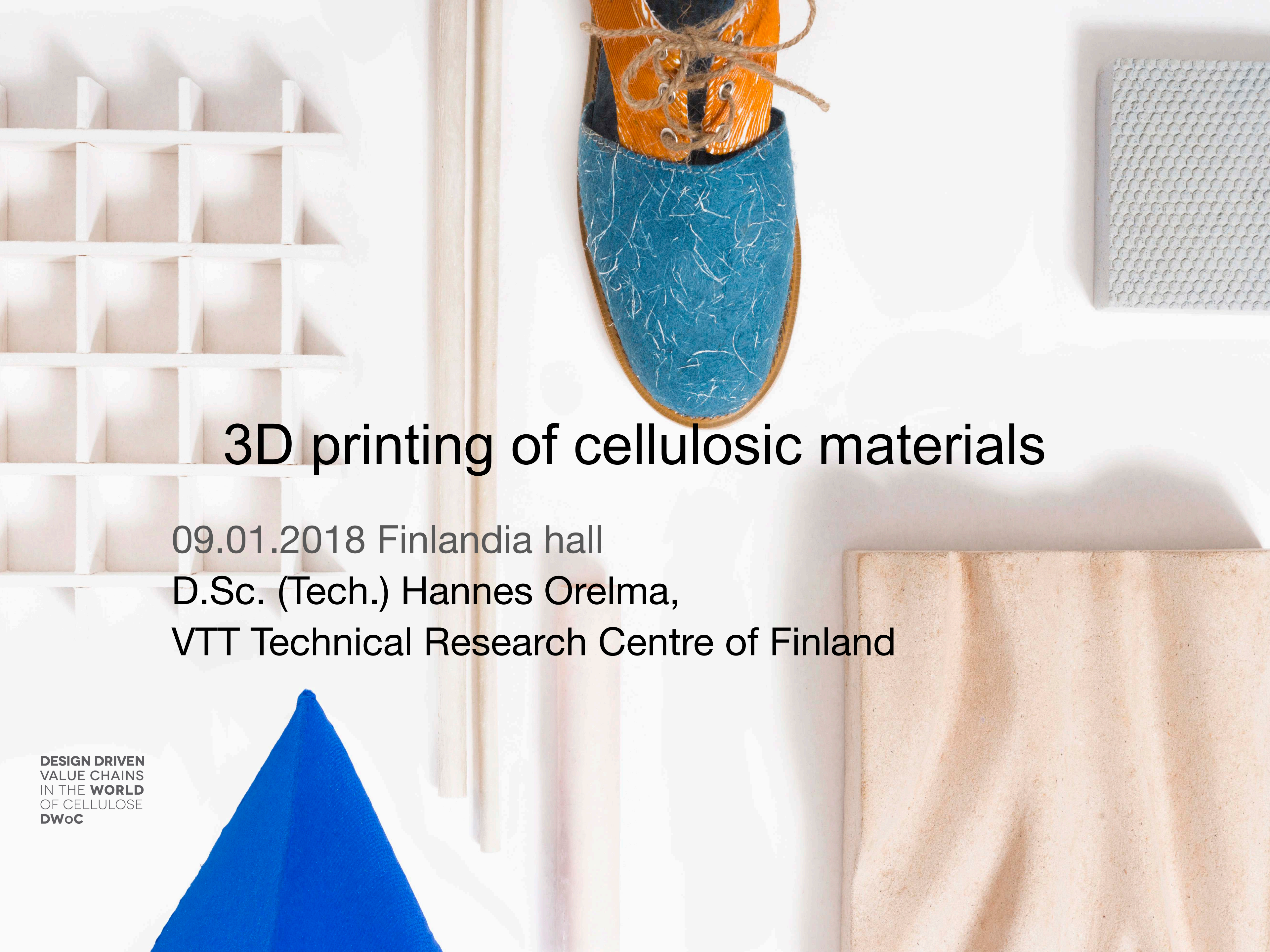

3D printing of cellulosic materials

09.01.2018 Finlandia hall

D.Sc. (Tech.) Hannes Orelma,
VTT Technical Research Centre of Finland

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Outline of the presentation

- Introduction to the 3D-printing
- People behind the research
- 3D-printing of cellulose materials
- Research in DWOC with 3D-printing
- Highlights results of DWOC
- Conclusions

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Research group of cellulose materials 3D-printing

Work package leader

- Hannes Orelma (VTT)

Researchers

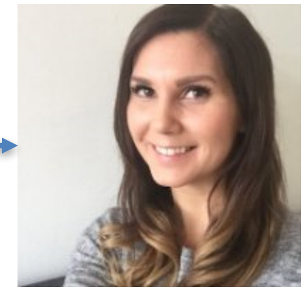
- Tiia Tenhunen (VTT)
- Ville Klar (Aalto Eng)
- Pyry Kärki (Aalto Eng)
- Steve Spoljaric (Aalto Chem)
- Arto Salminen (Aalto Chem)
- Jaakko Pere (VTT)

