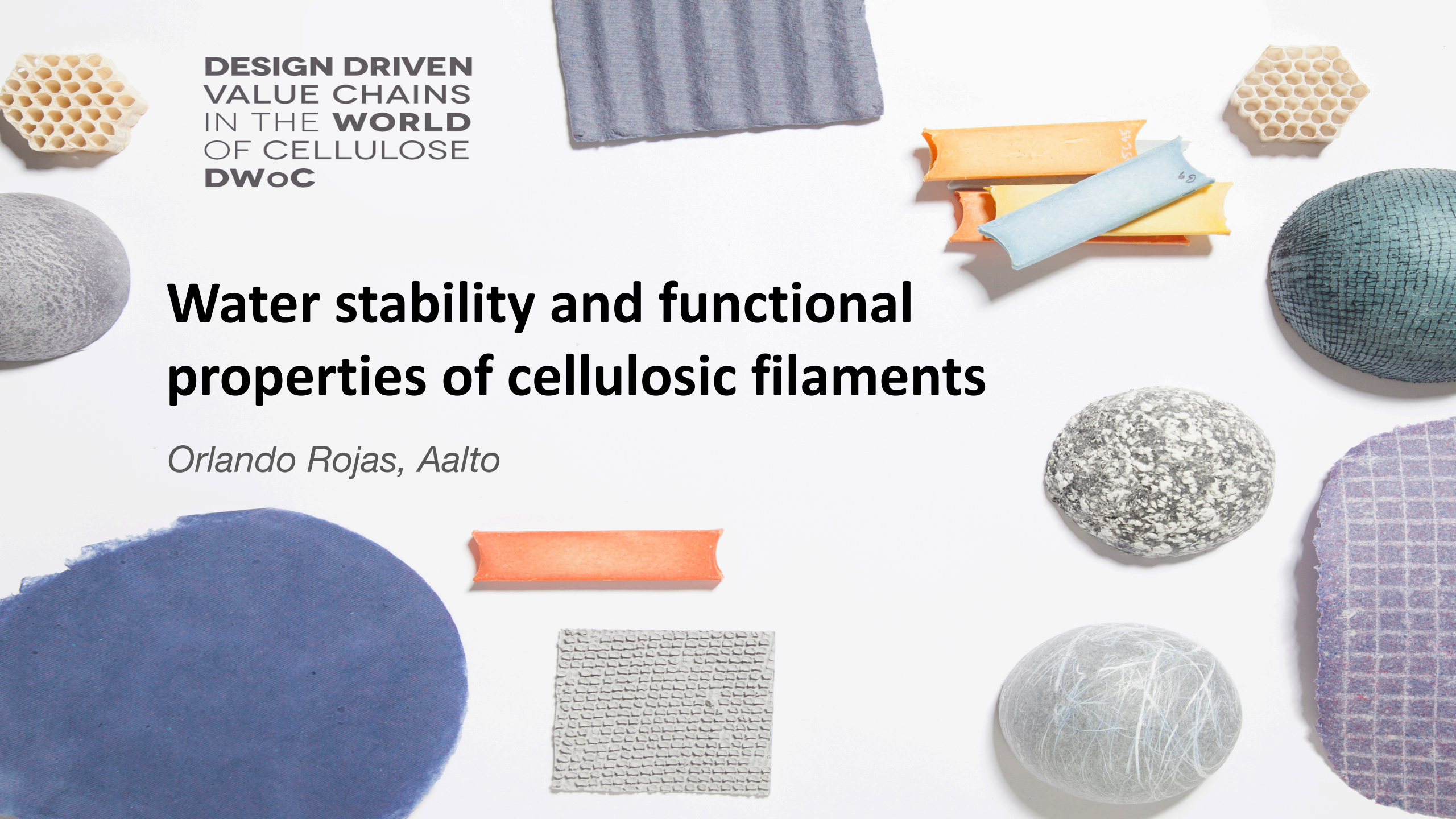
DESIGN DRIVEN
VALUE CHAINS
IN THE WORLD
OF CELLULOSE
DWoC

Water stability and functional properties of cellulosic filaments

Orlando Rojas, Aalto



Team work – contributors

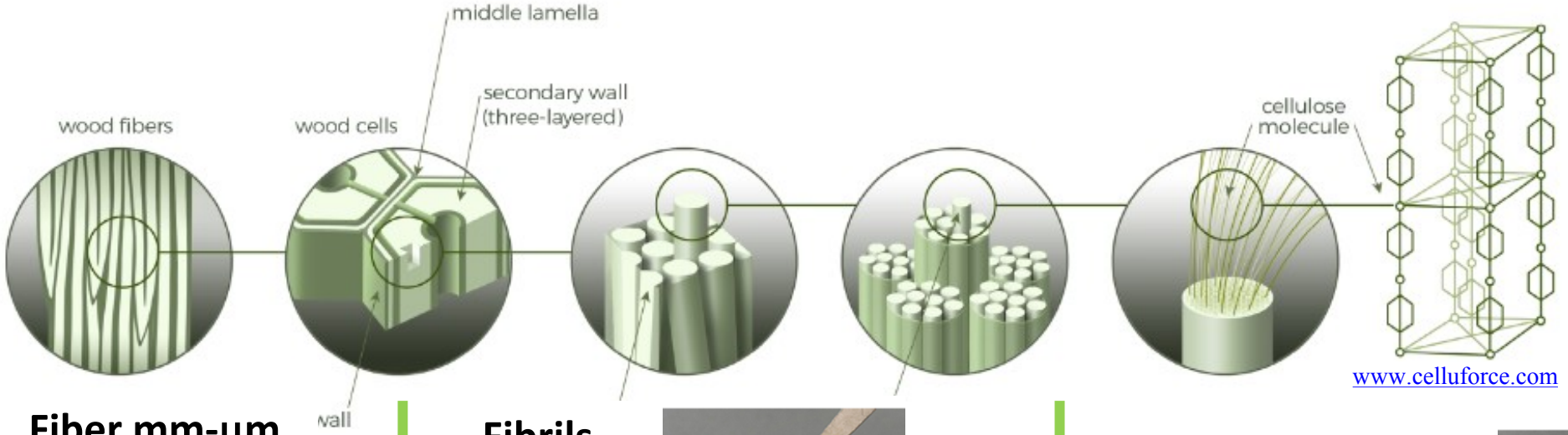
VTT: Hannes Orelma, Tiia-Maria Tenhunen, Hille Rautkoski, Minna Hakalahti, Ali Harlin, Pia Qvintus, Anna Suurnäkki, Yingfeng Shen, Asko Sneck, Kirsi Kataja.

