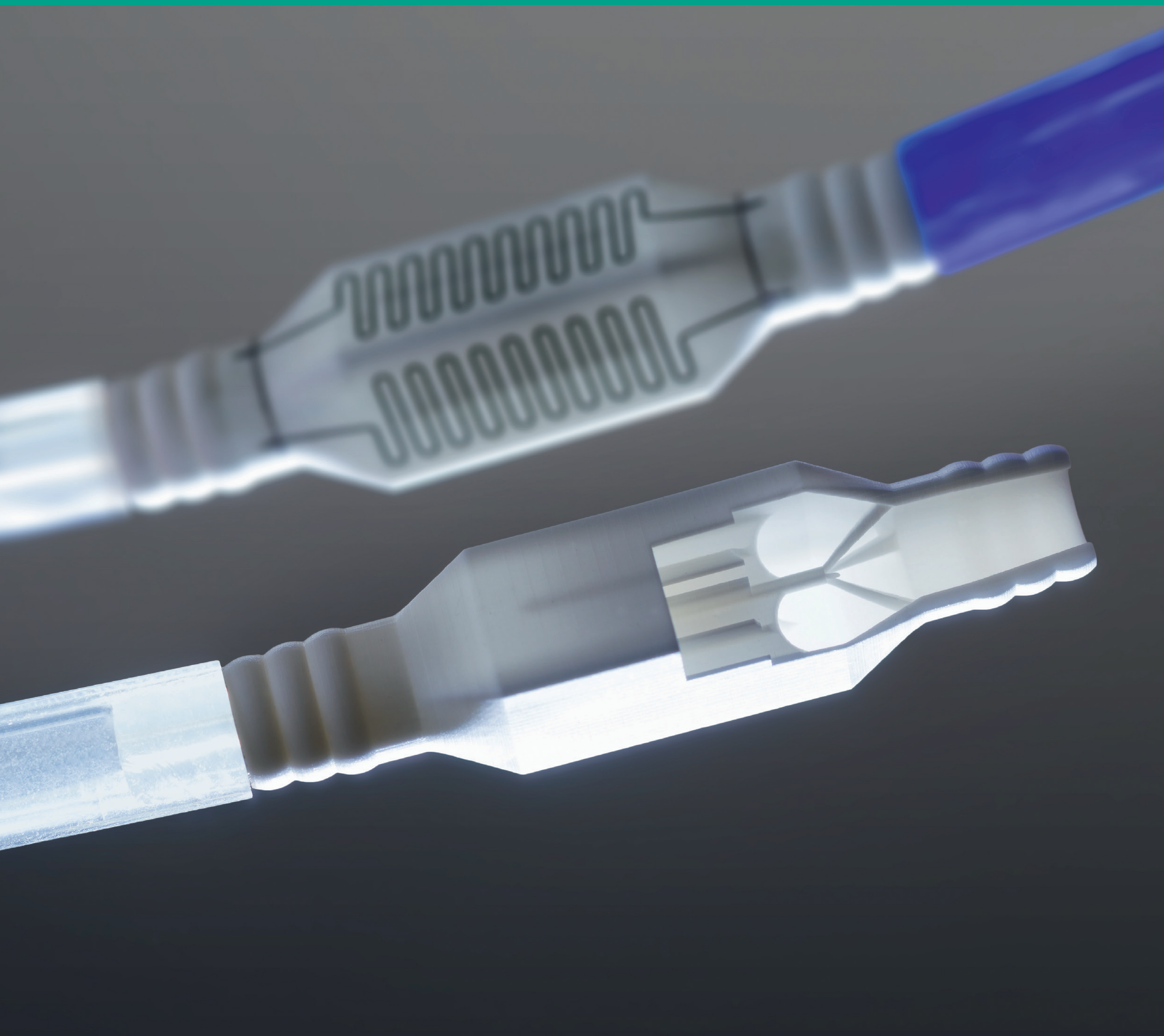
FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