Designers

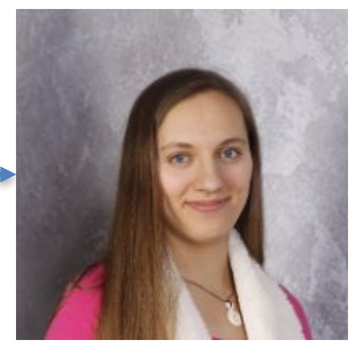
- Anastasia Ivanova (Aalto Arts)
- Pauliina Varis (Aalto Arts)
- Tiina Härkäsalmi (Aalto Arts)
- Pirjo Kääriäinen (Aalto Arts)

Professors

- Petri Kuosmanen (Aalto Eng)
- Jukka Seppälä (Aalto Chem)
- Ali Harlin (VTT)






What is 3D-printing

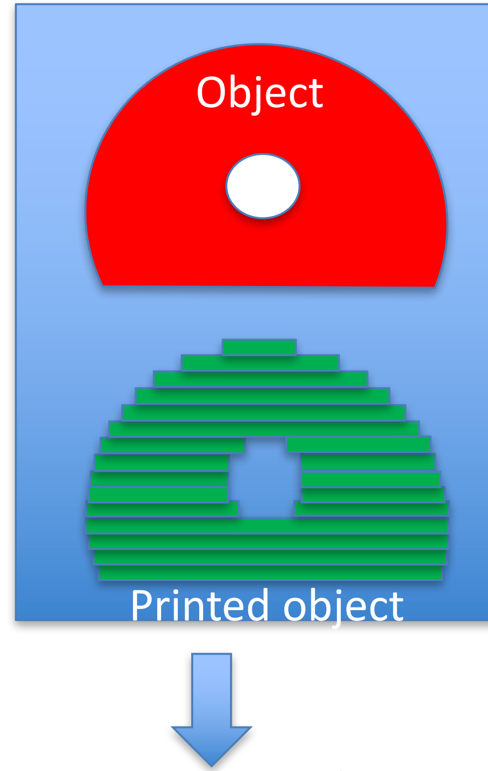
- **3D-printing is an “Additive manufacturing” technique**
  - **Three dimensional object is created by successive layers of material based to digital model data.**

Benefits

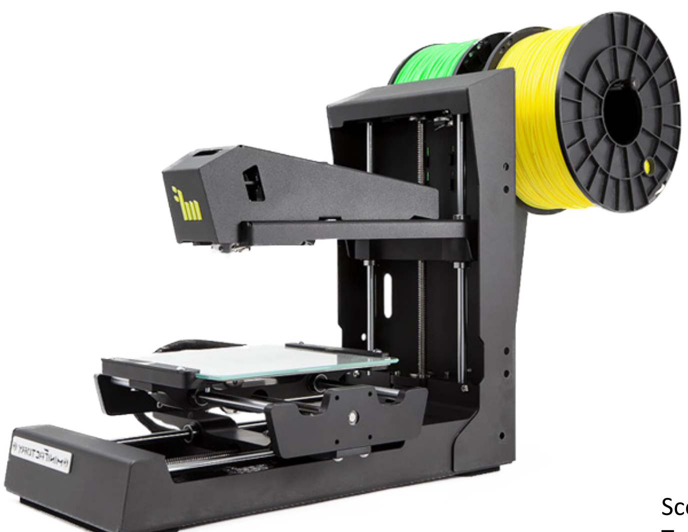
-Complex geometries can be form

-Layering with different materials possible

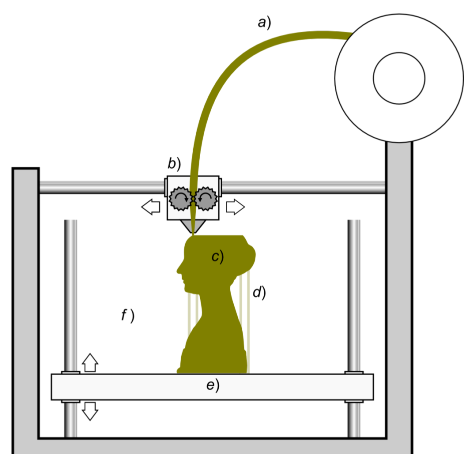
-Direct manufacture from CAD model.



Great Pyramid of Giza



Mini factory (MiniFactory Oy Ltd)



Scopigno R. et al. (2017). "Digital Fabrication Techniques for Cultural Heritage: A Survey". Computer Graphics Forum 36 (1): 6–21.