Aalto: Meri Lundahl, Ville Klar, Steven Spoljaric, Petri Kuosmanen, Ling Wang, Mariko Ago, Gisela Cunha, Tero Kämäräinen, Orlando Rojas

Macro level

Micro/nano level

Molecular level



Fiber mm-μm

Fiber yarns

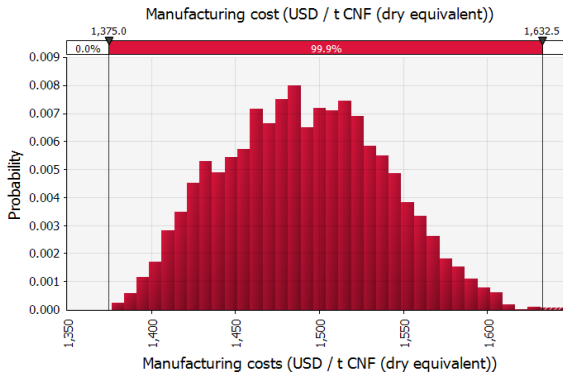
Fibrils
μm-nm

Nanocellulose (CNF)

Molecular structure Å

Cellulose dissolution and regeneration

Cost?



de Assis et al.
Biofuels, Bioprod Biorefining **11**:
682 (2017); accepted (2018)

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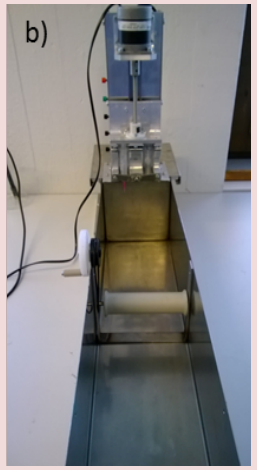
Filament forming

