Fraunhofer
IKTS

FRAUNHOFER INSTITUTE FOR
CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

ADDITIVE MANUFACTURING OF CERAMICS

"ADDITIVE MANUFACTURING PROCESSES ARE READY TO TAKE THEIR PLACE ALONGSIDE MULTIAXIS MACHINING CENTERS AND INJECTION MOLDING MACHINES ON THE PRODUCTION FLOOR." *Source: VDI*

ADDITIVE MANUFACTURING

Fraunhofer IKTS develops starting materials, processes, and systems for additive manufacturing of advanced ceramic and functionally integrated components. The research institute also offers technologies and equipment for in-line process monitoring. Thus, it is a competent and innovative partner to ceramics manufacturers and users as well as developers and manufacturers of additive manufacturing systems.

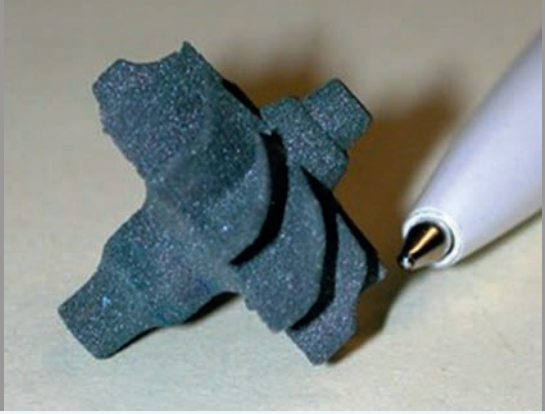
Additive manufacturing (AM) methods can be used to produce parts in which the geometric complexity precludes use of conventional ceramic shaping processes. Examples of such parts include components with intricate internal channel structures. The tool-free aspect of AM methods makes them suitable for cost-effective manufacturing of individualized items or small batches. AM processes are characterized by wide-ranging geometry capabilities paired with the ability to vary material composition in a pointwise manner.

3D PRINTING

The best-known additive manufacturing process is 3D printing (3DP). In this process, a printing head is used for pointwise dispensing of a liquid onto a powder bed; the liquid, the powder, and a binder, which can be either in the liquid or the powder, then interact to solidify the powder layer at each point. Because the achievable density of 3D printed green bodies is quite low, this process is most suitable for manufacturing of porous parts, such as bioactive ceramic structures made of hydroxylapatite, filter and catalyst support structures, or complex ceramic cores and molds for precision casting. The materials that can be processed using 3DP include oxide and non-oxide ceramics, glasses, hardmetals, and metals in powder form.

Services offered

- Materials selection and powder preparation for generating granules with high flowability
- Component design optimized for ceramics
- Development of components with commercially available 3D printer (installation space dimensions: 350 x 250 x 200 mm; minimum layer height: 87 µm)

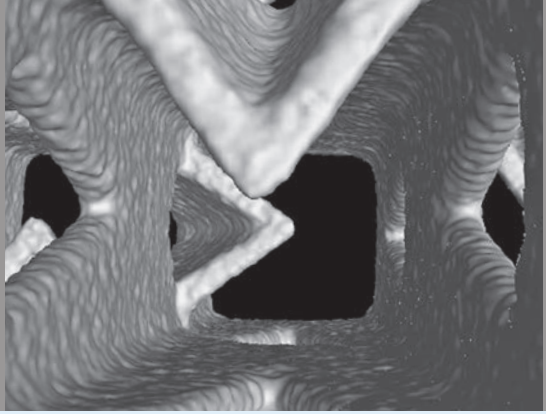


SELECTIVE LASER SINTERING

In selective laser sintering (SLS), a powder layer is applied via a doctor blade. Selective solidification with the laser beam can lead to a dense material structure if the ceramic powder contains a liquid phase-forming component (e.g., Al_2O_3/SiO_2 mixture). Like all other AM techniques, laser sintering can also simply be used for shaping ceramic green bodies, for example, for producing complex SiC parts, which are then converted to SiSiC in the usual thermal post-treatment steps. The material properties are comparable to those of materials produced using conventional technologies (pressing, green machining, and finishing).

