Recent developments in the field of AM of ceramic multi-material components open the door to highly functionalized components

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AMAREA

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Additive Manufacturing (AM) enables the geometric functionalization of components

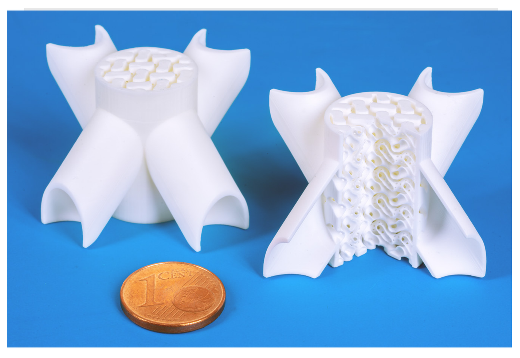
Ceramics are used where other materials fail. High-performance ceramics are recognized as key enabling materials, possessing combinations of properties not achievable in other material classes (e.g. very high thermal, chemical & mechanical resistance, mostly lower density than metals). However, it is precisely this combination of properties that makes it difficult to machine the materials, which is the requirement for ceramic components to be functionalized and miniaturized, as is usual with other classes of materials, in order to find a wide range of applications..

CerAMfacturing = Additive Manufacturing of Ceramics

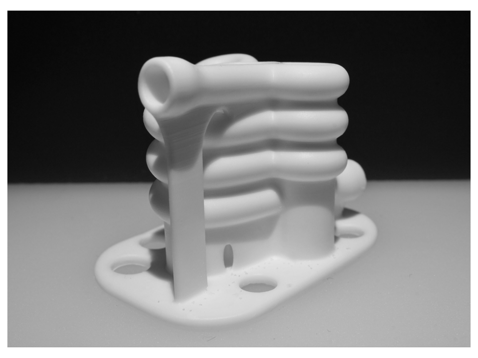
The advent of additive manufacturing (AM) of ceramics has enabled unprecedented geometrical complexity of products: a "game changing" manufacturing technology in the processing of ceramics. As a result, complex ceramic components can be realized cost-effectively, with minimal or no need for post-processing. Additively manufactured ceramics are now for the first time genuine alternatives to polymer and metal components, especially for applications in harsh conditions.

Further functionalization by CerAMfacturing of multi-material components

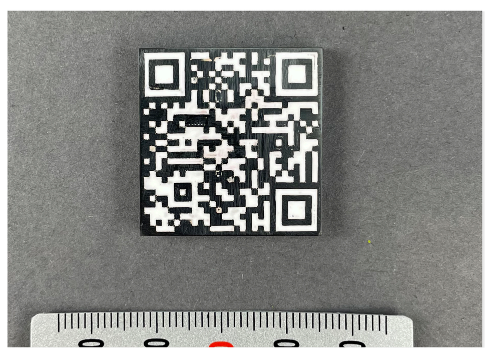
The integration of further functionalities is possible through the combination of different materials in one component to realize combinations of properties such as electrically and thermally conductive and insulating, hard and ductile, dense and porous, magnetic and non-magnetic or multicolor. The crucial challenge lies in the necessary co-sintering of the materials.



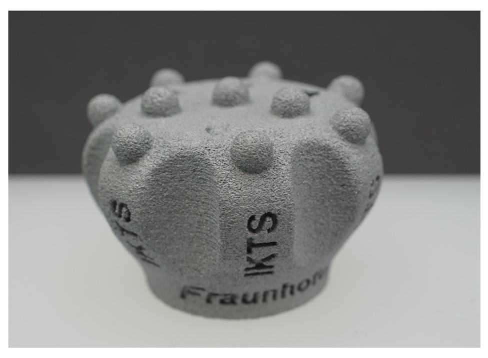
Static mixer with integrated thermal control, CerAM VPP, alumina.



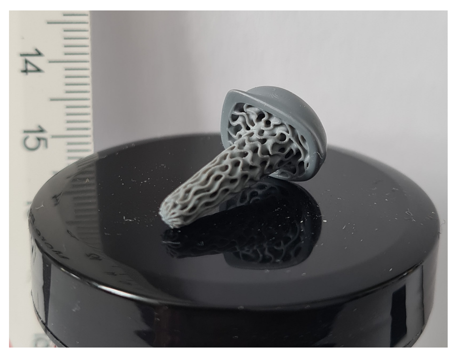
Tesla valve, CerAM VPP, alumina.



QR code, CerAM MMJ, zirconia black and white.



Hardmetal tool, CerAM BJT, WC-Co.



Finger implant, CerAM VPP, Si_3N_4.

Ceramic heating element, CerAM FFF, Si_3N_4-$MoSi_2$.

Three essential points for component properties:

- the material(s) used (in the case of composites),
- the geometry, and
- the surface finish.

Digital Process Chain tackling existing challenges:

- increased demands on design & simulation,
- monitoring of the manufacturing processes,
- consideration of the (ceramic) process chain as a whole.

