Polymer-Ceramic-Composites for 3D-Printing

D. Graf[1], U. Gleißner[1], C. Megnin[1], T. Eiselt[1], M. Mauck[1] and T. Hanemann[1,2]

[1] Laboratory for Materials Processing, Department of Microsystems Engineering - IMTEK, University of Freiburg, Germany
[2] Institute for Applied Materials- Material Science and Engineering, Karlsruhe Institute of Technology, Germany

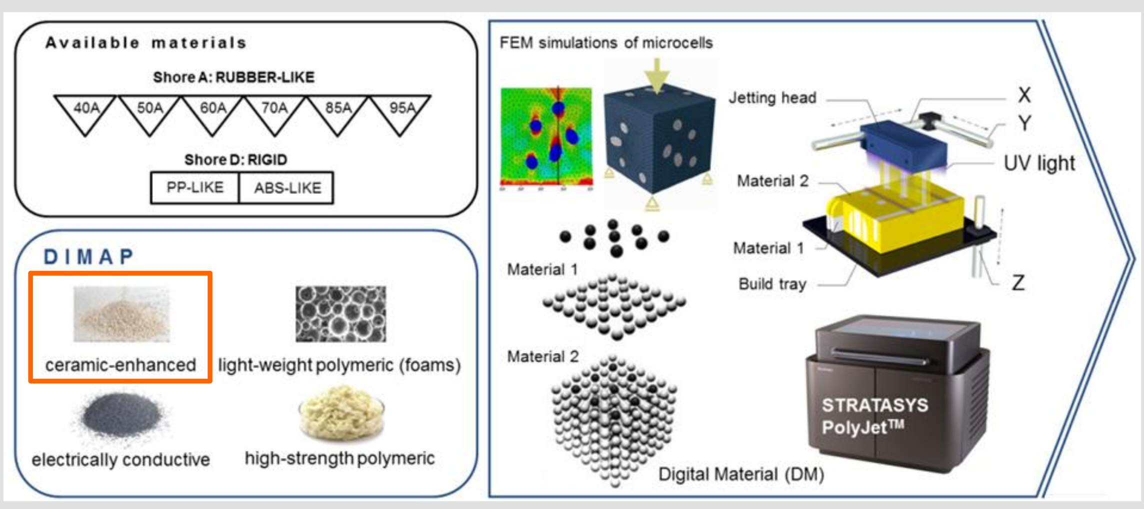
Summary

The aim of this project is the development of low viscous acrylate inks with a high ceramic content for 3d inkjet printing of robotic joints with adaptable mechanical properties. Ethylene glycol dimethacrylate (EGDMA) was chosen as matrix material and Al_2O_3 and ZrO_2 nanoparticles as fillers. For agglomeration prevention the surfactant 2-[2-(2-Methoxyethoxy)ethoxy]acetic acid (TODS) was used. The ink preparation was done via planetary ball milling. For first mechanical determination ISO 527-Typ 1A and 5A specimens were manufactured. Furthermore, printing trials have been conducted.

Motivation

Development of ceramic inks with adjustable mechanical properties for the usage in the Polyjet 3D printing system as part of the project Digital Materials for 3D Printing (DIMAP)

- Increasing Young's modulus in comparison to polymers
- Increasing tensile strength in comparison to polymers
- Integration in a multimaterial printing system



STRATASYS PolyJet™:

Freedom of form and composition

Figure 1: Overall approach of DIMAP: Development of novel multi-material systems for PoylJet inks that are not available currently.