3D-printing techniques

Materials	Technologies: Parts build by polymerization	Parts build by using bonding agent	Parts build by melting	Parts build by solvent casting
Ceramic		BJ	LM	
Metal		BJ	LM, EBM	
Powder		BJ		
Plastic	SL, PJ	BJ	FDM, LS	
Wax			MJ	
Colloids				DW

FDM = Fused Deposition Modeling
EBM = Electron Beam Melting
LM = Laser Melting
MJ = Material Jetting
SL = Stereolithography

BJ = Binder Jetting
HP = Hybrid Processes
LS = Laser Sintering
PJ = Photopolymer Jetting
DW = Direct writing /paste extrusion

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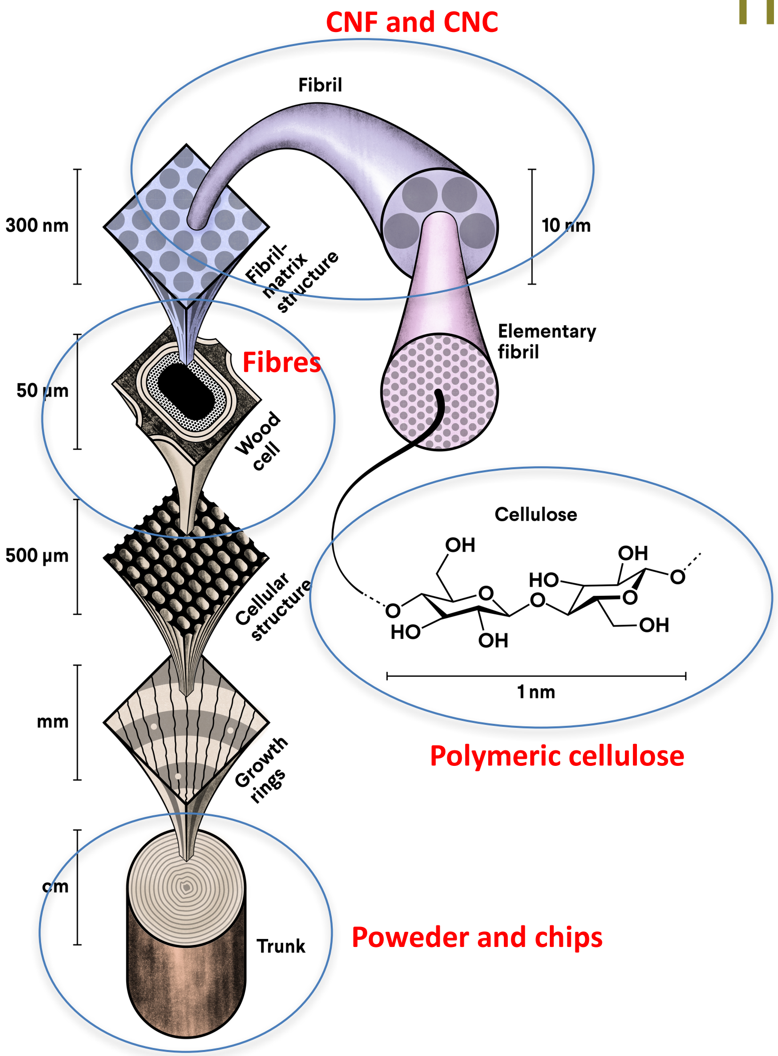
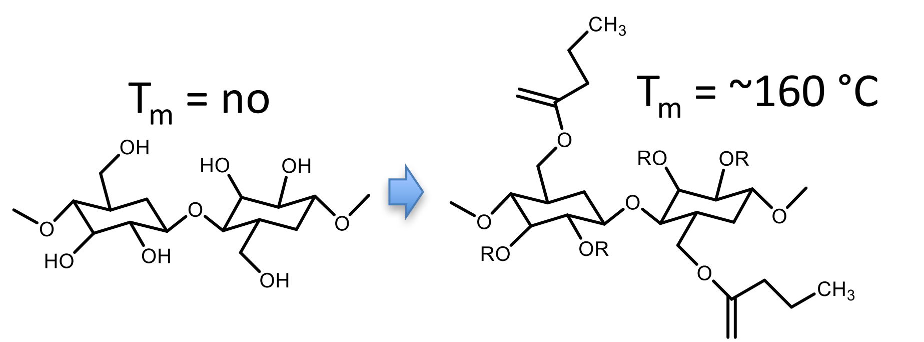
3D-printing of cellulose materials



- <u>Cellulose is not thermoplastic!</u>
- Cellulose consist of ether bonds of —O—, which are relatively weak chemical bonds
- The ether bonds are broken with thermal energies smaller than energies needed to separate cellulose chains
- Chemical grafting of side groups lowers the melting point of cellulose.