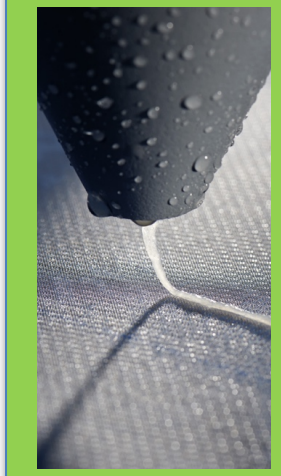
Wet spinning

Dry spinning

DES spinning

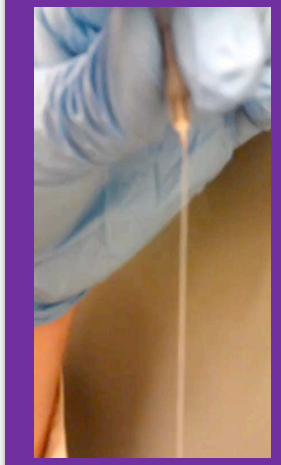


Pulp spinning

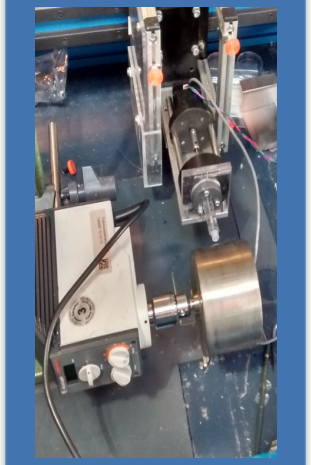


CNF wet spinning

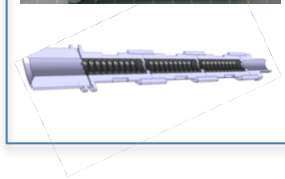
Dry pulp spinning



CNF dry spinning



Foam spinning



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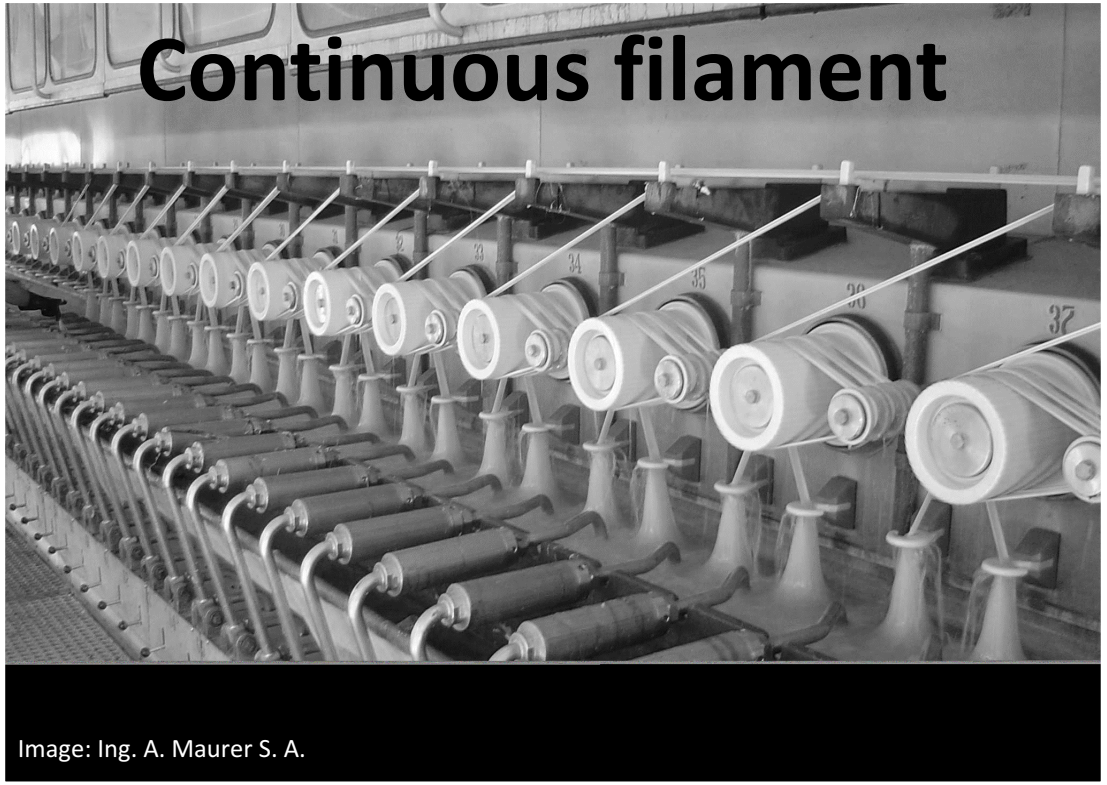
Challenges



How to **maximize spinnability** and **water resistance,** ***simulateneouly***?

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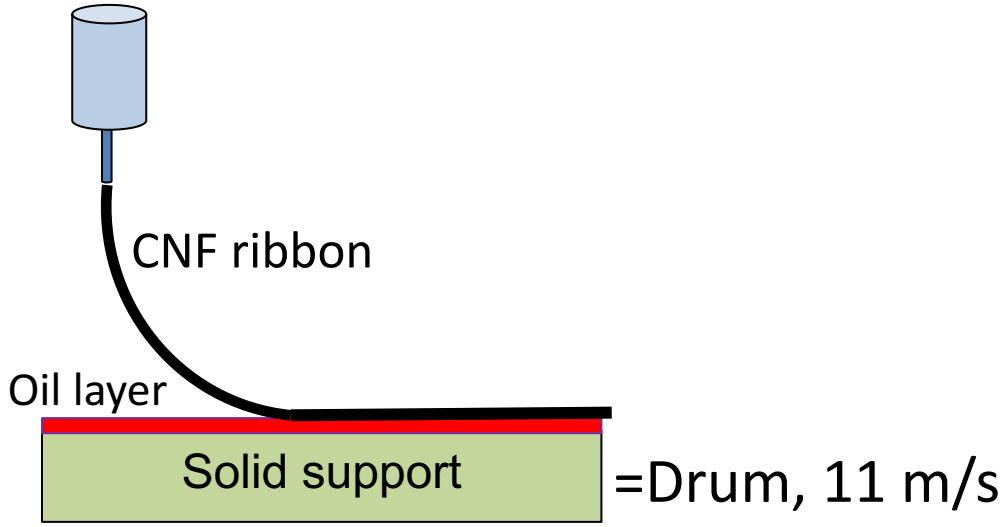
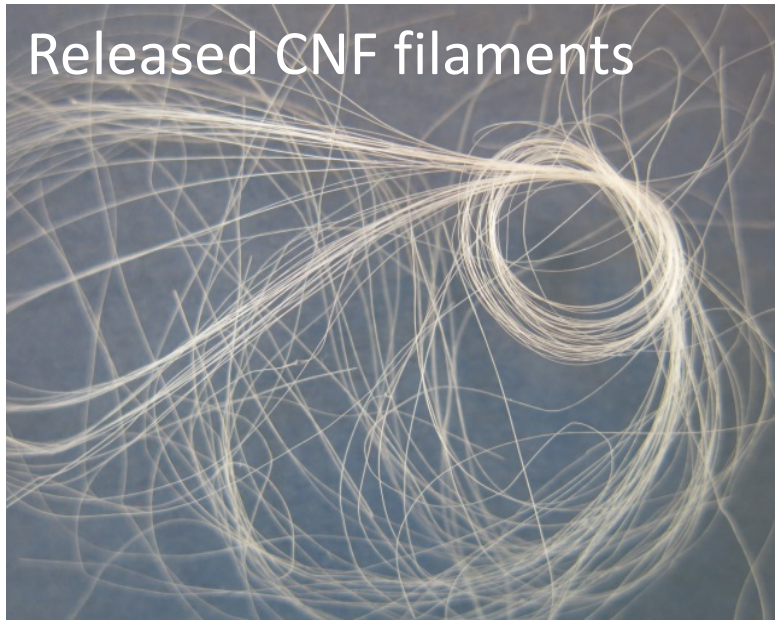
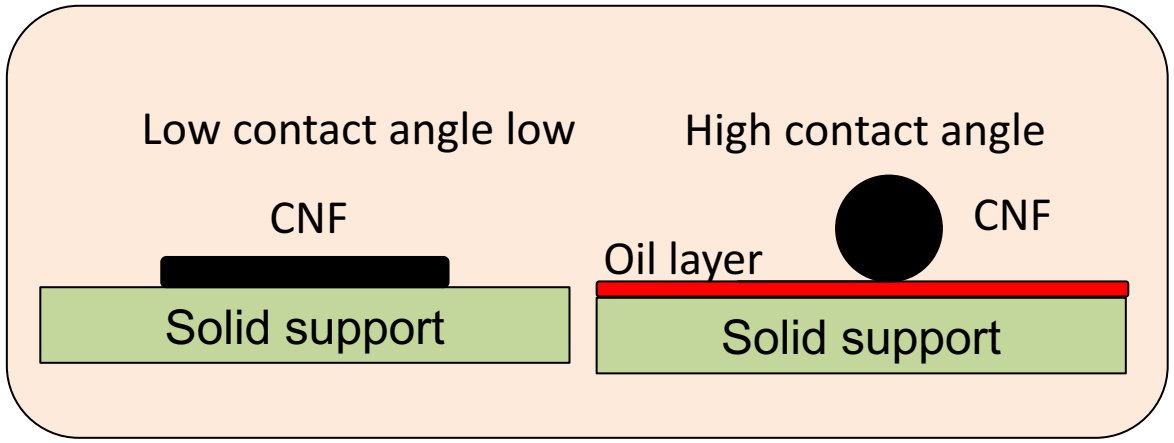
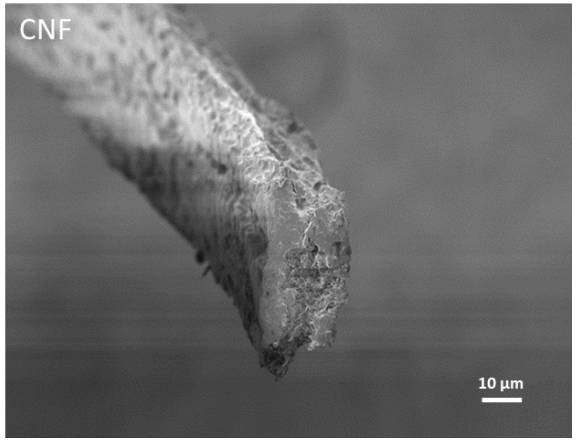
Dry spinning of nanocellulose