CerAMfacturing of multi-material components

- parallel processing of different materials in one component
- co-sintering as the main challenge

Outstanding properties (combinations)

High-performance ceramics
- outstanding thermal, chemical, and mechanical properties, relatively low density compared to metals

Additive Manufacturing
- extremely high degree of geometric freedom allows intensive geometric functionalization

Multi-Material components
- further functionalization through the integration of additional materials with other properties
- integration of sensor and actuator technology
- miniaturization

Functional AND production-optimized design

Ceramic process chain - long and highly complex
- AM only used for shaping of green bodies
- debinding and (co-) sintering essential (high shrinkage)

Designing – not only for functionality or manufacturing
- algorithmic design to generate a variety of potential geometries
- consideration of the limitations of AM technologies and subsequent process steps

Data
- capturing and linking of all process and component data to optimize functionality and manufacturing

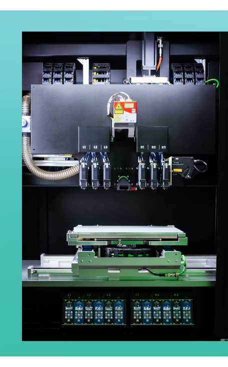
Multi-Material Jetting (CerAM MMJ)

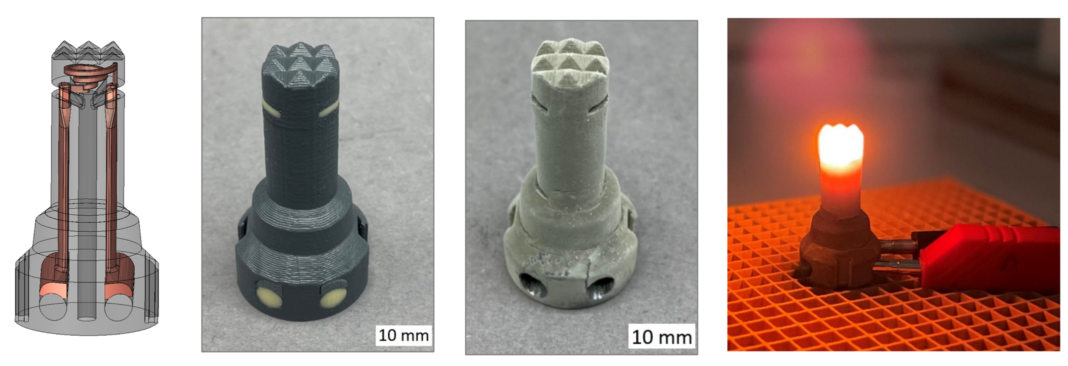
Predestined for AM of multi-material components
- selective deposition of highly particle-filled thermoplastic materials as single droplets
- ➢ consolidation by cooling
- ➢ wide material portfolio
- ➢ no cleaning step between material changes necessary

MMJ ProX-series of AMAREA (Fraunhofer IKTS spin-off)
- up to six print heads
- big building platform: (530 x 300 x 200) mm³
- in-line monitoring via profile sensor
- Laser for subtractive green processing during component manufacturing

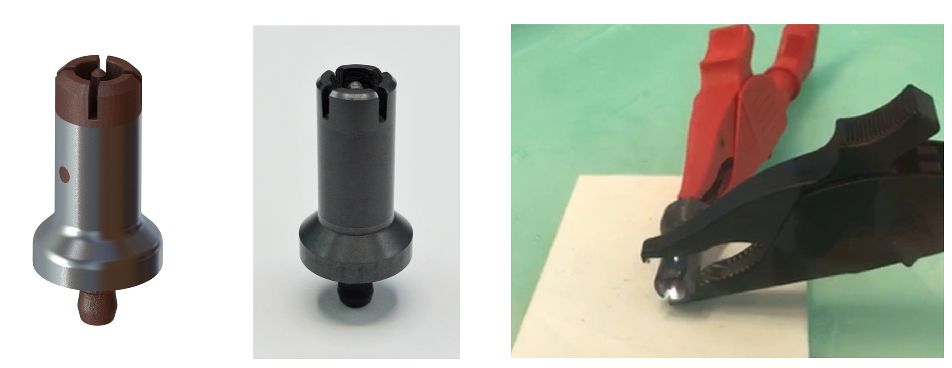
Highly functionalized (ceramic) components for manifold applications combining:

- different properties in a component due to the implementation of multi-material components with
- outstanding thermal, chemical, and mechanical properties of high-performance ceramic materials, and
- geometric functionalization due to the high degree of geometric freedom offered by AM technologies.

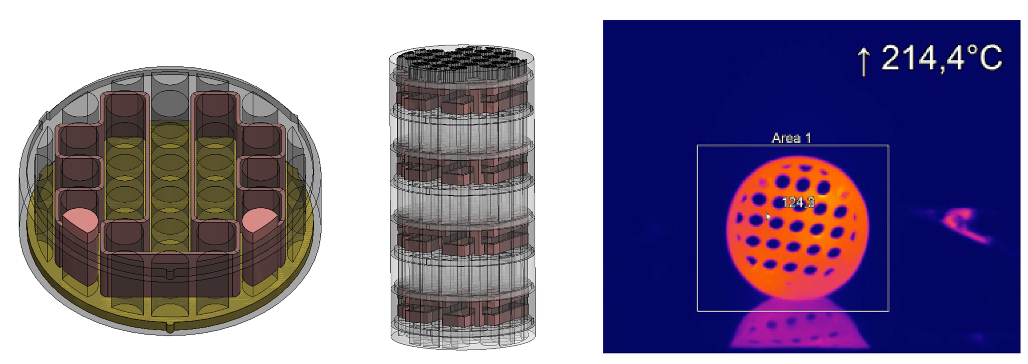




Ceramic forming tool with integrated heater, CerAM MMJ of electrically conductive and insulating Si_3N_4-$MoSi_2$.



Ceramic igniter for space applications, CerAM MMJ of electrically conductive and insulating Si_3N_4-$MoSi_2$.



Modular ceramic reactor concept of company 3D-cat with integrated heater, CerAM MMJ of electrically conductive and insulating Si_3N_4-$MoSi_2$.

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