Cellulose　　　Cellulose acetate butyrate

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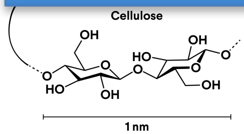
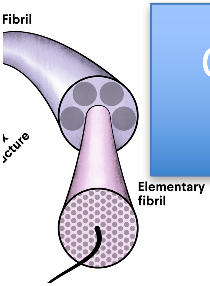
Processing routes to 3D-print cellulose materials

Polymeric



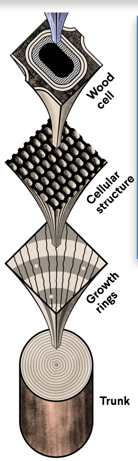
- Chemically deriving cellulose
  - Lower the T_m for enabling FDM printing
  - Solubilize in an organic solvent for paste printing
- Dissolving cellulose and regenerating after 3D-printing

CNF and CNC



- Direct paste printing of CNF dispersion
- Use CNF or CNC as a filler in polymer matrix in FDM or paste printing

Fibres and macro size wood particles



- Direct paste printing of fibre suspensions
- Mixing fibres with thermoplastic plasticizer that makes the solution thermoplastic.
- Wood particle mixed with a thermoplastic polymer for FDM printing

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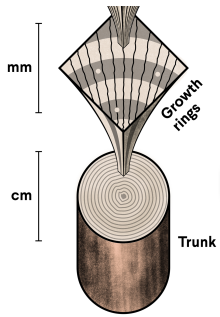
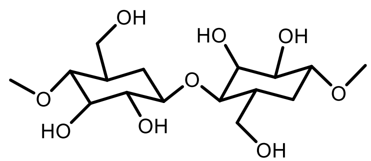
Research highlights from DWOC

