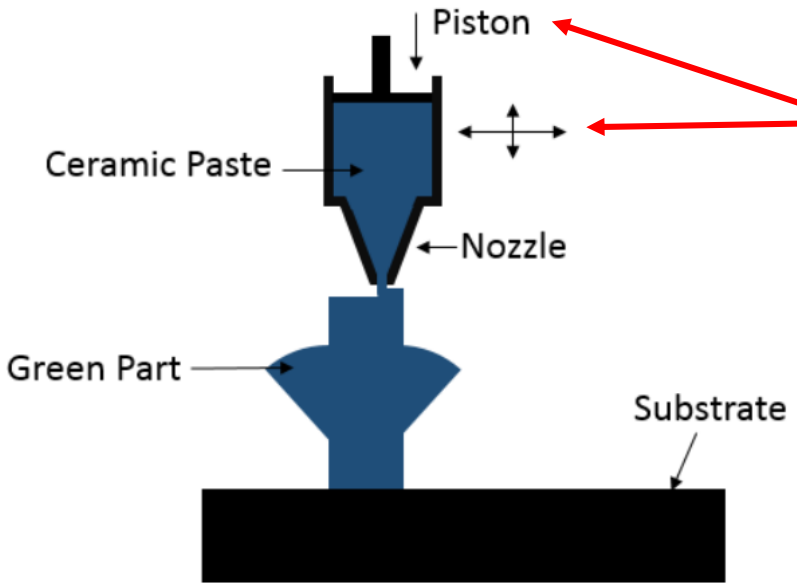
Challenges in the optimization of 3D printing and robocasting processes using zirconia based pastes

2018 NanoMatLab/Biomat Meeting

Robocasting - Introduction

- Layer-by-layer deposition of ceramic slurries (paste) through a nozzle (extrusion).



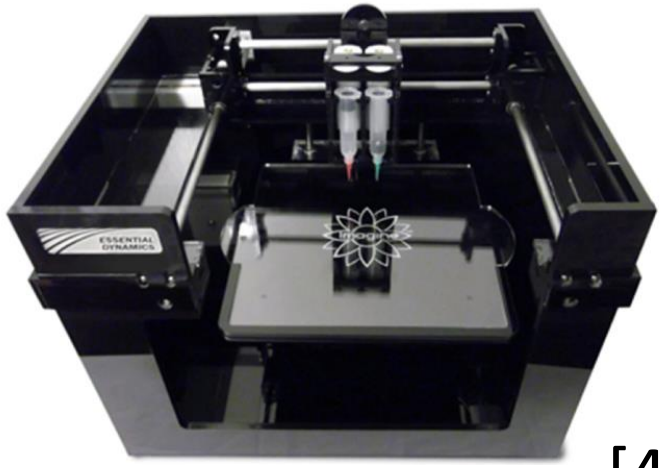
Picture source: [1]

- Computer numerical control over nozzle position coordinates and piston movement.

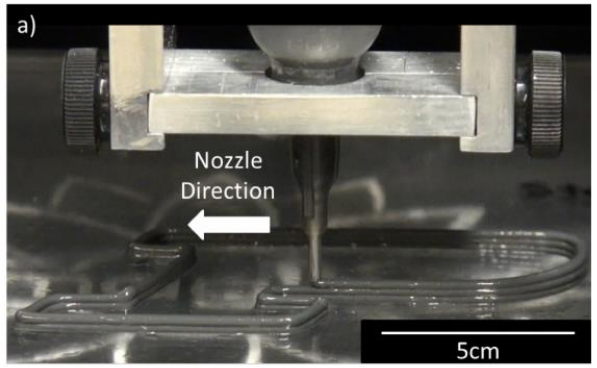
- Nozzle diameter ranging from 0.03mm to 2mm.

