3D-printing of ceramics by micro extrusion of thermoplastic composite granulates

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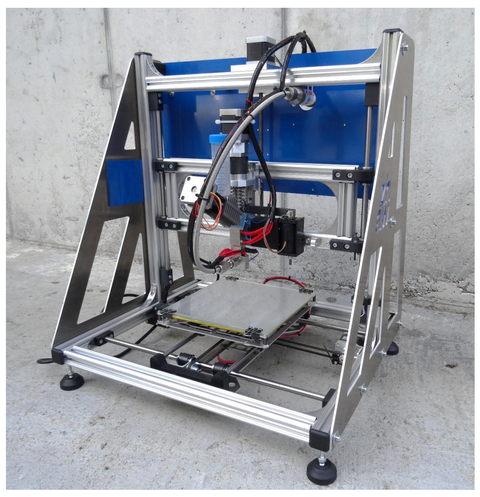
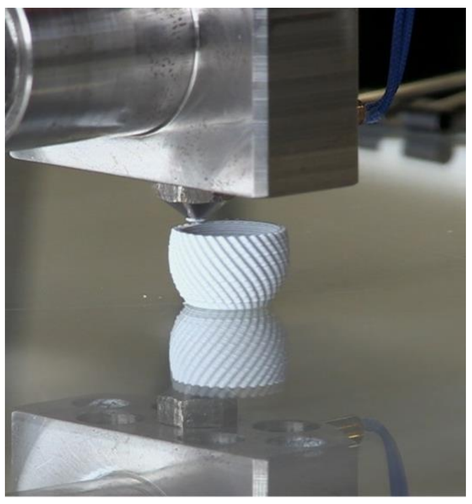
Fused filament fabrication (FFF) today is one of the most used standard technology of polymer printing. Many devices on all levels of professionality are available and an open community is sharing experience, hardware, electronics and software via the web. Nevertheless, for new materials and especially for ceramics, development and production of filaments is necessary. This reduces the degree of freedom due to requirements of filament properties. For ceramics, feasibility of FFF is demonstrated, but commercial filaments just start to be available for only few materials. A novel, self-constructed 3D printer device based on micro extrusion of composite granulates is presented here. The printing still follows the basic principle of controlled deposition of a filament of molten material. Here, however, a granulate feed containing a surface modified ceramic powder dispersed in a thermoplastic polymer (Al_2O_3/EVA in this study) is used instead of a prefabricated filament. The breaking strength of bars produced in that way shows a dependence on the direction of the infill. A maximum Weibull modulus of 7.1 was reached with an infill in x direction and a breaking in y direction. The breaking strength reached 238 N/mm². Further materials like zirconia (ZrO_2) or hardmetal (WC/Co) have successfully been printed and will be further tested.

3D-Printer

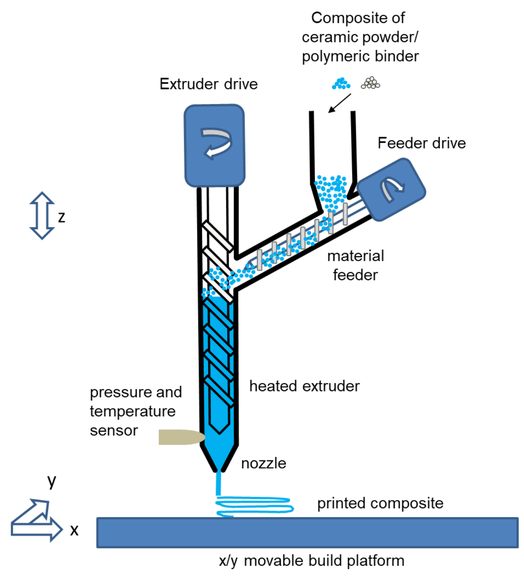


Microextrusion

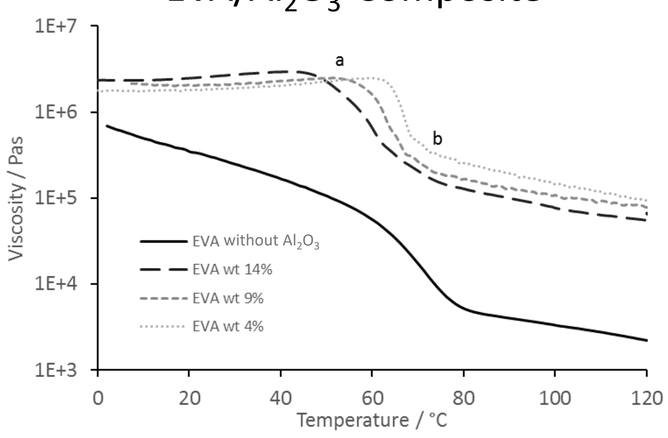


Debinding, Sintering

Scheme of operation principle

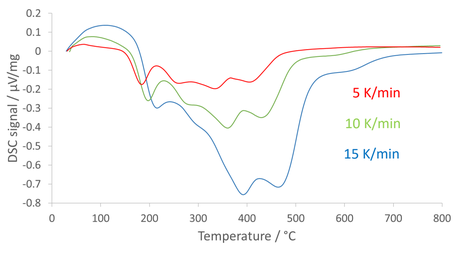


Melt Viscosity EVA/Al_2O_3-Composite

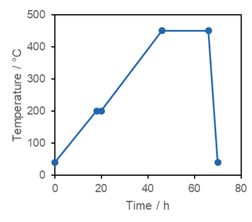


Viscosity as function of temperature for EVA/Al_2O_3-Composites, a-b: softening range, T > b process range

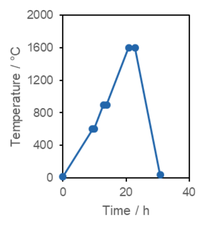
Solvent + thermal debinding, firing



DTA/TGA of EVA/Al_2O_3 composite with different heating rates as basis for a kinetic debinding and sintering model.