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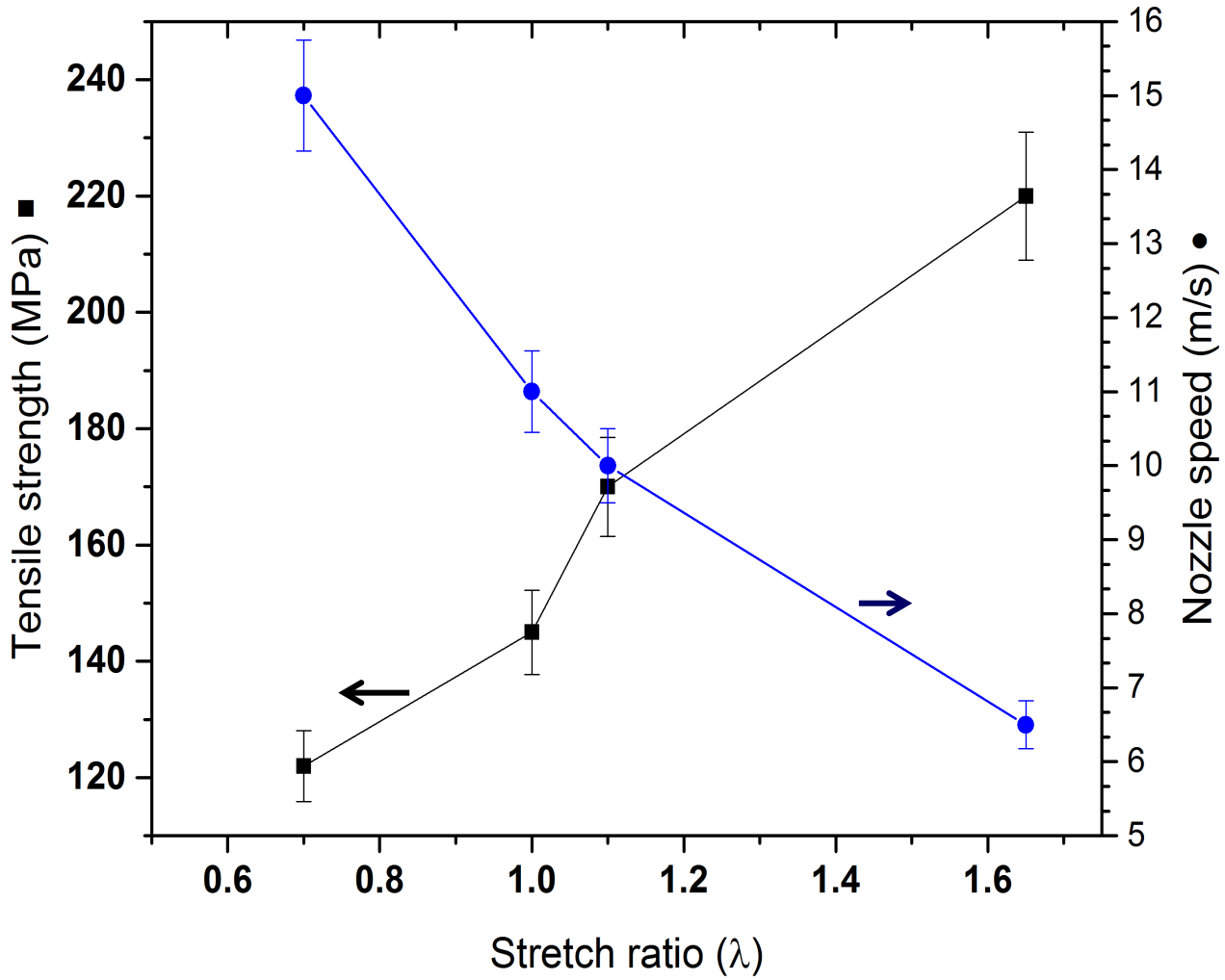
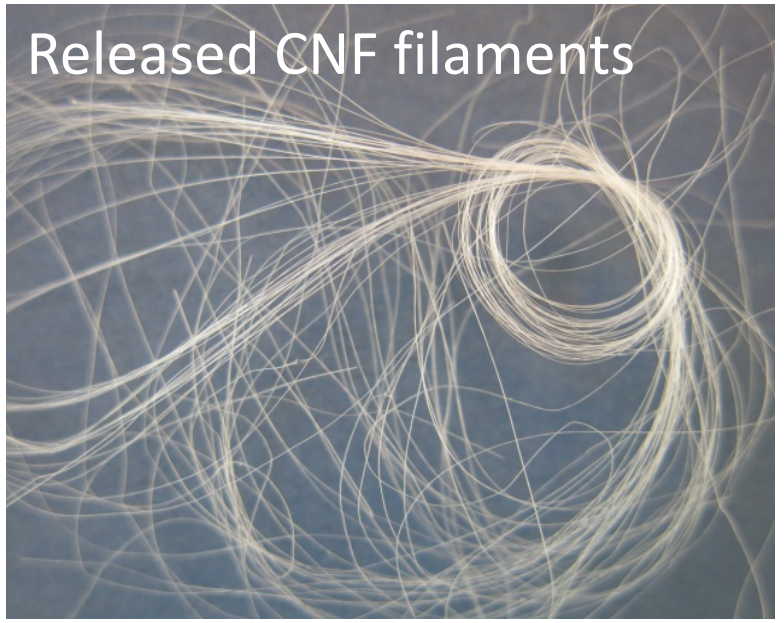
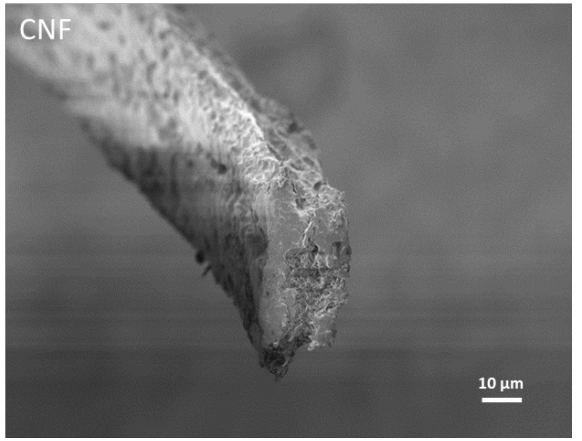
DWoC