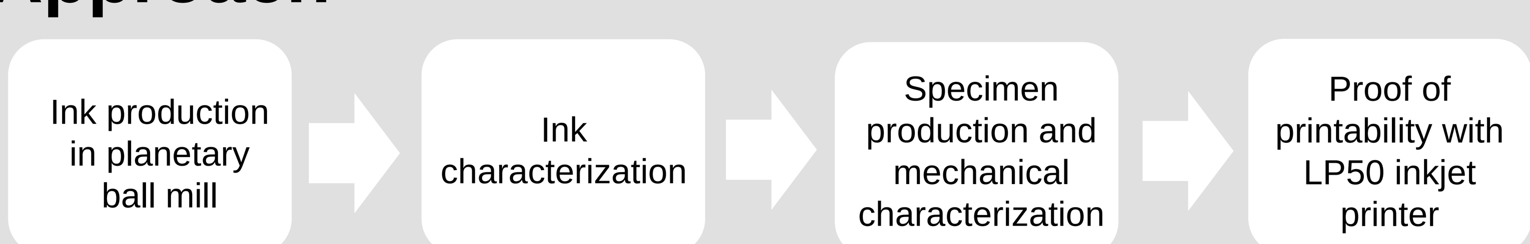
Materials

- Ceramic fillers: Al_2O_3 and ZrO_2 nanoparticles
- Polymer matrix: EGDMA
- Molecule for filler stabilization: TODS

Goals

- UV curable ceramic inks
- Ink viscosity <20 mPa·s at 60°C
- High ceramic content → Young's modulus of printed parts >4000 MPa
- High ceramic content → Tensile strength of printed parts >80 MPa
- Filler size (d_{100}) in suspension <5 µm (nozzle clogging prevention)

Approach



First Results – Particles and Inks

Table 1: Specifications: Ceramic inks prepared via planetary ball milling

	Matrix material	Filler material	Filler particle average size	Filler content	Stabilizer	Stability in monomer	Filterability (5µm)	Printing tests
Units	-	-	[nm]	[Vol%]	-	[h]	-	-
Ink 1-PM	EGDMA	Al_2O_3 (TEC)	13	3.2	TODS	>>2	Yes	Conducted
Ink 2-PM	EGDMA	ZrO_2 (TEC)	15	3.2	TODS	>>2	Yes	Conducted
Ink 3-PM	EGDMA	Al_2O_3 (TEC)	35	9.1	TODS	>>2	Yes	Conducted

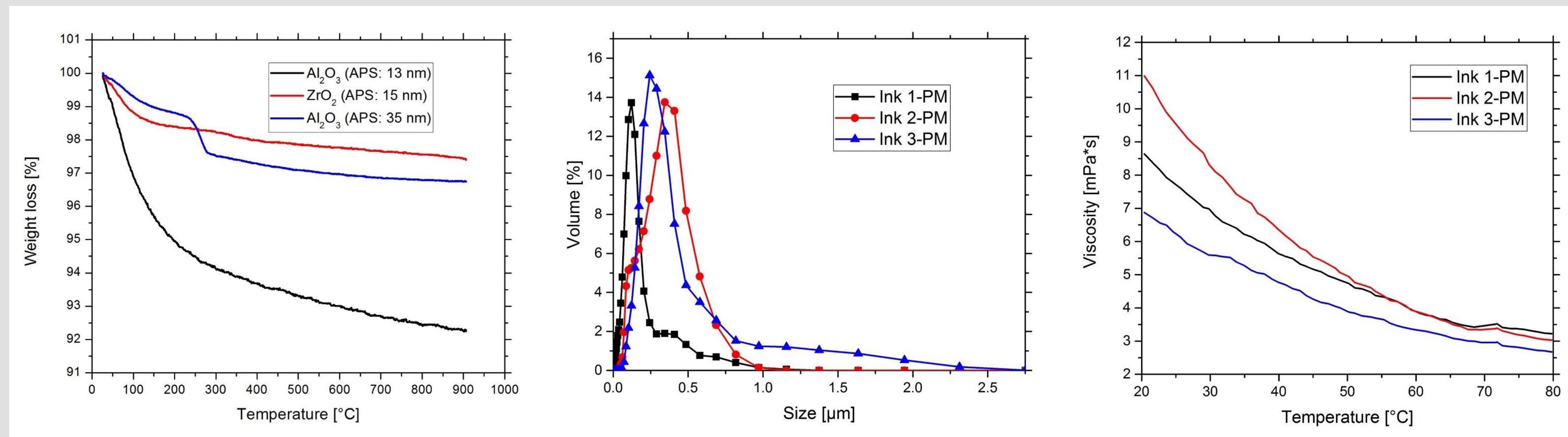


Figure 3: a) Thermogravimetric analysis of ceramic nanoparticles, b) Dynamic light scattering measurement and c) viscosity measurement of ceramic inks.

