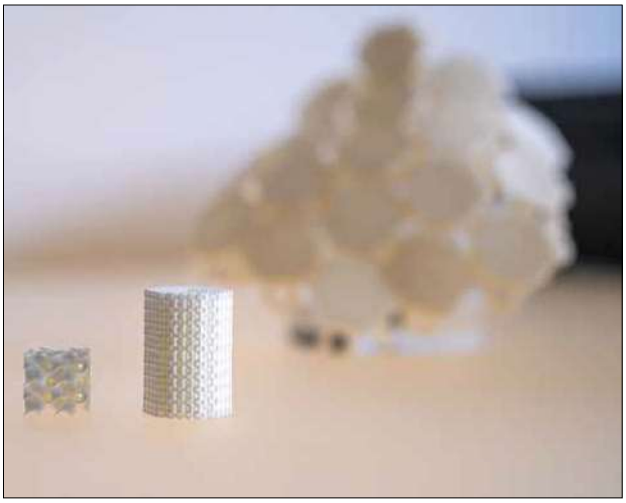

*Fig. 3*
*Examples of additively manufactured oxide ceramic components*

The aim is to identify economic processes that, taken together, overcome the obstacles of the state-of-the-art. To this end, the manufacturing processes to be applied individually to the material must basically be considered holistically along the entire process chain, which takes into account the raw materials, the binder groups and the sintering in the same way as the printing processes (Fig. 2).
AM of components is always preceded by the creation and preparation of a printable file. In this respect, a 3D scanner can provide a good introduction to the complex topic of data creation. The use of a 3D scanner makes it possible to capture even the most complicated structures within a very short time and without a great deal of simulation effort. The files generated in this way can be easily expanded to include the expected shrinkage values, thus enabling direct replication of existing components. It is thus possible to replicate existing geometries in detail and thus to record the direct influence of the respective shaping processes on the properties of the components and to highlight the corresponding advantages and disadvantages.

The preparation technology within the process chain of ceramic materials, especially technical and optical ceramics, is of great importance and justifies the implementation of a centrifugal mixer. In the development of concrete formulations, which have to be adapted to the requirements of contour crafting in the course of the project, the input of mixing energy has a significant influence on the flow properties of refractory concretes. Mixing is thus an adjusting screw with which 3D-CC shaping can be positively influenced with regard to the result. In order to be able to build on existing knowledge at the university and to carry out the scale-up planned in the course of the project as smoothly as possible, an intensive mixer from Maschinenfabrik Gustav Eirich GmbH & Co KG/DE is used for preparing the refractory concretes (model R08W, useful capacity up to 75 l). This is the only way to ensure the comparability and adaptation of the research results published so far and now also established in industry for the planned project.
Shaping is clearly at the heart of the AM process chain. A large number of existing processes enable the optimal interaction between printing technology, material and application. Thus, the equipment available at 3DK ensures the creation of printed parts in millimetre- to meter scale, from the application in the human body to the use in the steel mill.
Stereolithography (SLA) is currently regarded as the technology that allows high-performance ceramics to be processed to the necessary quality. The layer-by-layer build-up here is based on the photopolymerisation of a liquid resin filled with ceramic particles. Typical compositions for such suspensions include a monomer solution, a photoinitiator and additives for dispersing the ceramic powder, which can account for up to 60 vol.-%. The resulting high sintering densities and the use of fine ceramic particles are decisive reasons for making stereolithography useful for the production of technical (multi-material) ceramics in particular. In combination with the broad experience of FGK in the field of transparent ceramics, this equipment – a CeraFab Multi 2M30 from Lithoz GmbH/AT – will also be used for a comprehensive development of different material groups with transparent properties.
So far, not all materials can be processed using SLA. For example, non-oxides such as silicon carbide have such a high absorption


*Fig. 4*
*The equipment available at 3DK for creating printed parts from left to right: CeraFab Multi 2M30 from Lithoz GmbH/AT; ExAM 255 from Aim3D GmbH/DE; WASP 40100 Clay delta printer/IT; 6-axis industrial robot from ABB Automation GmbH/DE*

capacity with respect to the wavelengths specific to the process that they are no longer able to initiate the curing process of the photosensitive polymers to the extent required. However, in order to be able to process all materials relevant to technical ceramics, AM of both oxide and non-oxide ceramic materials at FGK is to be carried out by means of thermoplastic processing of feedstocks. In this respect, the CEM process (Composite Extrusion Modeling) is proving to be a suitable method, since there are virtually no limits to the choice of materials. In cooperation with the University of Koblenz-Landau, the complex mixtures of ceramic raw materials and chemical process additives are developed here and adapted and optimized for the printing process. An ExAM 255 from the company Aim3D GmbH/DE is available for this purpose.

In contrast to most technical ceramic materials, clays, as they occur in large quantities in the Westerwald region, exhibit wet plastic properties. Since this group of materials is very important for FGK, the Westerwald and its industry, it should also be opened up for additive manufacturing in terms of materials technology. In this case, the center is working with the WASP 40100 Clay delta printer. In the field of refractory ceramics, refractory concretes are additively processed using contour crafting under the leadership of Koblenz University of Applied Sciences. A 6-axis industrial robot from ABB Automation GmbH/DE with a maximum payload of 40 kg and a reach of over 2 m × 2 m is used as a carrier system (model IRB 4600-40/w2.55) to realise the layer-by-layer construction of the components. This makes it possible to create large-format components. In this way, the equipment available at 3DK ensures the creation of printed parts from millimetre- to meter scale, from application in the human body to use in steel mills. Only in this way is it possible to provide industry with a technology that is economical and therefore forward-looking.

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