INDUSTRIAL SOLUTIONS

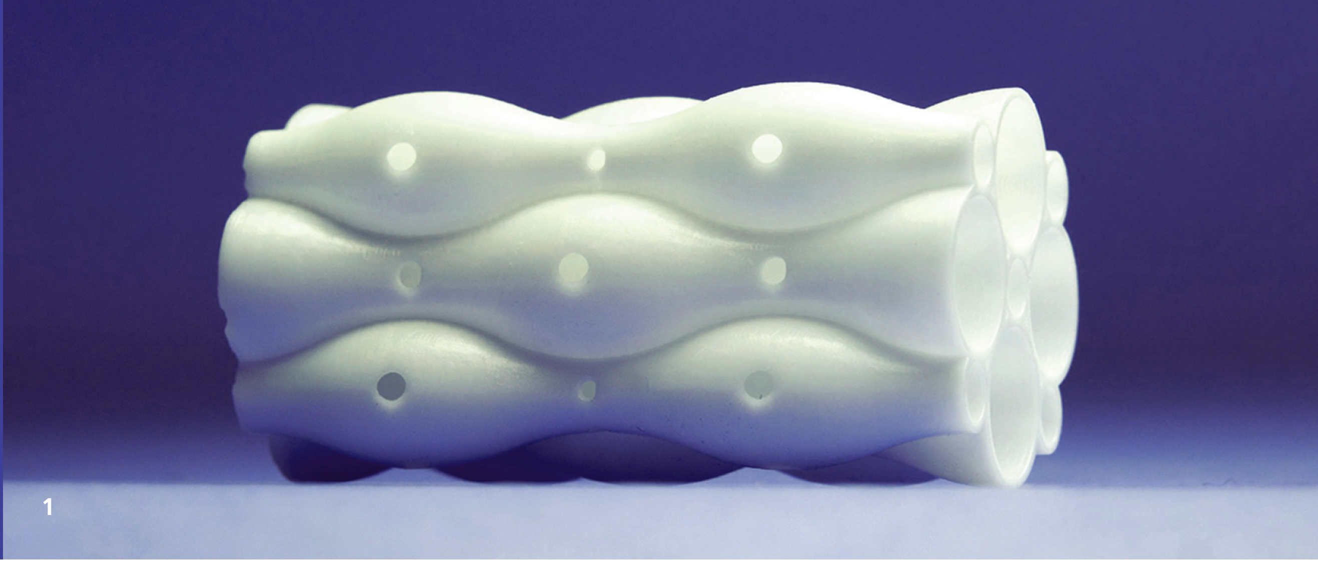
ADDITIVE MANUFACTURING

PRODUCTION | FUNCTIONALIZATION | QUALITY ASSURANCE



COVER IMAGE *Heating element made by additive manufacturing with printed conductive trace.*

1 *Lithography-based manufacturing of ceramics for mixer structures.*



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ADDITIVE MANUFACTURING

Additive manufacturing (AM) methods are used for generation of parts through successive pointwise, linewise, or layerwise application of material. This building principle makes it possible to create geometrically complex, functionalized structures that could not be realized at all or could only be produced at great cost using conventional methods. Another advantage of this building principle is the very sparing raw materials consumption; just the amounts of raw materials actually needed are used. These tool-free shaping methods can be used to produce customized one-offs or small batches with high efficiency and without the tooling expenses of conventional methods.

Fraunhofer IKTS has been using AM methods for ceramic components since the 1990s and was a founding member of the Fraunhofer Additive Manufacturing Alliance, which was established in 1998. Today, Fraunhofer IKTS offers complete AM solutions ranging from powder and suspension/feedstock development and production method selection to functionalization and quality control of novel parts and systems:

- Powder bed-based additive manufacturing methods: 3D printing (binder jetting) and selective laser sintering (SLS)
- Suspension- or feedstock-based additive manufacturing methods: lithography-based ceramic manufacturing (LCM), laminated object manufacturing (LOM), thermoplastic 3D printing (T3DP), and fused filament fabrication (FFF)
- Functionalization through application methods: inkjet printing, aerosol jet printing, screen printing, jet dispensing, and diode laser sintering
- Non-destructive testing methods for in-line process monitoring: laser speckle photometry (LSP), optical coherence tomography (OCT), and standard analysis methods (ultrasonic testing, X-ray computed tomography, etc.)

Advantages

- Freedom in design
- Multifunctionality
- Tool-free production
- Individualization
- Cost-effective small-batch production
- Reduced product development cycles
- Production on demand

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Additive Manufacturing

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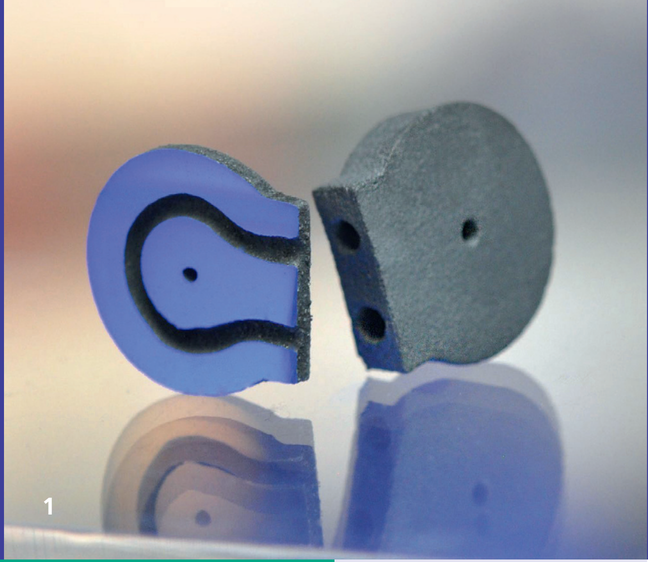
Applications

- Mechanical engineering
- Tool and mold making
- Medical components
- Aerospace
- Jewelry and creative industry
- Automotive industry
- Chemicals and pharmaceuticals
- Consumer goods



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PRODUCTION

Additive manufacturing methods can generally be divided into powder-based and suspension-based methods according to the starting material state.

Powder-based methods usually start with a powder bed in which powder granules with good flowability are spread out and bound together in layers. For the most part, the resulting components exhibit porous structures.

With suspension- or feedstock-based methods, the starting materials take the form of suspensions, pastes, inks, or semi-finished products, such as thermoplastic feedstocks, green films, or filaments. Because the particle distribution of the powder in a suspension is more homogeneous than in a powder bed, these shaping methods yield higher green densities, which result in sintered components with denser microstructures and lower surface roughness levels.