Specimens for tensile testing

ISO 527-Typ 1A

Challenges:

- Cracks during thermal curing
- Brittleness
- Specimen-mold interaction

Solution approach:

- Curing in layers
- Plasticizer: Butyl acrylate
- Polydimethylsiloxane (PTFE) mold

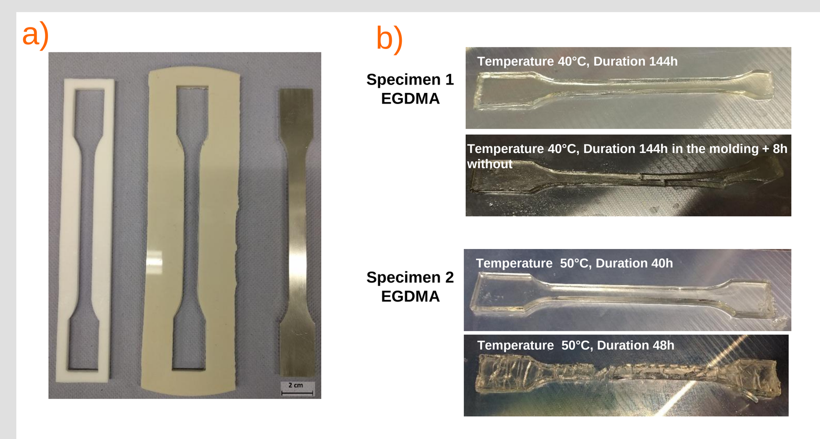


Figure 5: a) PTFE mold, PDMS mold and master structure for UV curing, b) cracks in cured specimen.

Proof of ink printability

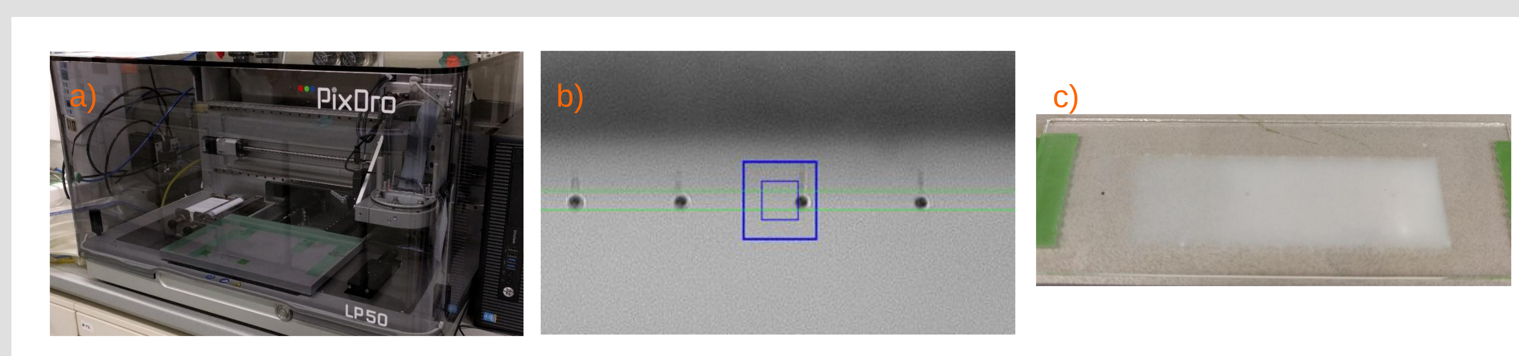


Figure 6: a) Pixdro LP50 inkjet printer, b) dropview of ceramic ink, c) five printed layers of Ink 1-PM.

Conclusions

Three ceramic inks were formulated and examined. Ink 3-PM with Al_2O_3 nanoparticles (APS: 35 nm) showed the best result. For mechanical tests, specimens were manufactured whereby cracks during thermal curing occurred. Curing in layers, as well as the usage of butyl acrylate and a PTFE mold can be a solution approach. Upon successful specimen fabrication their mechanical properties will be assessed and the ink suitability will be evaluated. Printing tests have shown the printability of the three inks.

Acknowledgements

The authors acknowledge the support from the European Commission in form of the DIMAP project.

DIMAP DIGITAL MATERIALS FOR 3D PRINTING · KIT Karlsruhe Institute of Technology · VIM · UNI FREIBURG