[1], [2], [3]

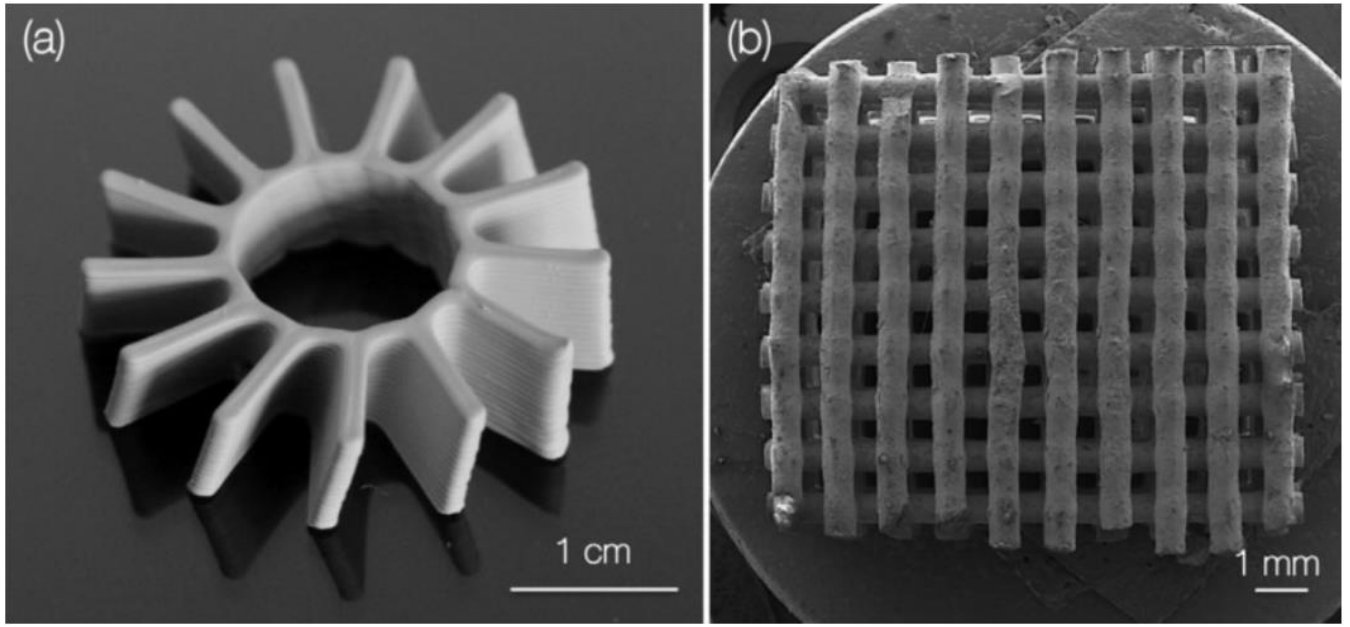
Robocasting – Products



[4]

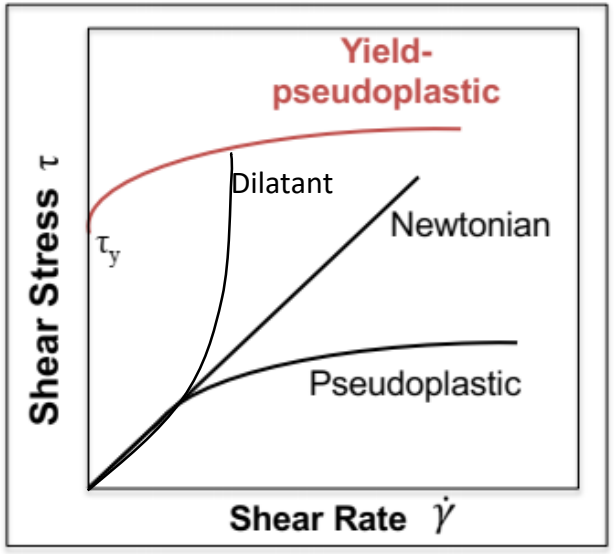


[1]