Typical to all additive manufacturing methods used for producing ceramic components is the need for post-AM thermal treatment steps such as debinding and sintering, which lend the ceramic component its final ceramic properties.

3D PRINTING (BINDER JETTING)

The best-known additive manufacturing method is 3D printing. As in a conventional inkjet printer, a liquid is dispensed onto the powder layer through a print head, whereby the interaction between liquid, powder, and binder results in pointwise solidification. The binder can be situated either in the liquid or in the powder. The densities of the printed green bodies are relatively low. The method thus offers advantages in applications in which porosity is explicitly required – for example, in bioactive ceramic structures made of hydroxyapatite. Components can also be manufactured for filtration applications and catalyst support structures or for complex ceramic cores and molds for precision casting. A wide range of materials – oxide and non-oxide ceramics as well as glass, hardmetals, and metals – can be processed in powder form by 3D printing.

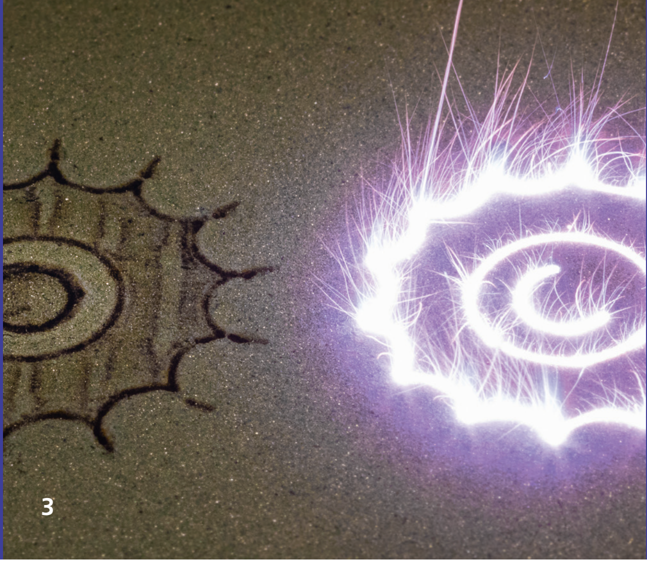
Services offered

- Development of granules with good flow behavior
- Materials selection and parts design optimized for ceramics
- Parts development based on customer-specific CAD files

Equipment type	Z510 (Z-Corp.)
Build chamber	350 x 250 x 200 mm³
Layer thickness	87.5 or 100 µm
Materials	Oxides, non-oxides, glass powders, hardmetals, metals, hydroxyapatite, and gypsum

1 *Hardmetal wire die with integrated cooling channel.*

2 *3D printing of a honeycomb with transverse channels.*



SELECTIVE LASER SINTERING (SLS)

In selective laser sintering, the powder particles are glued together by a laser beam treatment. The starting point is a powder layer applied with a doctor blade. To yield a dense material microstructure, the ceramic powder contains a liquid phase-forming component (e.g., Al_2O_3/SiO_2).

In addition, laser sintering, like all other additive methods, can only be used for shaping of the ceramic green body. In this way, for instance, complex SiC parts can be produced and then converted to SiSiC by liquid Si infiltration. The material properties of the parts are comparable to those achievable with conventional technologies (pressing, green machining, and finishing).

Services offered

- Materials selection and powder preparation
- Parts development based on customer-specific CAD files

Equipment type	EOSINT M 250 Xtended
Build chamber	250 x 250 x 200 mm³
CO_2 laser	10.6 µm wavelength, 1–240 W
Fiber laser	1.06 µm wavelength, 3–500 W
Layer thickness	0.02 mm – 0.2 mm
Scan rate	max. 1m/s
Materials	SiSiC, glass powders, metals, hardmetals, hydroxyapatite, and ceramics with glassy phase contents

3 *Selective laser sintering of an SiC microturbine.*

LITHOGRAPHY-BASED CERAMIC MANUFACTURING

This method, developed especially for additive manufacturing of ceramics, works according to the so-called digital light processing principle. For this, Fraunhofer IKTS uses the CerFab7500 system from Lithoz GmbH.

As in stereolithography, free radical polymerization of the binder system takes place with light of a defined wavelength, causing the suspension to solidify. Via a DLP module, the suspension is selectively irradiated with blue light, whereby all areas to be cross-linked on a given plane are exposed at the same time. The productivity is hence high. Achievable densities following conventional thermal treatment of the AM green bodies are at least 99.4 % of theoretical density for Al_2O_3 and at least 99.0 % for ZrO_2.

Services offered

- Development of photocurable suspensions of customer-specific powders
- Parts design optimized for ceramics
- Parts development based on customer-specific CAD files

Equipment type	CeraFab 7500 (Lithoz)
Build chamber	76 x 43 x 150 mm³
Layer thickness	5–100 µm
Lateral resolution	40 µm (635 dbi)
Build speed	2.5–10 mm/h
Materials	Al_2O_3, ZrO_2, hydroxyapatite, glass powders, AlN, and Si_3N_4

4 *Hybrid manufacturing of complex bone structures.*

THERMOPLASTIC 3D PRINTING (T3DP)

Thermoplastic 3D printing is based on a technology and equipment uniquely developed at Fraunhofer IKTS to overcome important limitations in existing methods. Focus is on the manufacturing of large ceramic green bodies, functionalization through use of various materials, and a significant increase in build speed.