= surface speed / jet speed





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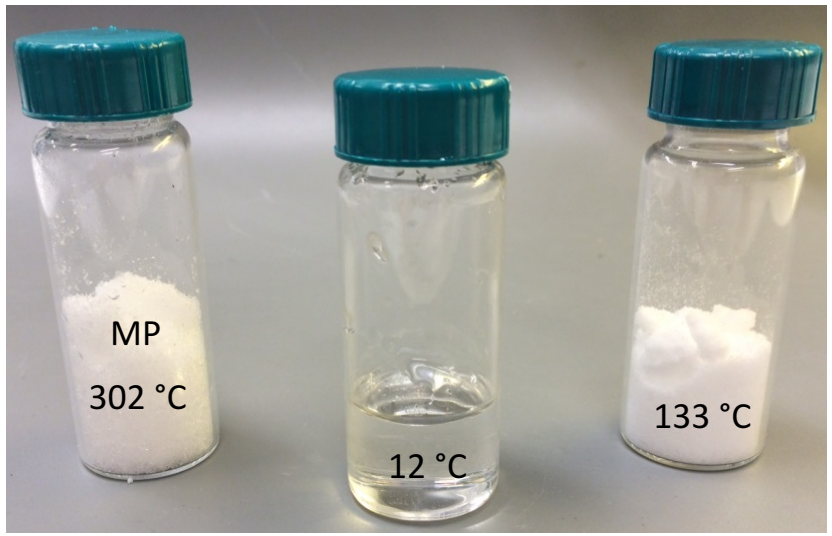
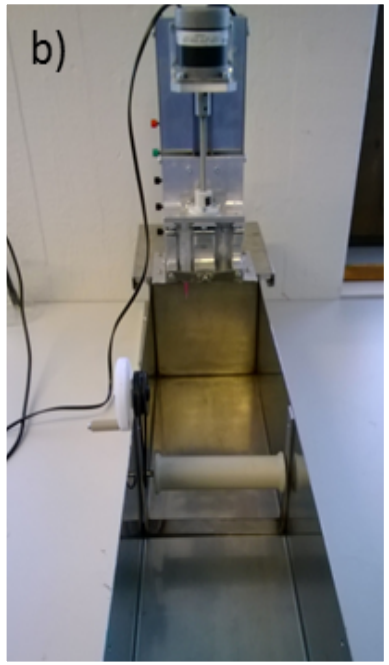
Spinning with deep eutectic solvents

Formation of pulp fibre yarns by using a solvent that does not dissolve cellulose but swells it → effect on interfibre bonding