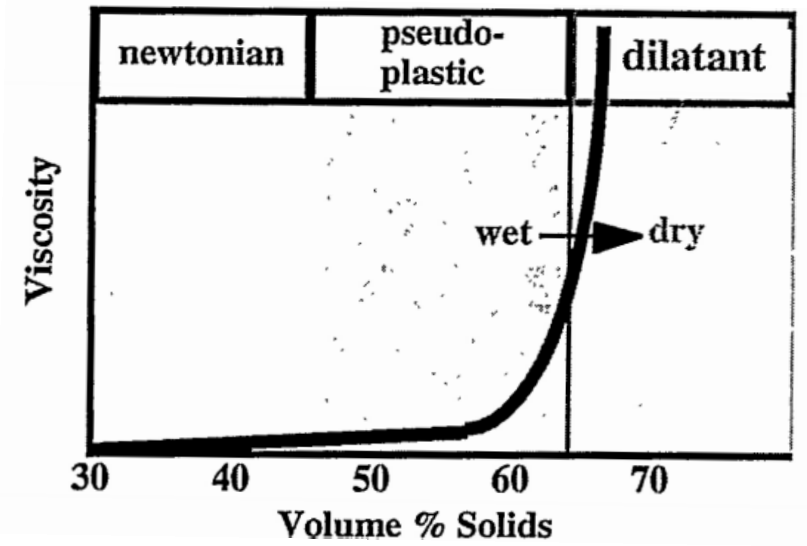


Robocasting - Slurries

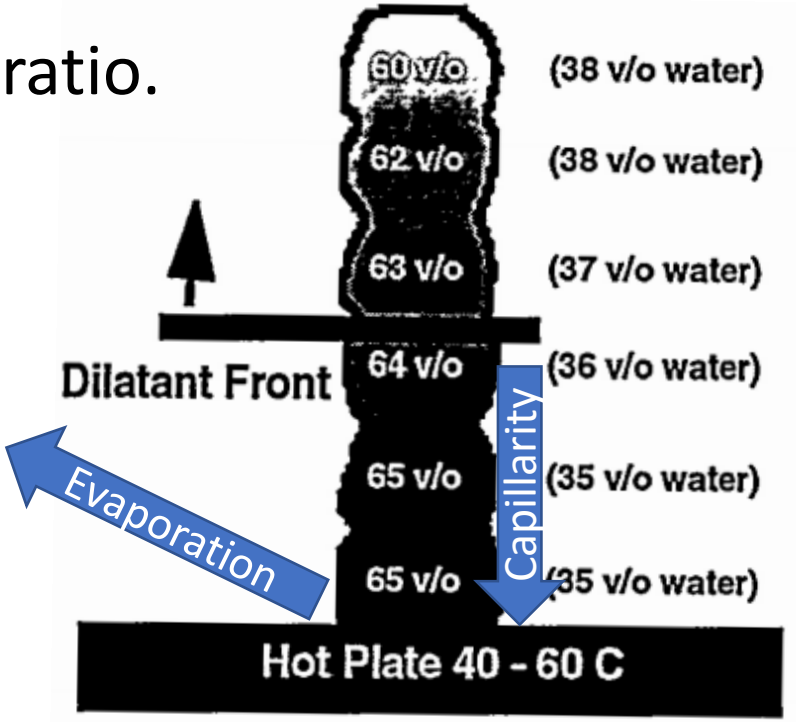
- Slurries must be pseudoplastic to flow through the nozzle.
- Slurry compositions are kept close to the dilatant ratio.



Adapted from [4]



[2]



Adapted from [2]

- Dilatant mass maintains structural integrity after minimal drying time.
- Heated bed speeds up the pseudoplastic to dilatant transition.

[2], [4]

Robocasting - Slurries

- Slurries of high solid fraction, usually 50-65 vol.% ceramic powder.
- 35-50 vol.% volatile solvent (usually water).
- Higher ceramic loadings decrease sintering shrinkage and cracking.
- Highly loaded slurries are prone to agglomeration, that can cause nozzle clogging during extrusion.

- Tested slurries:

Slurry designation	Zirconia powder loading	Powder/dispersant weight ratio
X	High	High
Y	Medium	Low
Z	Low	Low

[2], [3]

3D Printer

Commercial open source 3D printer “*Lulzbot MINI*”

Syringe (extruder) + Hypodermic needle (nozzle)