The advantage of T3DP over other methods is that it can be used to make multi-component and/or graded parts regardless of the selected material. The method is based on use of particle-filled thermoplastic mixtures with low melting points (80–100 °C) as well as relatively low starting mixture viscosities. Analogously to the fused deposition modeling approaches used for polymers, this method involves application of the material not over the entire surface, but instead only in the required spots. Multiple heatable dispensing units controlled in all three spatial directions move over a fixed platform. The thermoplastic mixture is heated until it is in a flowable state, is deposited at the desired position, and solidifies immediately on cooling.

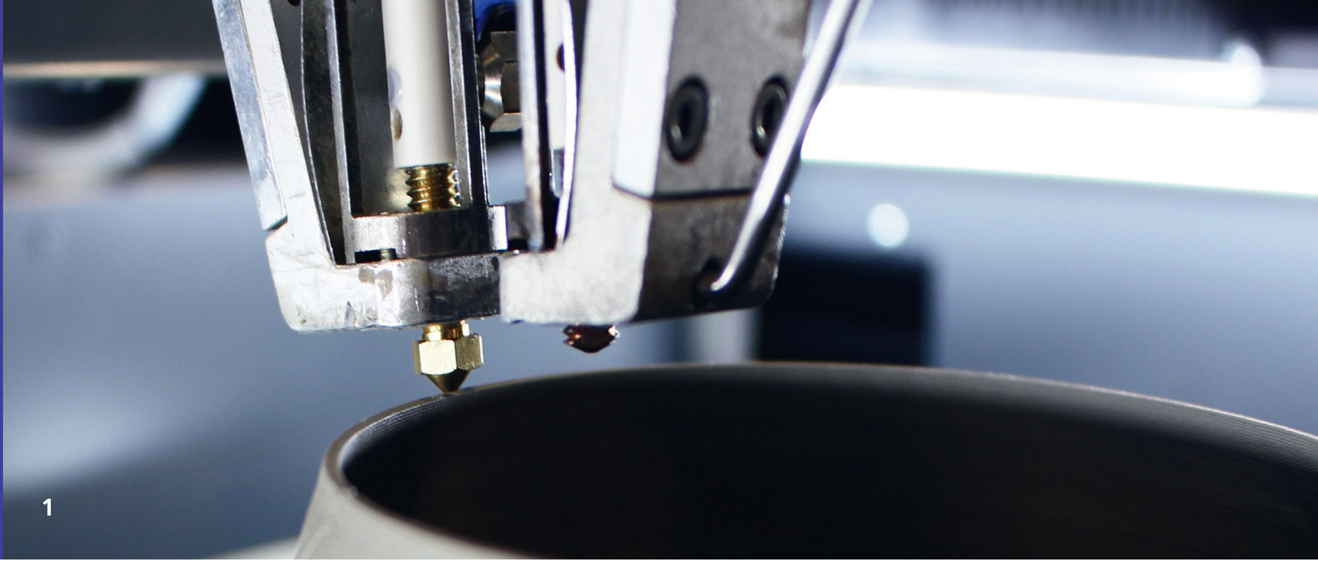
Solidification takes place nearly independently of the physical properties of the powders used. Several supply containers and dispensing units can be used for localized deposition of different materials, including supporting structures, in a part.

T3DP pushes back the technological boundaries of additive manufacturing for ceramics and can hence considerably expand the range of possible applications in various target industries.

Services offered

- Development and characterization of suitable thermoplastic mixtures made of customer-specific powders
- Materials selection for multi-component systems and development of thermoplastic mixtures with adjusted shrinkage properties
- Development of co-sintering routes for multi-component systems
- Parts development based on customer-specific CAD files

Equipment type	In-house construction
Build chamber	100 x 100 x 100 mm³
Layer thickness	approx. 50–100 µm
Lateral resolution	approx. 200 µm
Build speed	approx. 3 cm³/h per dispensing system
Materials	Al_2O_3, ZrO_2, Si_3N_4, WC-Co, and stainless steels



FUSED FILAMENT FABRICATION (FFF)

Like T3DP, fused filament fabrication is based on highly filled thermoplastic mixtures, but the viscosities are much higher. These mixtures are supplied as filaments to the individual print heads, melted, and deposited as strands. The material solidifies on cooling. Through the selective application of materials via the various print heads, diverse material and property gradients can be produced in the part. The relatively low resolutions associated with this method are compensated for by the very large build chamber, high productivity, and range of materials that can be handled. In addition, ceramic fibers can be integrated into the filaments to enable additive manufacturing of CMCs.

Services offered

- Development and characterization of thermoplastic mixtures of customer-specific powders
- Production of filaments from thermoplastic mixtures
- Materials selection for multi-component systems and development of thermoplastic mixtures with adjusted shrinkage properties
- Parts development based on customer-specific CAD files

Equipment type	HAGE 140L
Build chamber	700 x 500 x 400 mm³
Layer thickness	> 250 µm (depending on nozzle and material)
Lateral resolution	> 500 µm
Build speed	>> 5 cm³/h
Materials	Al_2O_3, Si_3N_4, SiC, and fiber-reinforced SiC

LAMINATED OBJECT MANUFACTURING (LOM)

Laminated object manufacturing was originally developed for build-up of electroceramic components (multilayer capacitors and stack actuators) and for production of ceramic multilayer substrates (LTCC, HTCC) in microelectronics. In the context of additive manufacturing, the LOM technology is used for building up three-dimensional microcomponents with integrated functionality. The basis for this is provided by (glass-)ceramic tapes produced by continuous tape casting. Fraunhofer IKTS has various casting machines available for producing these tapes.

