Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

wbk Institute of Production Science

Manufacturing and Materials Technology

CeraMMAM – Printed Multi-material Ceramics

Additive Manufacturing of Hybrid Parts for Future High-tech Applications

Thanks to their high strength and chemical stability, ceramics are suited for a variety of applications. Additive manufacturing by means of vat photopolymerization can be used to produce complex ceramic parts. Researchers from the wbk Institute of Production Science developed a system to combine different ceramics in printing as the basis of multi-material additive manufacturing. Two ceramic materials are processed and combined in a part by a single printing process only. In this way, various functional, mechanical, electrical, or thermal properties can be merged specifically. With a newly developed slurry, this novel approach to multi-material ceramics can be used to produce customized high-tech components and realize innovative designs and functions on an industrial scale.

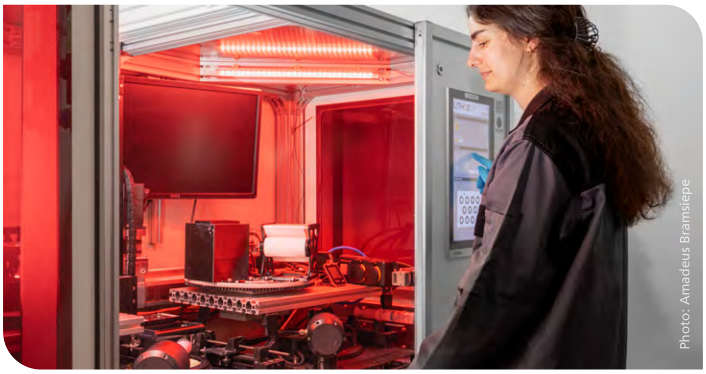
Layer-by-layer Curing in a Liquid Bath

Vat photopolymerization (VPP) is an established process for polymer printing. A liquid, photosensitive polymer resin in a vat is locally exposed to light layer by layer and cured selectively. Specific exposure to light of a defined wavelength results in local polymerization and curing of the material. At wbk, fine ceramic or metal powders are added to the resin to produce a homogeneously mixed fluid or viscous suspension. This so-called slurry additionally contains a binding agent that holds the powder particles together during layer-by-layer buildup. Thanks to the layered structure, the part produced is accurate in every detail and has a smooth surface. After printing, the binder is removed by a thermal follow-up treatment, as a result of which final material properties can be adjusted specifically.

Extended Platform for Multi-material Ceramics

The KIT-developed material system for multi-material additive manufacturing (MMAM) allows to combine two ceramic materials in a single part printing process. Researchers use viscous slurries that contain a binding agent, ceramic microparticles, and a photoinitiator. The additive workflow includes process preparation, coating of ceramic layers and their exposure to light, change of the material during printing, if necessary, layer-by-layer buildup, cleaning, debindering, and final sintering. It is particularly suited for the production of small and highly precise multi-layered ceramic parts. Tailor-made printing materials are used. Both printing and subsequent thermal process steps can be adapted specifically.

Mixing of the material-specific slurries under inert atmosphere in a glovebox.



Lithoz 2M30 multi-material printer.

Materials and Mixes

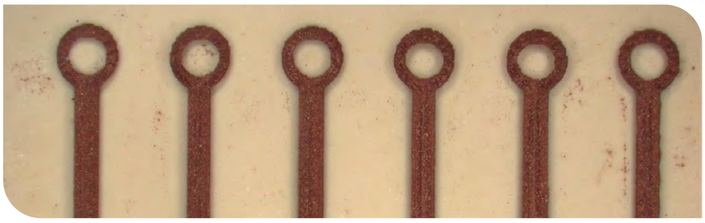
Researchers so far have been working with ceramic-ceramic combinations made of aluminum and zirconium oxide and their mixes alumina-toughened zirconia (ATZ) and zirconia-toughened alumina (ZTA). These material systems are highly compatible as their behavior in the following thermal treatment is about the same. Moreover, porous and compact structures can be combined in order to control heat and mass transfer. Researchers have developed comprehensive know-how in the development of additive multi-material manufacturing. Work has resulted in a universal binding system that makes various inorganic materials compatible and enables controlled thermal follow-up treatment. It is key to identify suitable parameters for each material composition and to map them with a least-possible adaptation effort to other material systems. First tests with copper particles have demonstrated the high potential of ceramic-metal hybrid parts.

Promising Applications

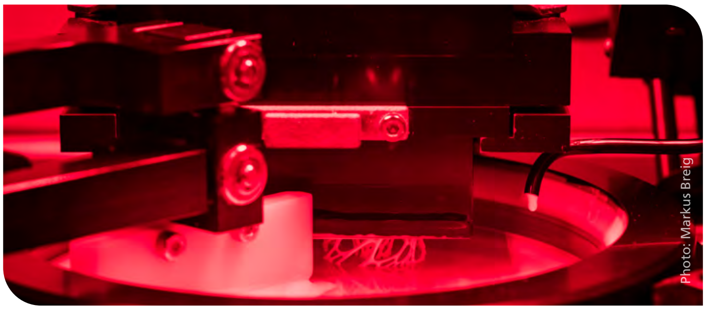
The combination of various ceramic properties in a part opens up new design and functional options. It is possible, for example, to produce components with specifically adjusted curing and porosity zones. This results in a variety of applications: Wear-resistant components in mechanical engineering, patient-specific bone and tooth implants in medical engineering; heat-resistant, lightweight, and high-strength structures for aerospace technology; chemically inert ceramics of high temperature resistance for use in energy technologies; multi-material ceramics for electronics and sensors.

Precision Manufacturing of Prototypes and Small Series

Multi-material printing can be used to produce customized high-tech parts with specifically combined mechanical, electrical, and thermal properties. The platform allows to manufacture components of up to 40 x 70 mm in dimension on the xy plane and 170 mm in z direction. It is particularly suited for the production of small,


Printed multi-material part with conductor structures made of ceramics and copper.

highly precise components. Thanks to a lateral pixel resolution of 40 x 40 µm, parts have high dimensional accuracy and are accurate in every detail. No additional mechanical finishing steps, such as milling or turning, are required after sintering. As several parts can be processed in parallel during both printing and thermal treatment, the process is of high potential for the economically efficient production of prototypes and small series.



In the slurry-filled vat, a component is cured layer by layer.

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