Choline chloride 1:2 mole ratio **Urea**



- Cheap and non-toxic (& recyclable)
- Simple yarn manufacturing process



Water stable yarn from bleached pulp fibres

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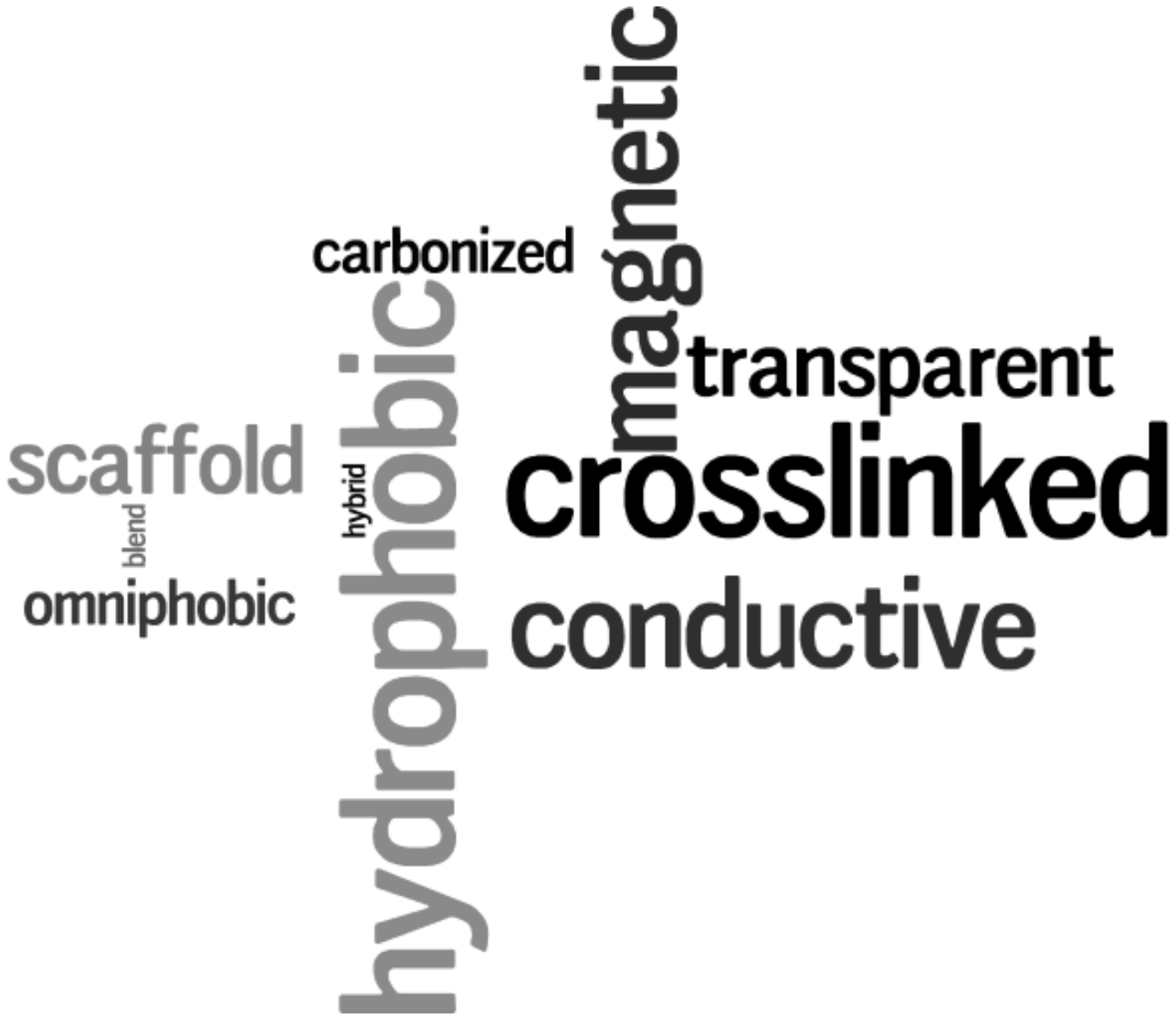
IN THE WORLD
OF CELLULOSE
DWoC 2.0