Following mechanical or laser-based structuring of the individual layers, the layers are printed with functional pastes or inks (see "Functionalization" section) and laminated together. During subsequent co-firing, i.e., sintering of all materials contained in the multilayer in a single step, the desired component properties are obtained with a concomitant volume shrinkage. Special attention must be paid to compatibility between materials with respect to such aspects as shrinkage, sintering atmosphere, chemical compatibility, and thermal expansion.

Services offered

- Development, preparation, and characterization of application-specific inks, pastes, and tapes
- Component design, development, and characterization
- Electrical packaging technology
- Technology development, optimization, and scale-up

1 *FFF production of ceramic components.*

FUNCTIONALIZATION

While additive methods offer fundamentally new geometry, design, and functionality options due to their working principle, they create even more possibilities in terms of functions and applications when combined with established 2D and 2.5D methods.

Digital printing methods that can be used for high-resolution application of functional structures to freeform surfaces represent the key technologies for functionalization of 3D components. These technologies are well-established for polymer materials, but they are still in the development stage for ceramic functional layers.

Especially promising for use within the framework of additive manufacturing of ceramic parts are adapted inkjet and aerosol jet printing methods, each of which exhibits special features. Whereas functional inks can be deposited over large areas by multiple print heads in a non-contact inkjet printing process, aerosol jet printing is suitable for application of finer structures to three-dimensional objects.

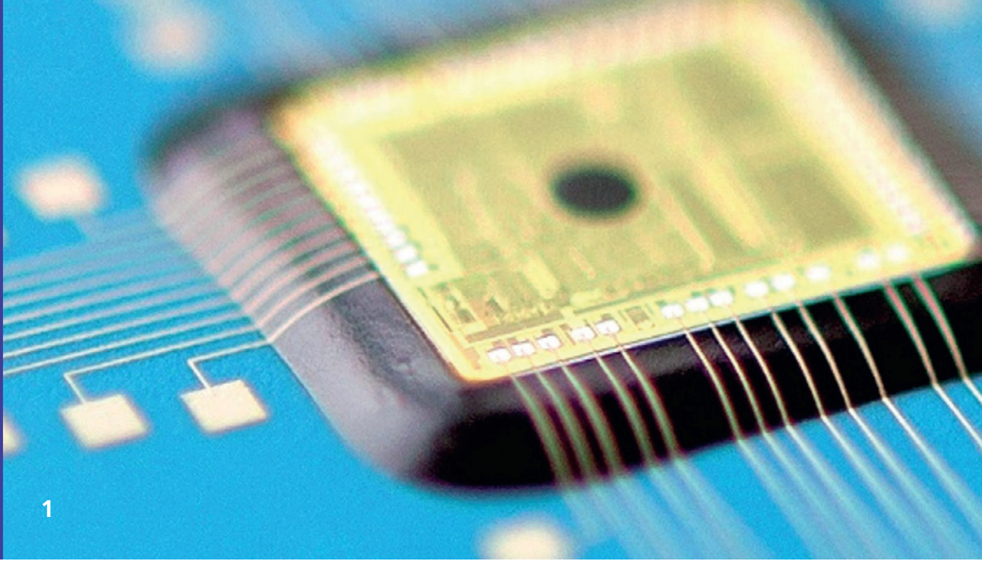
Current research at Fraunhofer IKTS is focused on adaptation of materials and technologies, integration into overall process and equipment concepts, and testing in prototypical applications with project and industry partners.

INKJET AND AEROSOL JET PRINTING

The non-contact method of inkjet printing has long been the state of the art in graphic design applications and polymer-based functional structures. The drop-on-demand (DOD) method used at Fraunhofer IKTS works with high-viscosity inks, which are sprayed onto a planar substrate by means of a print head. Multiple nozzles are used for printing of components with large surface areas.

Fraunhofer IKTS has been developing highly specialized nanoparticle inks for functionalization of ceramic microsystems by inkjet printing for a number of years now. Current efforts are aimed at adaptation of these inks for use with other additive manufacturing methods. Special expertise can be demonstrated in adapted noble metal inks (Ag, Au, Pt, and Pd), metal inks (Cu, Ni, and Si), and carbon inks.

As a direct-writing method for three-dimensional deposition of functional layers (conductive traces, resistors, sensors, etc.) with an extremely high resolution, aerosol jet printing closes the gap between screen printing and lithography. Offering minimum structural widths of less than 10 µm, this method opens up a multitude of new application possibilities, especially in combination with AM components. The inks required for printing are atomized into a fine mist and then introduced into a gas stream. The aerosol is densified and conveyed to the print head. The resultant focused droplet stream has a diameter of less than 10 µm. Due to the high droplet waist length, printing is also possible on 3D substrate topographies.