3D printing of cellulose derivatives



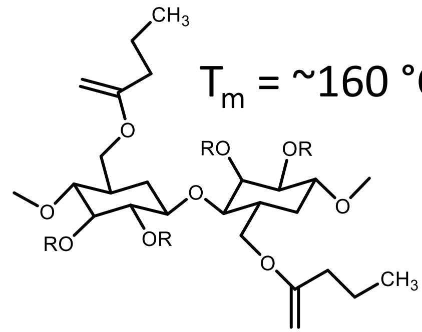
Dissolution

T_m = no



Cellulose

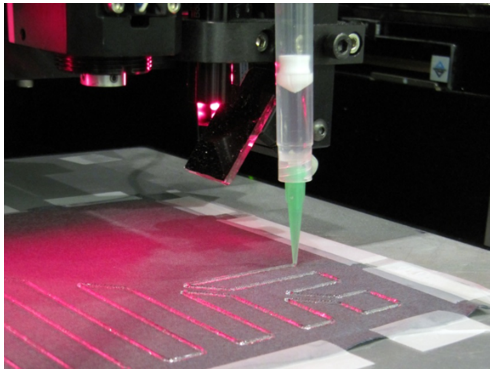
T_m = ~160 °C

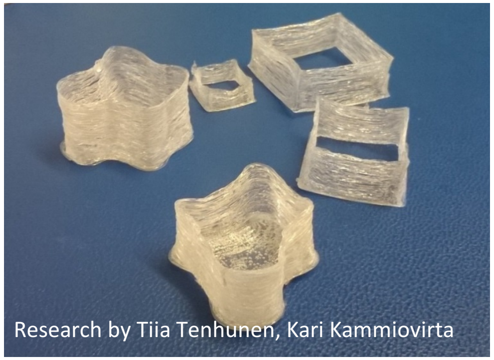


Cellulose acetate butyrate

Paste printing

Dissolved in acetic acid





Research by Tiia Tenhunen, Kari Kammiovirta

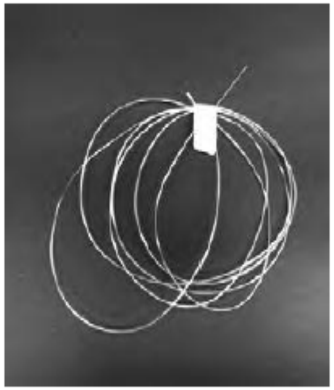
Application

Research by Pauliina Varis, Tiia Tenhunen

Textiles with functionalities

FDM

Extrusion manufactured CAB 3D-filament



→

FDM 3D-printing

→

Hard printed structure

Research by Steve Spoljaric, Arto Salminen, Jukka Seppälä

1. Polymeric cellulose materiala

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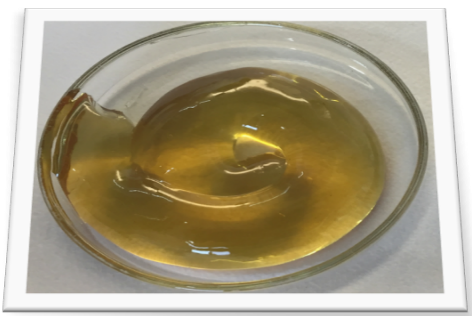
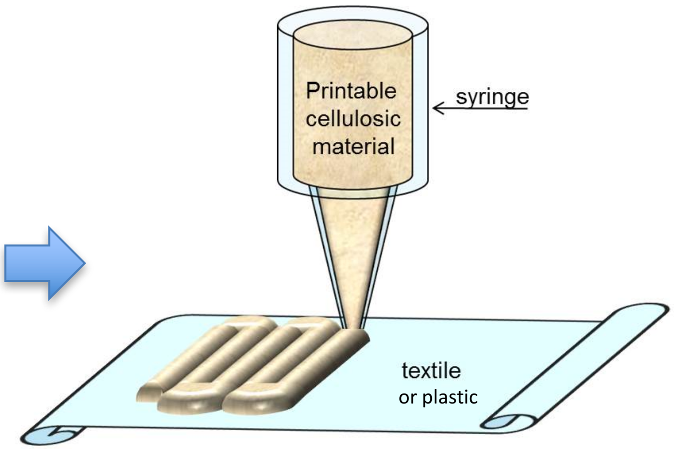
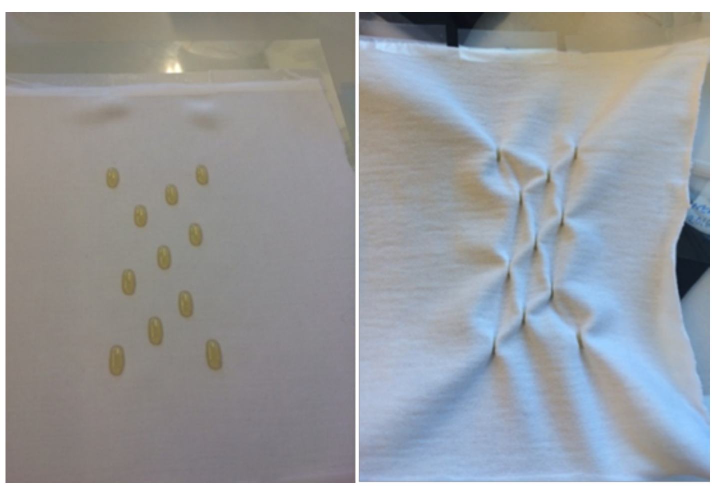
3D-printing of cellulose dissolved in ionic liquids

Cellulose dissolved in EMIMOAc ionic liquid





Regeneration in water and drying



Application: Smocked textiles

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Research by Tiia Tenhunen, Pauliina Varis, Pirjo Kääriäinen, Kari Kammiovirta, Hannes Orelma

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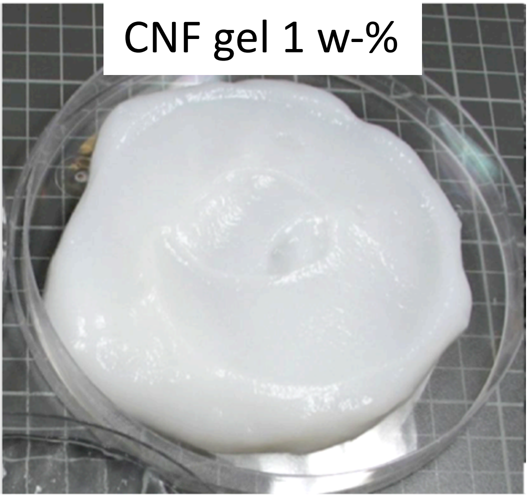
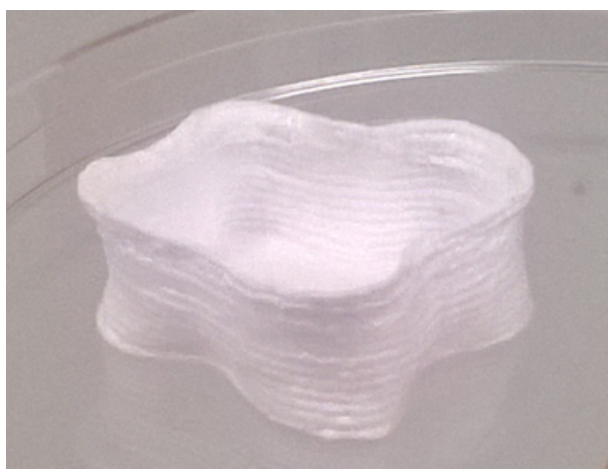
3D-printing of cellulose nanofibrils



Paste printing

Freeze drying



Drying in room condition

Problem: High water content causes the collapse.
Solution: Use of CNF powder as a filler in CNF.

3D-printed all-CNF structures first time with room drying

Design: Anastasia Ivanova, photo: Eeva Suorlahti.

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Research by Tiia Tenhunen, Anastasia Ivanova, Ville Klar, Pyry Kärki, Tuomas Hänninen, Hannes Orelma

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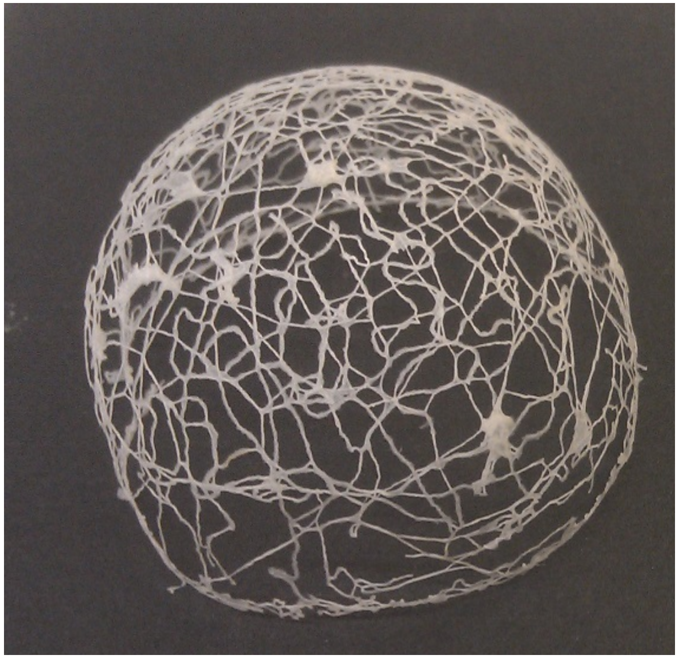
3D-printing of self standing CNF structures without supports