Water stability and functional properties



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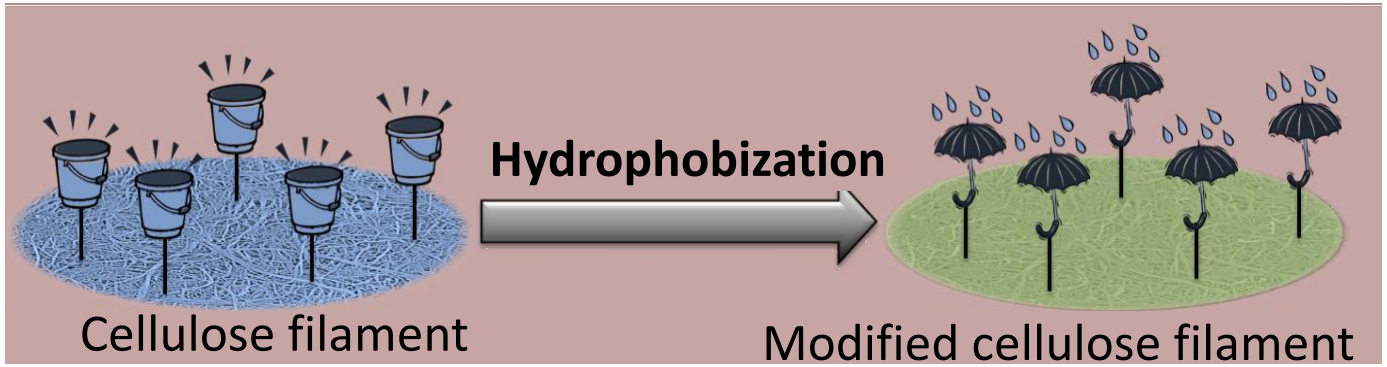
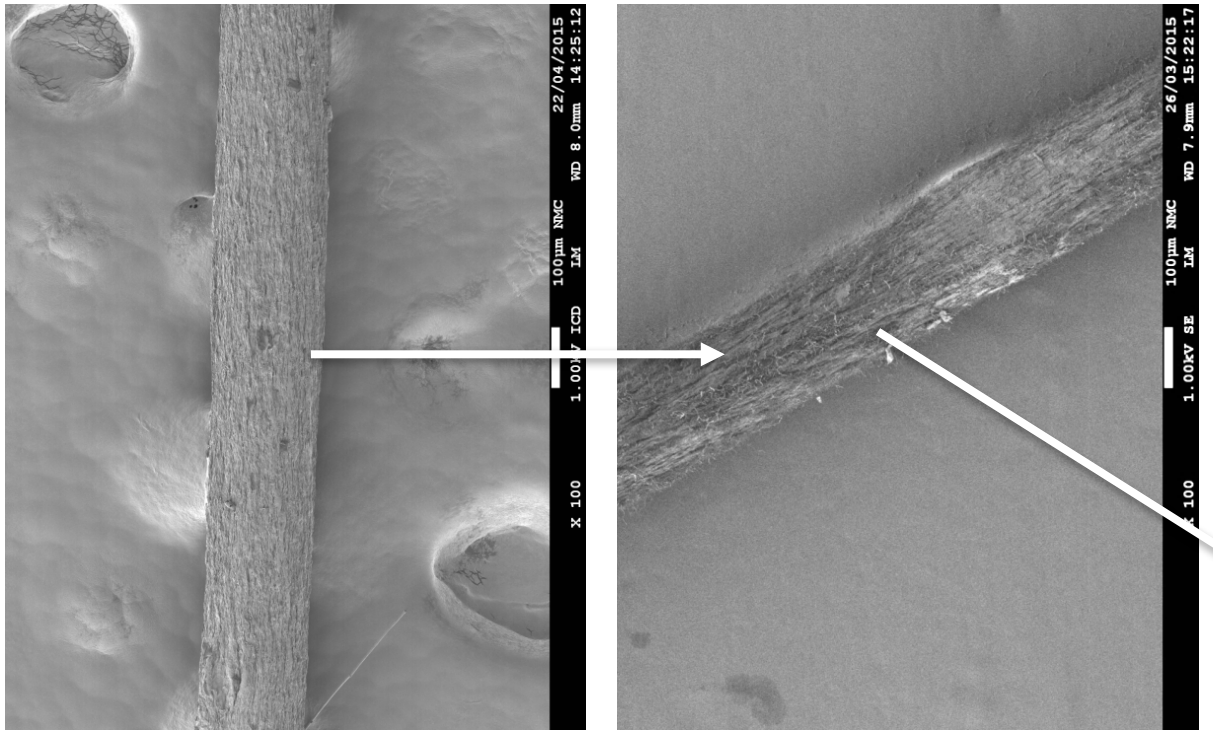
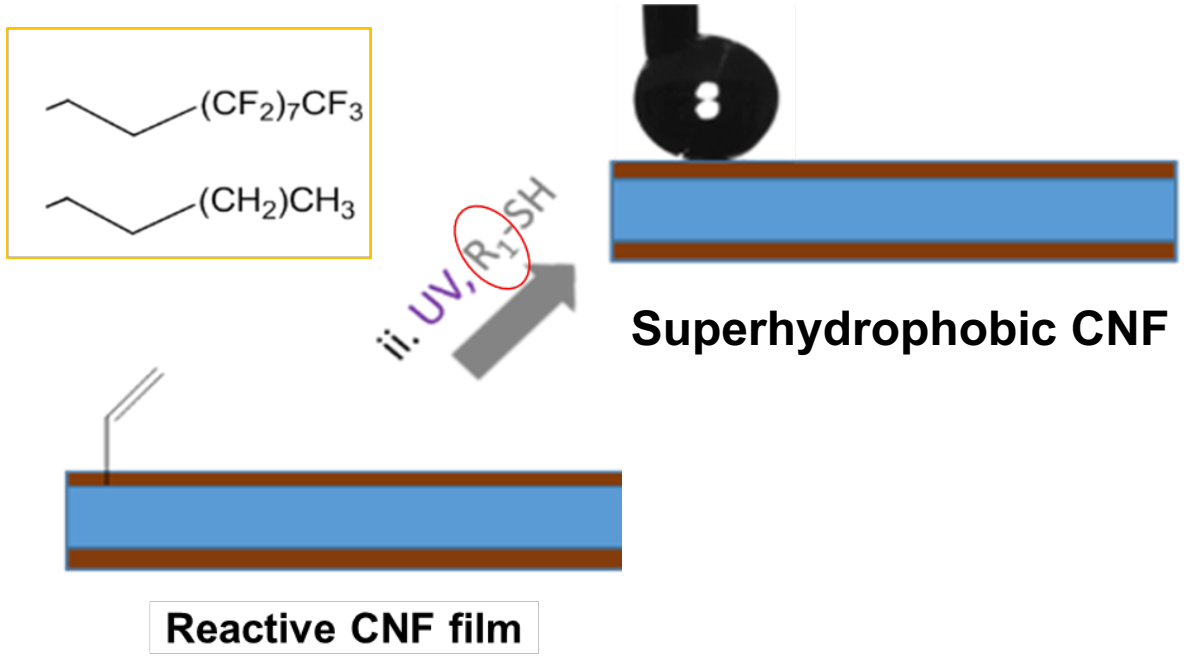
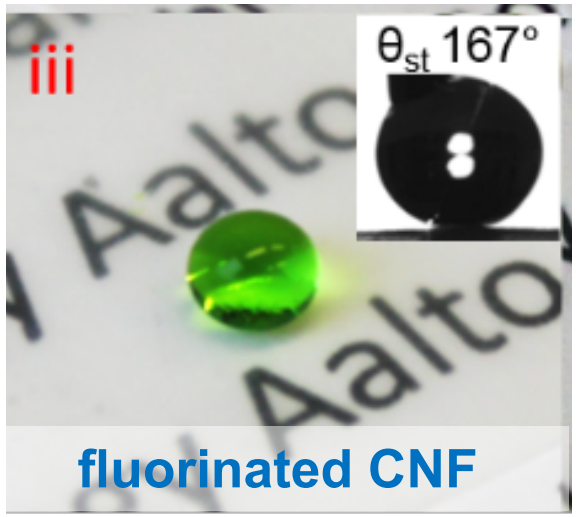
DWoC