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Fraunhofer IKTS possesses unique know-how in the preparation and processing of optimized inks, especially for meeting the special requirements of ceramic parts with respect to co-sintering and shrinkage behavior. These inks are composed of organic components (binders, dispersants, and solvents) and solid particles (e.g., metals, glasses, or oxides).

Development is moving towards multi-component suspensions with properties, adhesion, and expansion behavior that, as in the established thick-film pastes, can be adjusted for different substrate materials through the use of special glassy phases, besides single-component inks based on precipitated particles. For ensuring good ink printing properties, the glassy phase grain size is brought down to < 1 µm through high-energy milling. The wetting properties and the rheology of the inks can be adjusted through suitable selection of the liquid phase and dispersants.

Services offered

- Preparation of submicron single- and multi-component printable functional inks
- Characterization of inks (stability and rheology)
- Printing of layer thicknesses between 3–20 µm on 3D objects of 20–50 µm width
- Application-specific solutions for conductive, resistive, heater, and insulator inks
- Adaptation of thermomechanical properties to specifications of various substrate materials
- Technology and component development

Inkjet printing

Equipment type	DoD300 from Schmid Tech. with Dimatix print heads SE, SQ, and DMP class
Build chamber	300 x 300 mm²
Layer thickness	0.1–1 µm/pass
Lateral resolution	50 µm
Build speed	0.1–10 cm/s
Materials	Metals

Aerosol jet printing

Equipment type	Optomec M3D
Build chamber	200 x 200 x 10 mm³
Layer thickness	0.5–5 µm/pass
Lateral resolution	10 µm
Build speed	0.1–10 cm/s
Materials	Metals, glasses, ceramics, and polymers

1 *2.5D contacting via aerosol jet printing.*

SCREEN PRINTING AND JET DISPENSING

Besides digital printing technologies, classic screen printing and jet dispensing technologies can also be used for functionalization of AM parts. Deposition of functional layers by screen printing and stencil printing has long been used in hybrid electronics, production of electroceramic components, and energy technology. Screen printing offers high cost efficiency and performance capabilities. In the last few years, it has become possible to reduce the maximum structural resolution to less than 30 µm and to print layers with locally differing thicknesses via step-up/step-down stencils.

Fraunhofer IKTS is specialized in the development of functional pastes for a wide range of applications and printing technologies. The chemical compositions of the solids and rheological adaptation of the pastes to the desired layer morphology and given printing technology are important factors that are considered.

Fraunhofer IKTS also has digital (i.e., direct-writing) printing technologies, such as microdispensing and jet dispensing, available for paste application. These methods are primarily used for paste deposition on 3D surfaces or non-planar part topographies and hence are highly suitable for AM components.

Services offered

- Development and preparation of customer-specific functional pastes
- Technology and component development according to customer specifications
- Paste characterization (rheology, printing behavior, sintering/shrinkage behavior, layer morphology, and electrical/dielectric properties)
- Reliability analyses (moisture, heat, thermal cycling, power cycling, etc.)

Screen and stencil printing

Equipment type	EKRA E5
Build chamber	350 x 450 x 20 mm³
Layer thickness	0.35–25 µm
Lateral resolution	30 µm
Build speed	3.5 s/print
Materials	Diverse functional pastes

Microdispensing and jet dispensing

Equipment type	ASYMTEK Axiom TMX 1010
Build chamber	500 x 540 x 90 mm³
Layer thickness	5–25 µm
Lateral resolution	50 µm
Build speed	1–1000 mm/s
Materials	Diverse functional pastes

1 *Preparation of pastes as a starting point for suspension-based methods.*

DIODE LASER SINTERING

AM structures require special post-treatment for removal of organic components and/or sintering of metal/ceramic particles. Especially for functionalized surfaces with traces, resistors, or antennas, conventional additive processes are faced with the challenge of developing integrated process steps.

New post-processing approaches incorporating the advantages of 2D functionalization and adapting them to the new application area are needed for efficient processing of multi-material components. The efficiency of this processing contributes decisively to the cost-effectiveness of the overall manufacturing process.

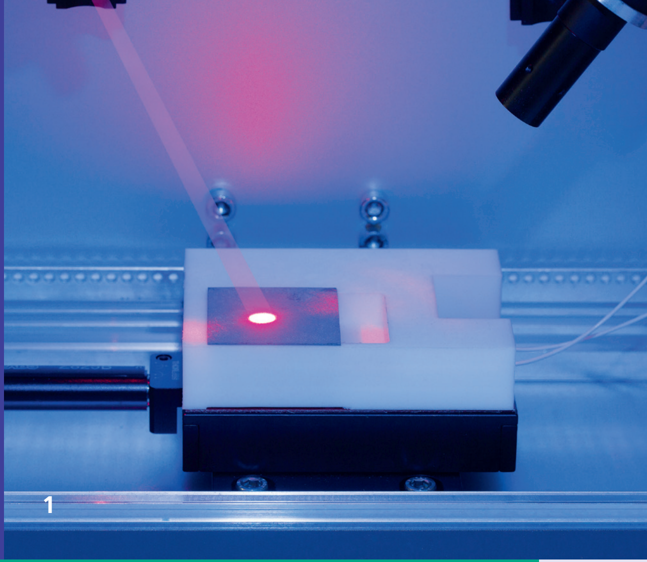
Fraunhofer IKTS employs an innovative method based on a microoptically optimized high-power diode laser line (HPDL). With this technology, extremely fast functionalization of printed materials from metals with high melting points and conductive ceramics is made possible. Thanks to continuous diffusion of heat, processing with an HPDL is about 20 times more efficient than with conventional standard point laser systems. In addition, this method's ultrafast heating/cooling (> 10^6 K/s) enables selective and precise energy transfer as well as processing in air.