- Problem: 3D-printed structures require support layers when printed on air.
- Solution: Use of chemical cross linker that hardeners the material simultaneously within the 3D-printing.

Dope
- Enzymatically-fibrillated CNF (HEFCEL)
- Cross-linker and lubricant: poly(vinyl alcohol) (PVA) and glutaraldehyde (GA)

Paste 3D-printing → Air drying



Research by Steve Spoljaric, Jukka Seppälä

Tekes, Aalto University, Tampere University of Technology, University of Vaasa, VTT

3. Research platform for developing cellulose 3D-applications

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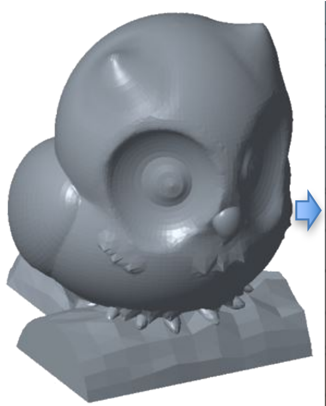
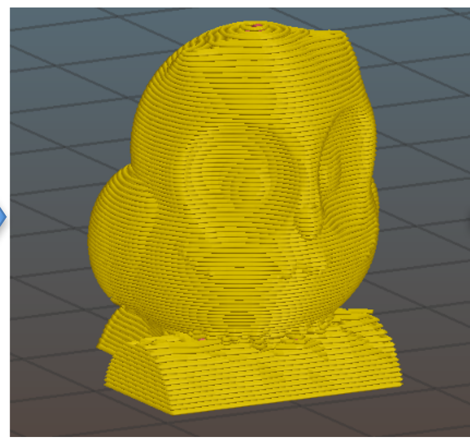
Development of 3D-printing of native cellulose materials

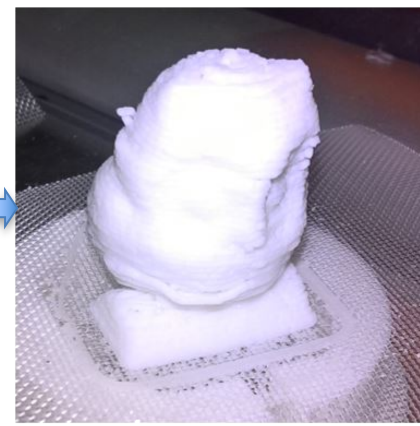
CAD – model



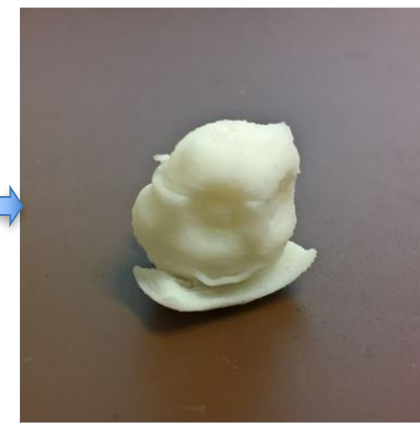
Slicing (output gcode)