Services offered

- Materials selection and powder preparation for generating granules with high flowability
- Parts development
- SLS system with CO_2 laser (wavelength: 10.6 µm; output power: 100 W) and fiber laser (wavelength: 1.06 µm; output power: 3–500 W) as well as installation space dimensions of 250 x 250 x 200 mm

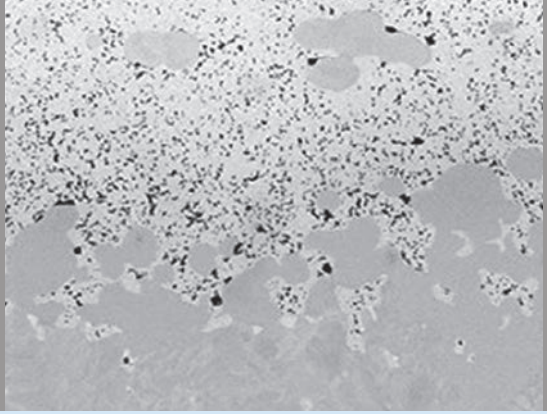


LITHOGRAPHY-BASED CERAMIC MANUFACTURING

Lithography-based ceramic manufacturing (LCM) was developed especially for ceramics. In this process, the building platform is immersed upside down in a ceramic suspension, and all areas to be cross-linked are simultaneously exposed to and solidified by light of a defined wavelength. This yields a much higher productivity than is achievable with the pointwise radiation used in stereolithography. After curing, the part is raised by an amount corresponding to the layer thickness and the process of suspension application and exposure to light is repeated. Following conventional thermal processing of the green bodies, densities of min. 99.4 % of theoretical density for Al_2O_3 and min. 99.0 % for ZrO_2 can be obtained.

Services offered

- Development of light-curable suspensions from customer-specific powders
- Parts development based on customer-specific CAD data
- Consulting on component design
- LCM system (installation space dimensions: 76 x 43 x 150 mm; layer height: 25–100 µm; lateral resolution: 40 µm)



THERMOPLASTIC 3D PRINTING

Thermoplastic 3D printing (T3DP) is the only additive manufacturing method for ceramics that is largely material-independent as well as suitable for producing multicomponent and/or graded parts. The process is based on the use of particle-filled thermoplastic mixtures of low melting temperature (80–100 °C). The mixtures are applied pointwise with a heated dispenser, which can be moved in all three spatial directions across a fixed platform. Because the thermoplastic solidifies almost immediately after application, the solidification process is nearly independent of the physical properties of the powders used. Multiple supply tanks and dispensers can be used for depositing different materials at different locations in a component.

Services offered

- Development of suitable thermoplastic suspensions from customer-specific powders
- Materials selection for multicomponent systems and development of thermoplastic mixtures with adjusted shrinkage properties
- Development of co-sintering routes
- Parts development based on customer-specific CAD data

FUNCTIONALIZATION OF 3D COMPONENTS

Digital printing processes are the key to coating complex 3D or freeform components with functional structures, such as conductors, resistors, heat conductors, or sensors. For this, various microextrusion and dispensing techniques as well as inkjet and aerosol jet technologies are used. The latter technologies are especially suitable because through atomization (aerosolization) of a large number of particle-free or particle-containing inks, application of extremely fine structures even down to the micron scale is possible. Apart from single-component aerosol inks based on precipitated metal particles, multicomponent suspensions offering unique potential due to the possibility of tailoring their properties, adhesion and expansion behavior for different substrate materials through special glass phases can be used.

Services offered

- Preparation of submicron single-component and multi-component printable functional inks
- Printing of layers between 3–20 µm thickness on 3D objects of 20–50 µm width
- Application-specific solutions comprising conductive, resistive, heater, and insulating inks for various substrates

FIELDS OF EXPERTISE

Materials systems

SiC (SiSiC)	Al_2O_3, AlN	ZrO_2	Glass/bioglass
Si_3N_4	ZTA, ATZ		(Hard)metals

Materials preparation

Materials selection	Powder and suspension preparation	Binder selection/ modification

Production methods

Powder bed-based	Suspension-based
Selective laser sintering (SLS)	Lithography-based ceramic manufacturing (LCM)
3D printing (3DP)	Thermoplastic 3D printing (T3DP)
	Fused deposition modeling (FDM)

In-line process control

- Optical coherence tomography
- Laser speckle photometry (LSP)
- Ultrasound
- X-ray CT

Functionalization

- Inkjet/aerosol printing
- Screen/pad printing
- Microdispensing
- Diode laser sintering

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FRAUNHOFER IKTS

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes.

The institute operates in eight market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, optics as well as materials and process analysis.