Current research efforts are concentrated on investigating the interactions between HPDL parameters, ink and paste properties, and the required structure and functionality. The range of processable materials encompasses nickel and molybdenum on aluminum oxides as well as silver, gold, and copper, which are suitable for polymer, glass, and Al_2O_3 substrates. Recent sintering tests on printed molybdenum layers suggested heating of printed structures at temperatures of > 1600 °C.

Services offered

- Functionalization of printed metal and ceramic structures
- Realization of unique material properties by fast melting/solidification, e.g., by spinodal decomposition
- Feasibility studies and demonstration on the laboratory scale

Equipment type	Diode laser system
Build chamber	250 mm x 300 mm
Max. optical power	900 W, near-infrared diodes
Diode line length	30 mm
Build speed	0.01–60 m/min
Materials	Ag, Au, Cu, Pt on polymer, glass, and Al_2O_3 substrates as well as Ni, Mo on Al_2O_3 substrates



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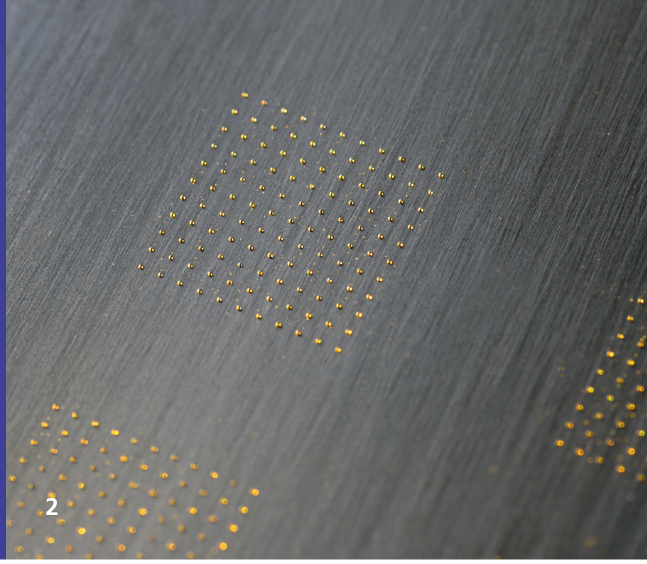

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QUALITY ASSURANCE

Especially in the field of ceramics, for additive manufacturing to become established as a competitive manufacturing method for applications beyond prototyping and small batch manufacturing, a number of issues concerning quality assurance, process duration, and overall economic efficiency must first be addressed.

In-line monitoring of additive manufacturing processing is indispensable for ensuring high-quality, reproducible part results. At present, possible process errors and part defects can usually only be detected indirectly. The existing systems do not deliver concrete material parameters enabling direct evaluation of part quality during production. Potential defects are hence only found at the end of the production process, lowering the efficiency in terms of raw materials usage, cost, and time.

In the future, in-line analysis should enable defects, such as pores or delamination, to be detected right when they arise in the building process and hence eliminated promptly, yielding higher quality or higher output. At Fraunhofer IKTS, existing and new non-destructive test methods are being researched intensely for various materials and AM methods as well as being further developed for use in industry.

LASER SPECKLE PHOTOMETRY (LSP)

The laser speckle photometry method developed at Fraunhofer IKTS offers special potential for in-line quality assurance for various material classes. The method is based on analysis of the changes in speckle patterns over time by means of a specially optimized algorithm.

Speckle patterns are visible when a rough surface is irradiated with a coherent light source. A spatial structure with randomly distributed intensities, which can be read out by means of a CMOS chip, arises. If the examined object is additionally thermally or mechanically excited, a correlation function can be used to determine the interactions between the speckle dynamics and the condition of the surface. Laser speckle photometry is highly sensitive to out-of-plane and in-plane displacements.

A test system based on speckle sensors is hence capable of detecting concrete material parameters (porosity, stress state, and strength) as well as surface defects during the production process in a non-contact manner. Due to the small amount of data yielded, a high measurement speed and hence real-time analysis of the relevant quality criteria in AM parts are possible. Another advantage of laser speckle photometry is its suitability for use on metals, non-metals, and organic materials.

1 *Excitation and analysis of speckle patterns.*
2 *Investigation of gold contacts on a nickel alloy.*

Services offered

- Characterization of parts made by additive manufacturing
- Process optimization
- Development of test systems from the lab scale to in-line process monitoring for recording of material parameters and surface defects

Equipment

- Various laboratory setups with the components laser/optical elements/camera/thermal or mechanical excitation – adaptable to a wide range of applications
- Automated laboratory test station with working area of up to 20 x 20 mm² (extendable)

Lateral resolution	30 µm (metals) – 400 µm (ceramics)
Measurement speed	20 measurements/s 30 images/min
Materials	Metals, ceramics, plastics, and suspensions
Light wavelength	400–900 nm

X-RAY BACKSCATTER TOMOGRAPHY

In the quality control of individual components X-ray methods are very common. However, suitable in-line inspections of e.g. very large or compact components could not be performed up to now due to long testing times. Therefore, Fraunhofer IKTS is developing an alternative X-ray backscatter tomography method which is working at a much higher testing speed.