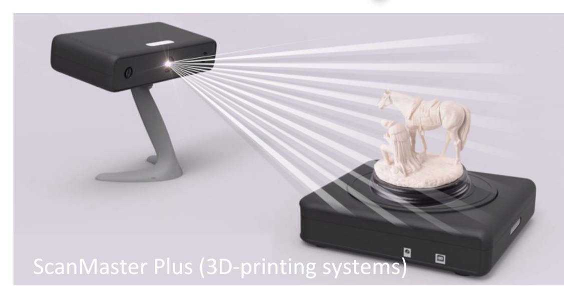
Printed model



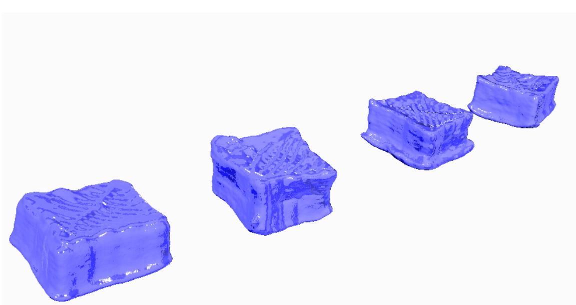
Model after drying



3D-scanning



Information on the deformations within the manufacture



Model: https://www.thingiverse.com/thing:709768/apps

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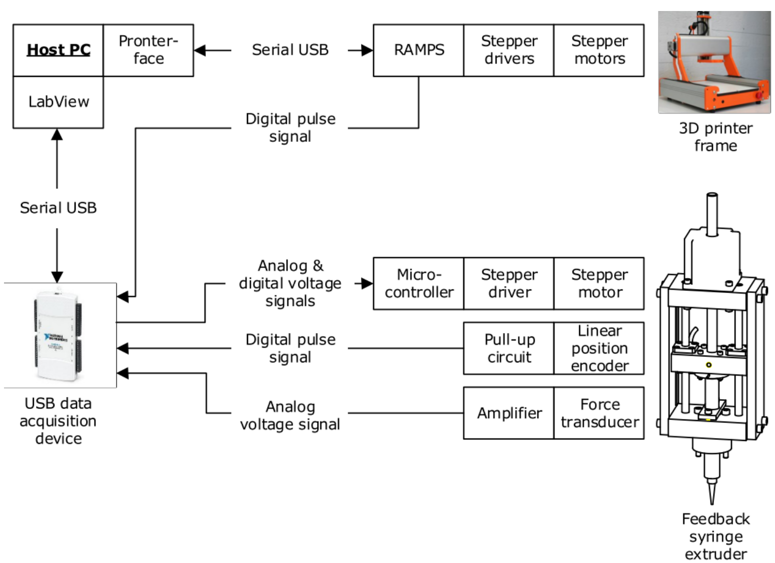
Modular 3D-printing platform

DWOC 3D-printer
- Affordable and precise CNC frame (From Stepcraft)
- Sturdy spindle mount (less restrictions in terms off mass on extruder prototypes)
- Standard Ø 43 mm spindle mount (Easy to test different extruders).



- Standard 3D printing software-toolchain
  - Gcode produced by standard slicers (Slic3r) can be used
- Separate software for control and measurement of extruder
- Efficient testing of different parameters and development of control algorithms.

Research by Ville Klar, Petri Kuosmanen

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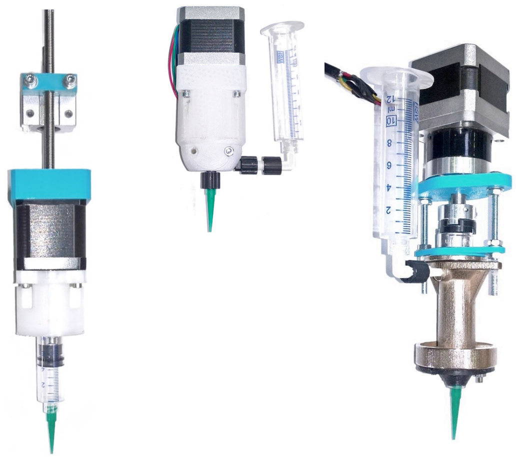
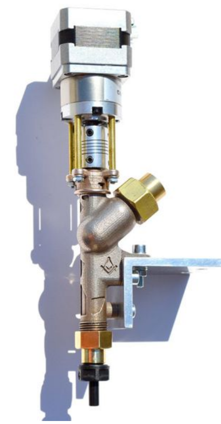
Extruder designs



https://www.preeflow.com/en/products/1k-dispenser/



http://lutum.vormvrij.nl/

- Iterative development of different extruders
- Testing of both own designs and commercial options
- Best performance in term of dosing accuracy and control with closed-loop control (position and pressure) syringe pump.