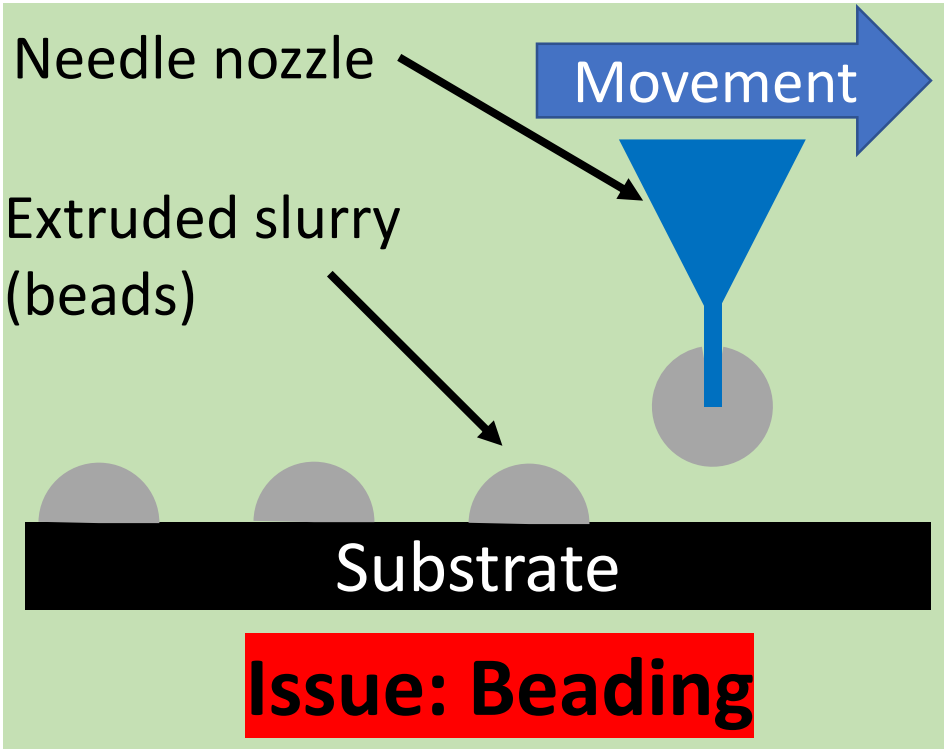
Printing parameters

Infill	
Infill Density	100 %
Infill Line Distance	0.25 mm
Infill Pattern	Lines
Infill Line Directions	[ ]

Speed	
Print Speed	10 mm/s
Infill Speed	10 mm/s
Wall Speed	5.0 mm/s
Outer Wall Speed	5 mm/s
Inner Wall Speed	5 mm/s
Top/Bottom Speed	5.0 mm/s
Travel Speed	15 mm/s

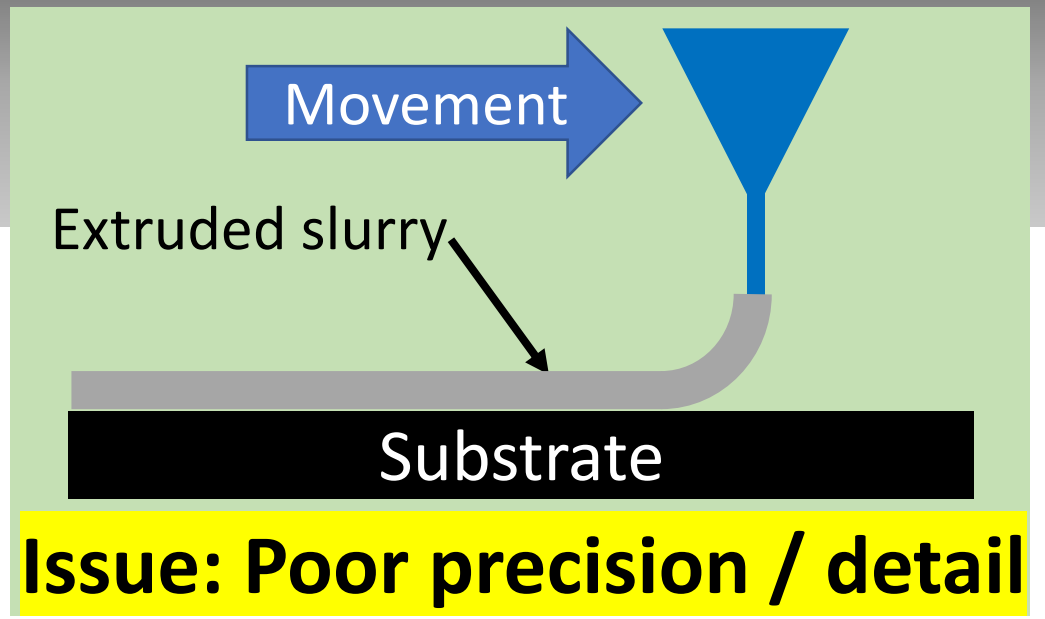
Build Plate Temperature	35 °C
Part Removal Temperature	35 °C
Keep Heating	✓
Build Plate Temperature Initial Layer	35 °C
Diameter	2.85 mm
Flow	115 %
Initial Layer Flow Rate	100 %
Enable Retraction	✓
Retract at Layer Change	
Retraction Distance	1.5 mm
Retraction Speed	10 mm/s