When X-ray beam impacts material, its intensity decreases as a function of the specific material and of the radiation energy. This process generates the imaging effect in X-ray radiography applications. Additionally, the X-ray beam is scattered. This scattered radiation is mostly non-directional. This leads to the possibility to detect the scattered radiation in the opposite direction of the incident beam as well. Using that so-called backscatter effect it is possible to examine large and compact components only from one side.

X-ray backscatter tomography can be used to generate a three-dimensional high-resolution image of a component during manufacturing – contactless and with a high penetration depth for a wide range of materials. Besides the detection of defects such as cracks and pores in different surface layers, unfavorable variations of microstructure can also be characterized. Therefore, the method shows great potential for additive manufacturing of different kinds of components.

OPTICAL COHERENCE TOMOGRAPHY (OCT)

Optical test methods are rapid, non-contact methods that can be adapted very flexibly to different processes. Optical coherence tomography offers special potential for efficient, low-cost integrated monitoring of additive manufacturing processes. The method is especially qualified for this due to its ability to capture information on part surfaces as well as volume information down to a depth of several hundreds of microns.

In OCT, near-infrared light and a combination of interferometric and spectroscopic processing are used for mapping the spatial distribution of scattering intensities. From the 3D information gained, the geometry as well as the internal structure (defects and inclusions) down to the layer-to-layer interface in parts made by additive manufacturing can be depicted. High measurement speeds allow up to 700 virtual cross-sectional images to be taken per second. The recorded volumes of the test object are imaged with a spatial resolution ranging from 2 µm to 10 µm.

With the help of application-specific image analyses, the image data are classified for extraction of quantitative product and defect characteristics. Important quality criteria include the thickness of the last layers deposited, the adhesion between individual layers, the dimensional stability of the part, and the homogeneity of the material.

The multitude of product characteristics that can be supplied at a high frequency enable detailed process monitoring as well as implementation of feedback loops for process control. Errors arising in the production process can be pinpointed rapidly, allowing the necessary corrective measures to be taken or the production process to be aborted. Optical coherence tomography can also be used for non-contact part inspection following the manufacturing process.

Spatial resolution	2–10 µm
Measurement speed	Up to 700 cross-sectional images per second
Materials	Ceramics, plastics, and suspensions
Light wavelength	NIR (800–1300 nm)

Services offered

- Characterization of parts made by additive manufacturing
- Process optimization
- Development of test systems from lab scale to in-line process monitoring

Equipment

- High-resolution OCT system with resolution of 3.5 µm
- Long-range OCT system with resolution of 10 µm
- Various measuring heads with resolutions of 2 µm to 10 µm and scanning fields with dimensions of 5 x 5 mm² to 35 x 35 mm²
- Automated test stations with working areas of up to 400 x 400 mm²

1 *Demonstration objects made using LCM.*


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POTENTIAL NEW APPLICATIONS

The technologies shown here pave the way for a new generation of tool-free methods for small-batch, cost-efficient manufacturing of complex, multi-functional ceramic components made of different materials. Personalized, demand-based production (production on demand) for diverse industries and application areas is made possible by shorter development and manufacturing times.

Mechanical engineering

Ceramic components are used in mechanical engineering wherever other materials fail. Thanks to new possibilities in terms of design and functional integration and the cost-effectiveness of manufacturing small batches, products, such as optimized nozzles with integrated cooling channels, burners, seals, and thread guides, can be made.

Tool and mold making

Whereas casting molds and cores are already being used in the metal industry, the potential possessed by functionalized tools, such as grippers, is far from being exhausted.

Medical technology

Additive manufacturing is drawing significant attention in medical technology because of its potential for allowing patient-specific adaptation of endoprosthetic implants in the future. It can also enable cost-effective low-volume production of multi-functional, complex surgical instruments, such as grippers, forceps, and endoscopes.

Aerospace

Mirrors, housings, or actuators for high-performance applications in harsh environments – the aerospace industry is one of the largest drivers of innovation in additive technologies.

Jewelry and creative industry

Already today artists have completely new design options available to them through AM methods allowing elaborate casting molds and cores to be made for jewelry components. The possibility of directly manufacturing ceramic jewelry components, personalized watches, and glasses frames also appeals to designers.

Automotive industry

Especially in the premium segment, the aesthetically pleasing aspects of scratchproof ceramics present a unique highlight for controls and other interior components. New levels of design freedom and integration of functional elements are elevating this application area to the realm of discriminating tastes.

Chemicals and pharmaceuticals

Complex reactors and mixers with integrated functionalities are just two examples of the application possibilities in the chemical and pharmaceutical industries.

Consumer goods

Additive manufacturing has already been used with polymer materials to demonstrate the myriad of potential applications in sporting goods, cell phone cases, and numerous other everyday objects. Together with customers, Fraunhofer IKTS is conducting tests on AM ceramic products.

FRAUNHOFER IKTS IN PROFILE

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. Test procedures in the fields of acoustics, electromagnetics, optics, microscopy and laser technology contribute substantially to the quality assurance of products and plants.

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.

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