Research by Ville Klar, Petri Kuosmanen

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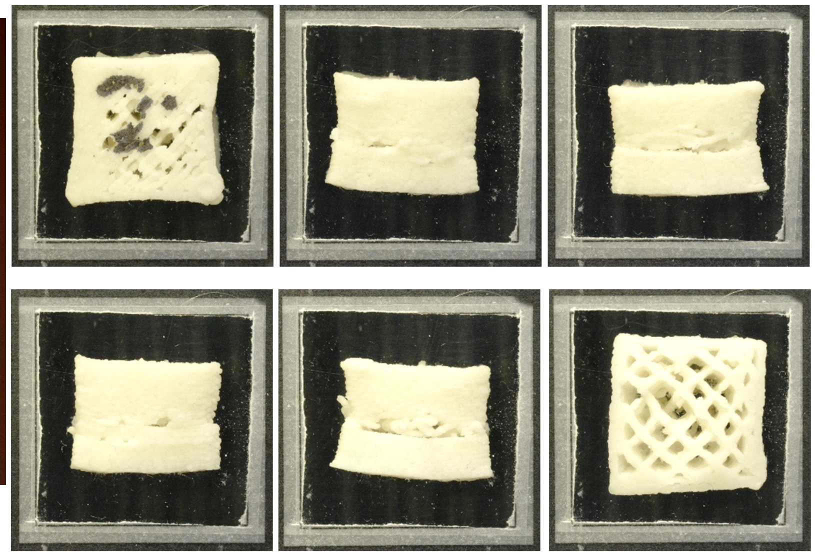
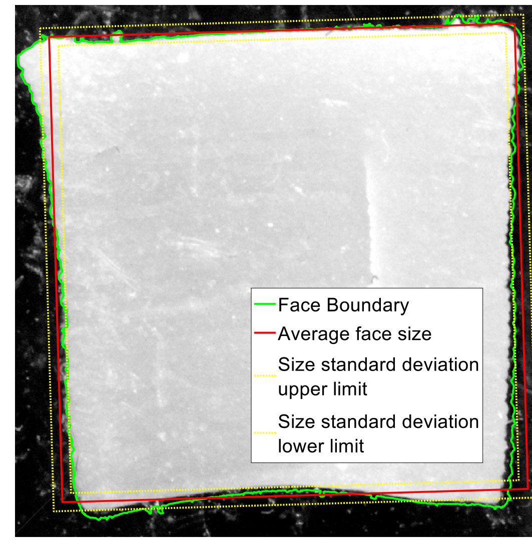
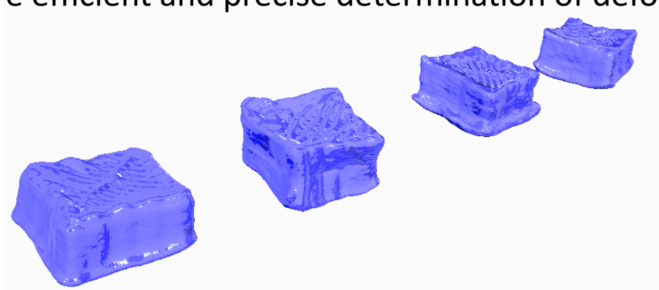
Analysis of geometrical fidelity

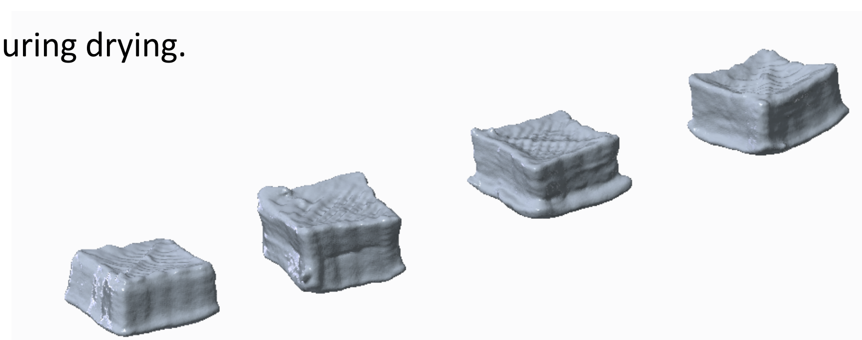
Determination of both overall deformation (shrinkage) & geometrical deformation (warping)





- New method: 3D scanning of 3D printed HefCell structures
- More efficient and precise determination of deformation during drying.





Pyry Kärki, 3D printing of cellulose-based materials, Master's thesis, 2017
Research by Ville Klar, Petri Kuosmanen

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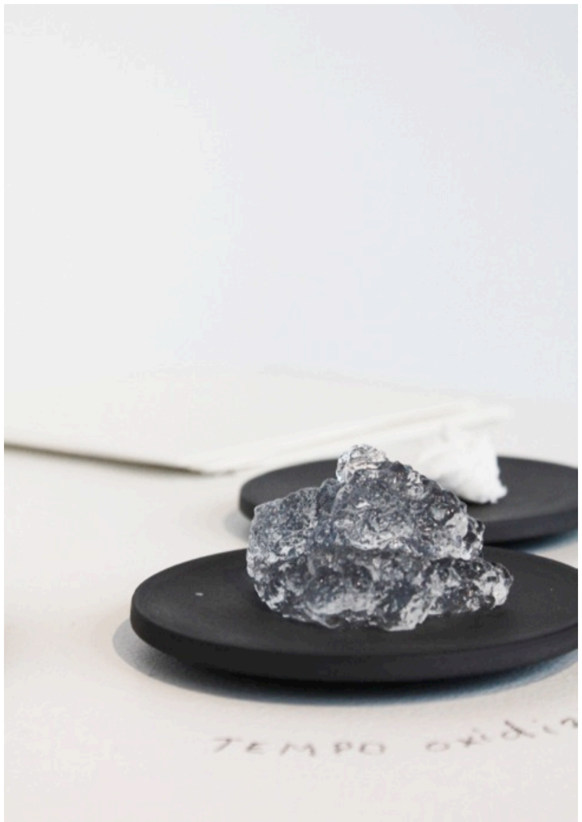
Conclusions



- Cellulose materials offer new opportunities for 3D-printed applications.
- Cellulose materials can be printed with varying 3D-printing techniques including FDM and paste printing (direct writing).
- In DWOC project we have gained significant knowledge about the processing of native and cellulose derivatives on solid and textile supports.

Thank you for your attention!