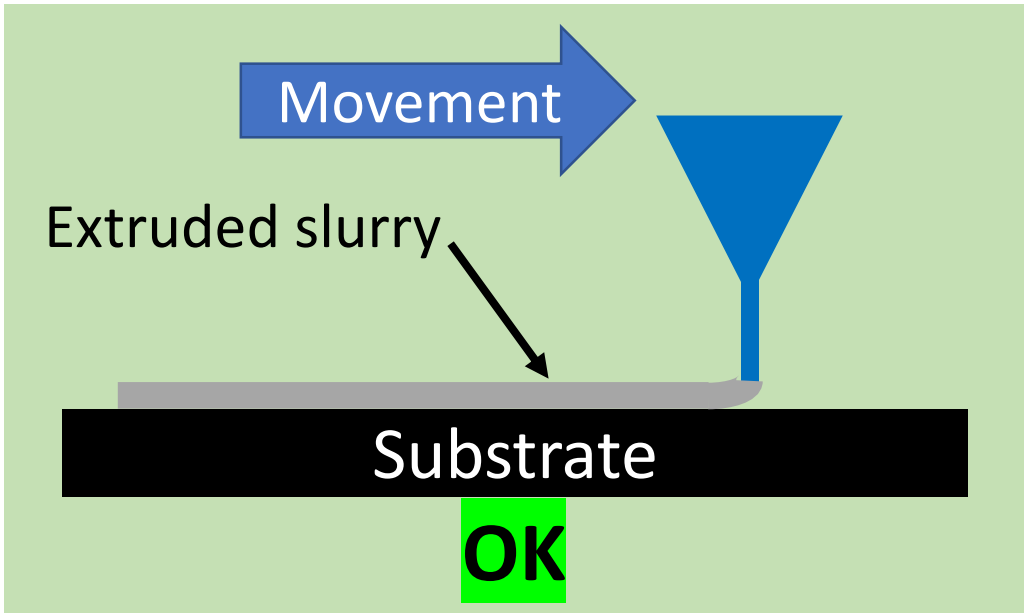
Optimization - Example



Increase flow

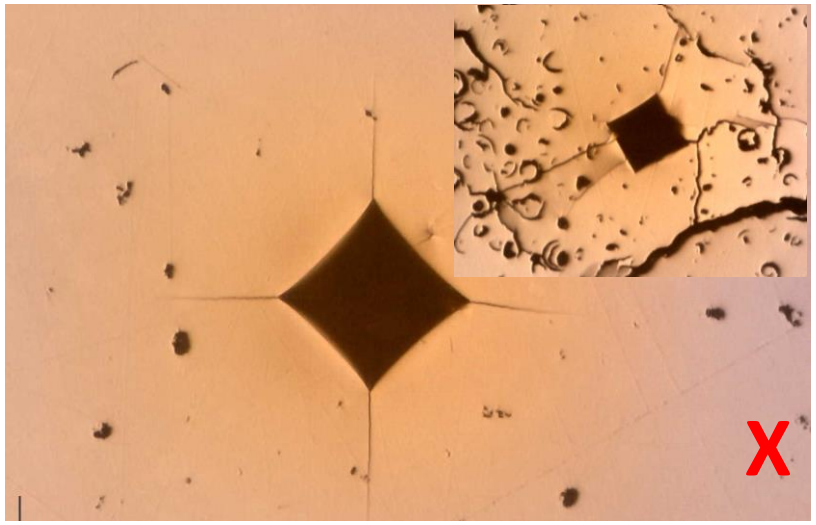
Decrease deposition height

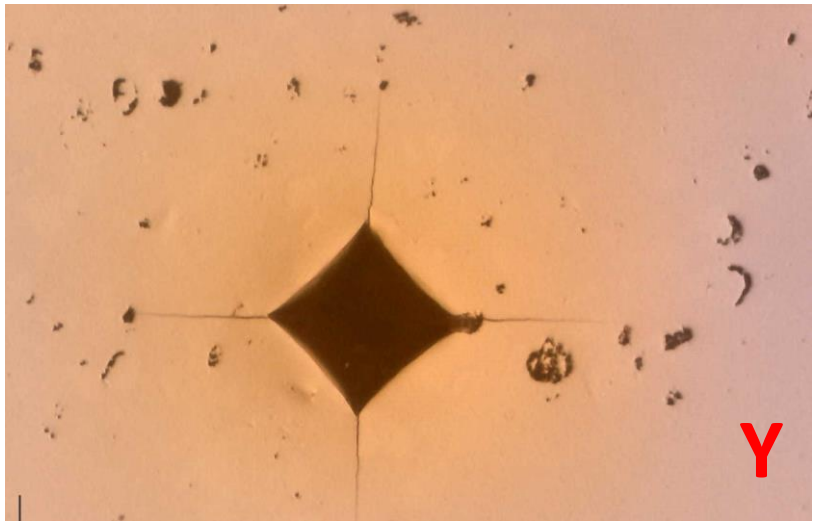


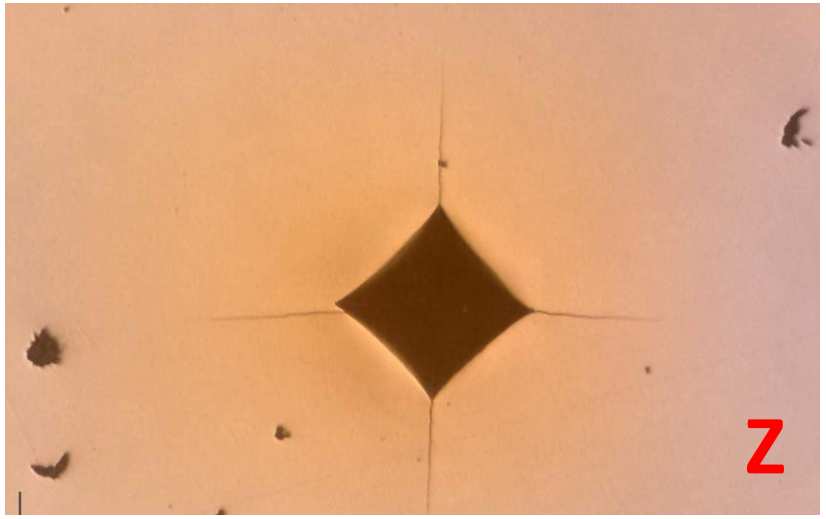


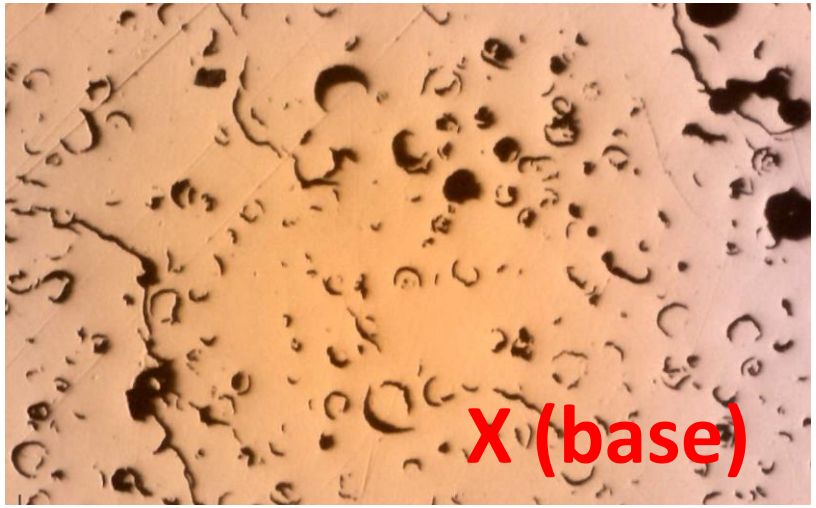
Printing results

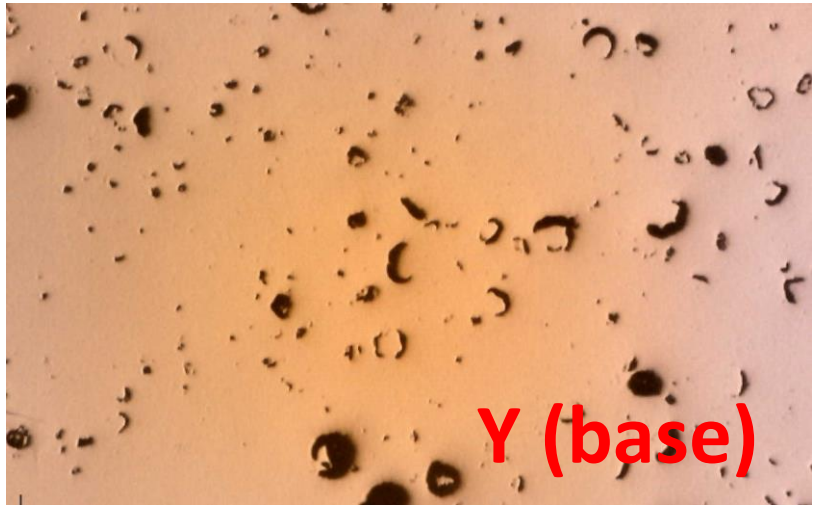
Slurry	Powder loading (wt%)	Dispersant/powder Weight ratio (%)
X (3D printed)	High	High
