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Glass-3D-Printing via Fused Filament Fabrication; Investigation of the Complete Process Chain for a Commercial Glass Powder

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OBJECTIVES

Using Fused Filament Fabrication (FFF) as a technology of additive manufacturing for the fabrication of glass components is a highly attractive approach with the potential to cut costs and energy. In addition, complex geometries can be manufactured. FFF is well known for processing thermoplastic polymers and is also quite good for printing highly filled binder systems with metal and ceramic powder. There is still a lack of knowledge of glass, particularly regarding the replication and sintering behavior.

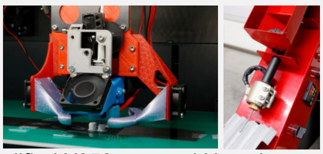
METHODS

FEEDSTOCK DEVELOPMENT

Mixing of the glass powder and the binder system consisting of polyethylene glycol, polyvinyl butyral and stearic acid (PEG/PVB/SA). Continuous measurement of the torque during the mixing process and subsequent determination of the viscosity over a wide shear rate range.

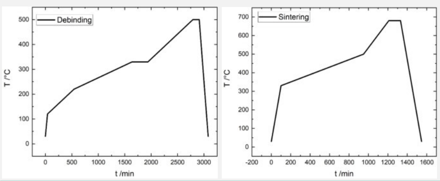
GLASS 3D-Printing, FFF

The feedstock filaments are produced with an extruder (Notzek, GB). All samples are printed with a modified Fused Filament Fabrication printer (X350 pro, German Reprap, Germany).



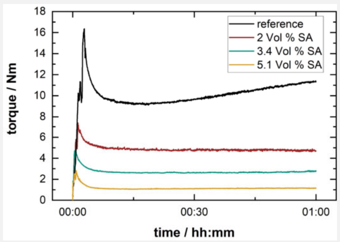
Modified X350 pro, and Notzek extruder

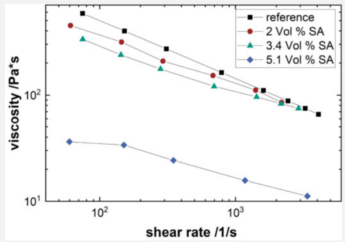
THERMAL DEBINDING / SINTERING



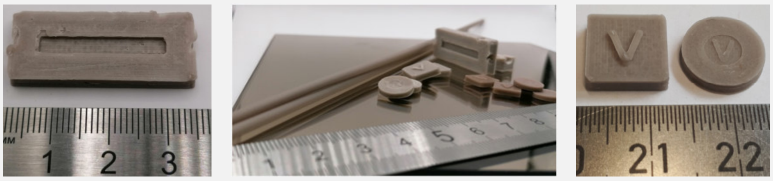
The soluble pre-debindered samples were thermally debindered at 500 °C and subsequently sintered at 680 °C. Sintering was carried out under air conditions.

RESULTS

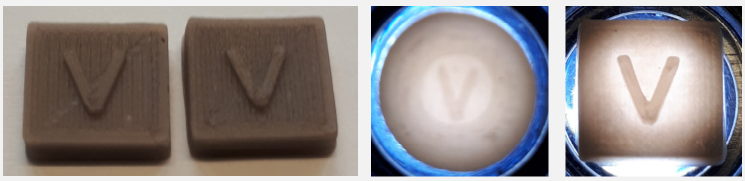




The main focus in feedstock development is on low feedstock viscosity combined with high green strength for a robust printing process. This is achieved with a feedstock of at least 55 Vol% glass powder, 22.5 Vol% PEG, 22.5 Vol% PVB and different amounts of SA. The amount of SA was subtracted from the amount of PVB. In addition, the feedstock can be used for small, precise components (< 1 cm) and large components (> 3 cm).



Filaments made of the binder system conclude PEG/PVB/SA were printable by the FFF. Due to the low viscosity of the feedstock with 5 Vol% SA, the shape accuracy is lower than for the feedstocks with 2 and 3.4 Vol%. Thus, the differences between the green body and 3D model are between 1-3 % for the feedstocks with lower SA content and 2-5 % for the 5 Vol% SA feedstock.



Test structures made with the 55 Vol% feedstock consisting of PEG/PVB/SA have a good accuracy after the sintering and a sinter density close to 100 %. The samples are translucent. Due to the contamination of the glass by Mn, Fe etc. the component appears brown.

CONCLUSION

3D printing was used to produce variously sized and challenging geometries for a commercial glass powder. For this purpose, the glass powder was embedded in a PEG/PVB/SA binder system. The components were then processed into the final product without distortion or defects by optimized debinding and sintering processes.

ACKNOWLEDGEMENTS

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