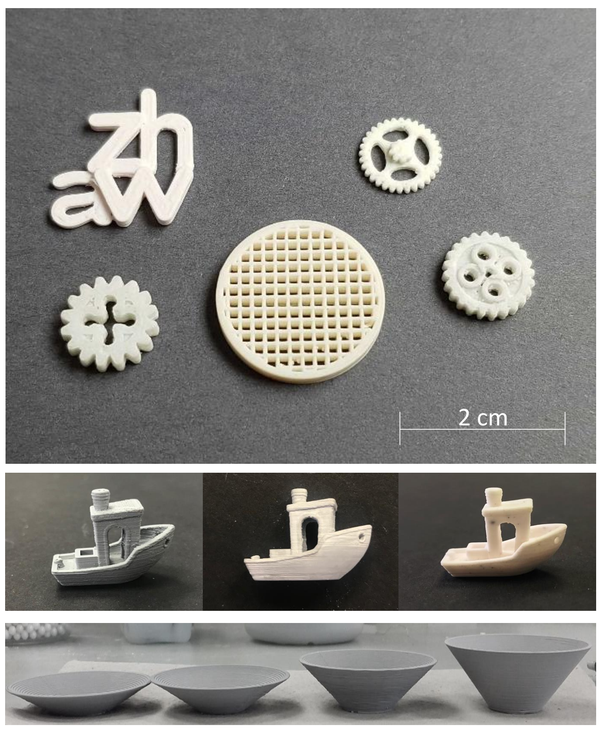


Debinding programm 70 h

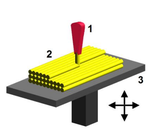


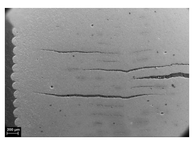
Firing programm 31 h

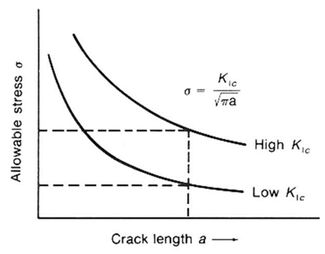
Examples of printed parts



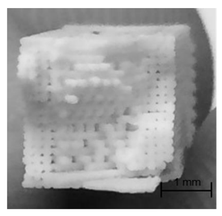
Strength of ceramics produced by FFF



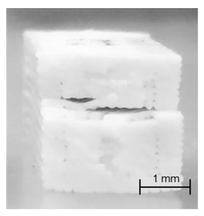




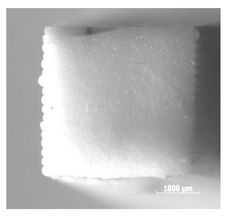
Size of defects, voids and surface structure matters !!!



Voids



Cracks, Delamination

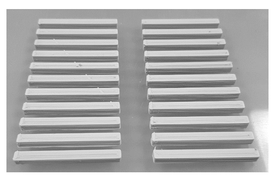


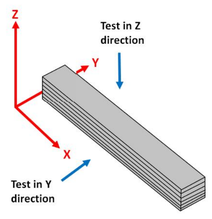
Dense

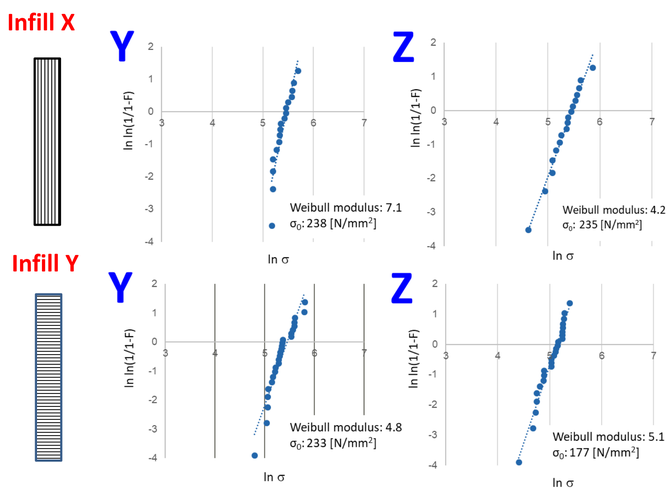
3D printed ceramics for engineering applications have to be as dense and flawless as possible, otherwise they will find no acceptance.

Printing parameters, surface finish, debinding and firing have to be adjusted carefully.

Investigation of strength in relation to print orientation







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