Y (3D printed)	Medium	Low
Z (Slip cast)	Low	Low

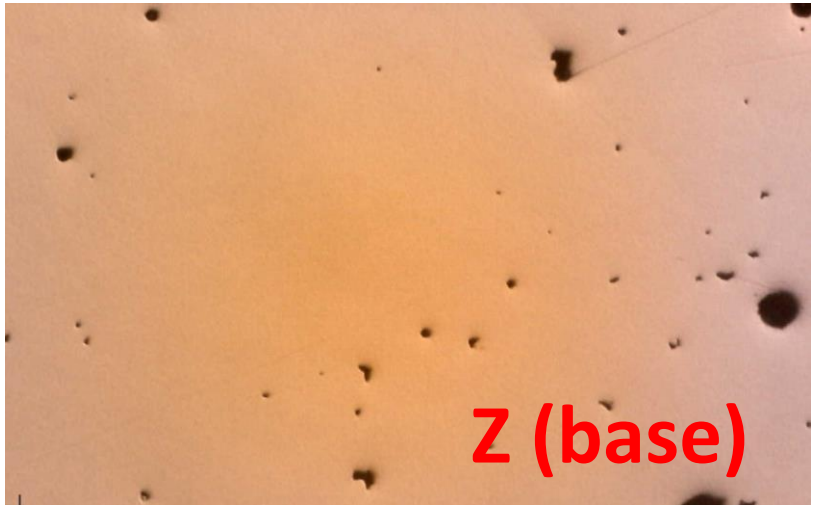












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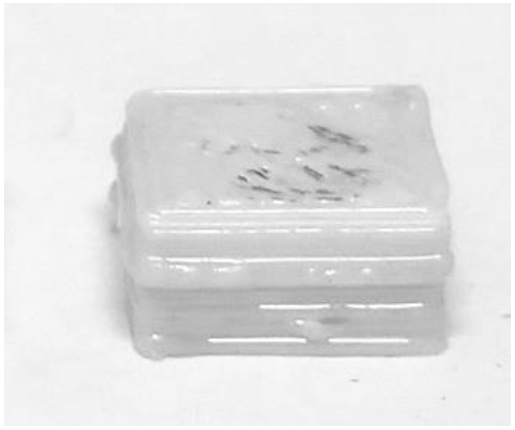

References

[1] E. Feilden, Additive Manufacturing of Ceramics and Ceramic Composites via Robocasting, 2017.

[2] J. Cesarano, B.H. King, H.B. Denham, J. Cesarano III, H.B. Denham, Recent developments in robocasting of ceramics and multimaterial deposition, Solid Free. Fabr. Proceedings, August, 1998. (1998) 8 p. : digital, PDF file.

[3] E. Peng, X. Wei, U. Garbe, D. Yu, B. Edouard, A. Liu, J. Ding, Robocasting of dense yttria-stabilized zirconia structures, J. Mater. Sci. 53 (2018) 247–273. doi:10.1007/s10853-017-1491-x.

[4] W.C. Jr, L. Rueschhoff, P.R. Trice, P.J. Youngblood, Additive Manufacturing of Boron Carbide via Robocasting of Aqueous Ceramic Suspensions, 1–16.