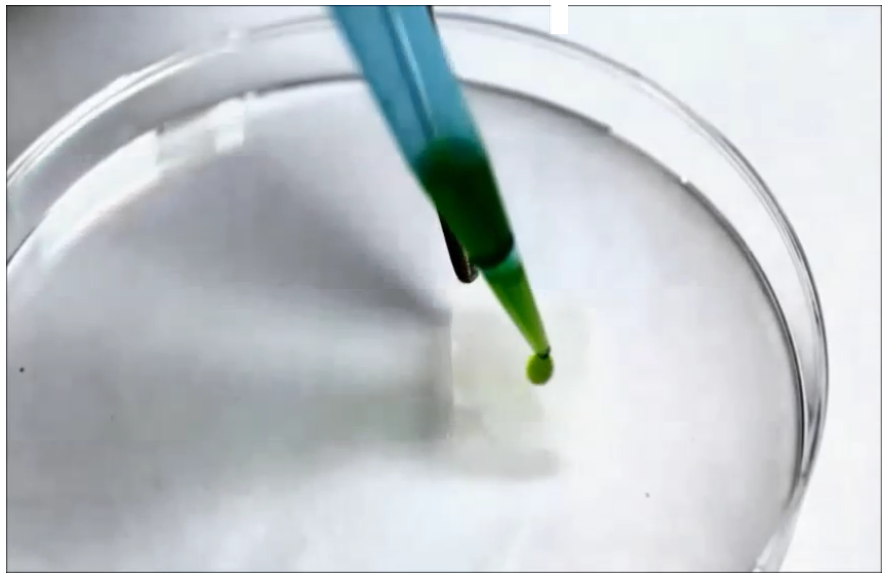


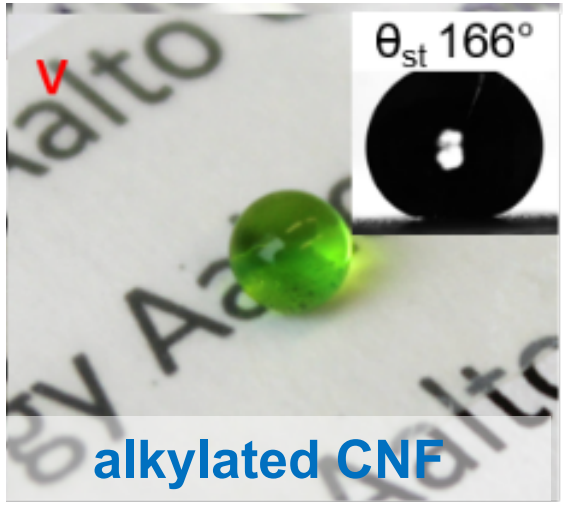
Thiol-ene click for superhydrophobic nanocellulose





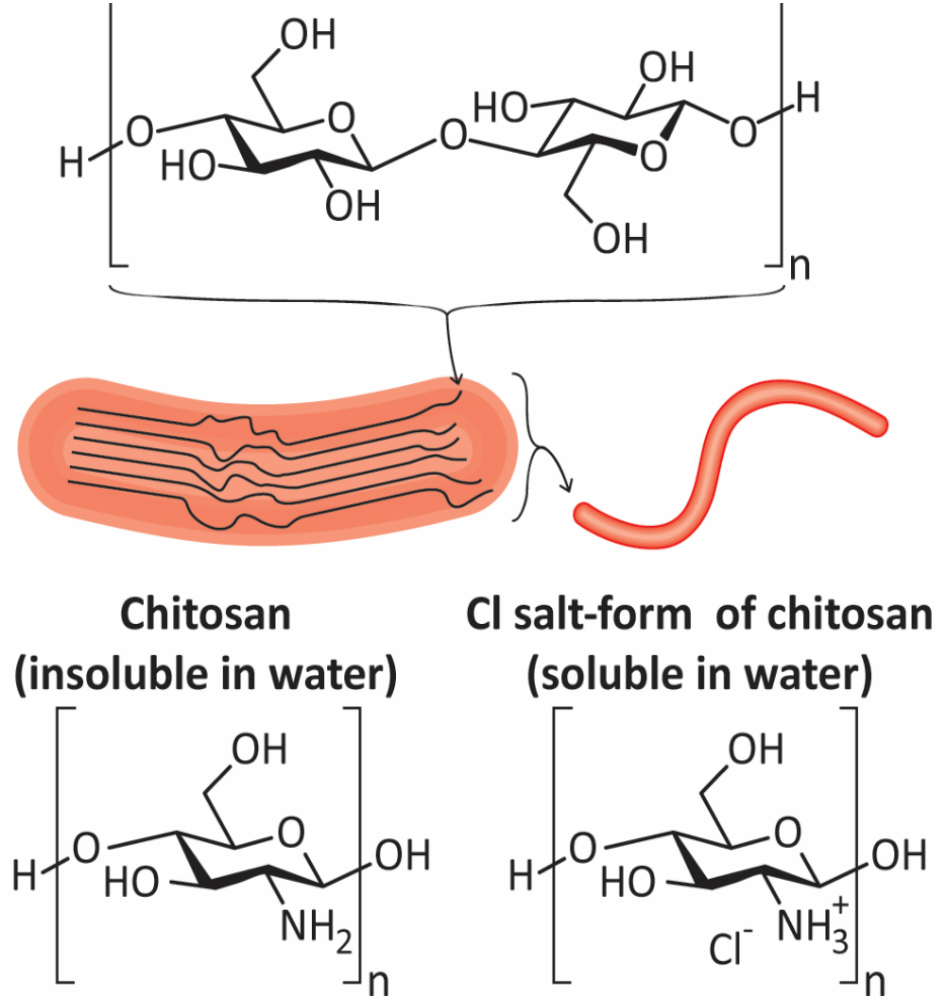
WCA hysteresis <3°

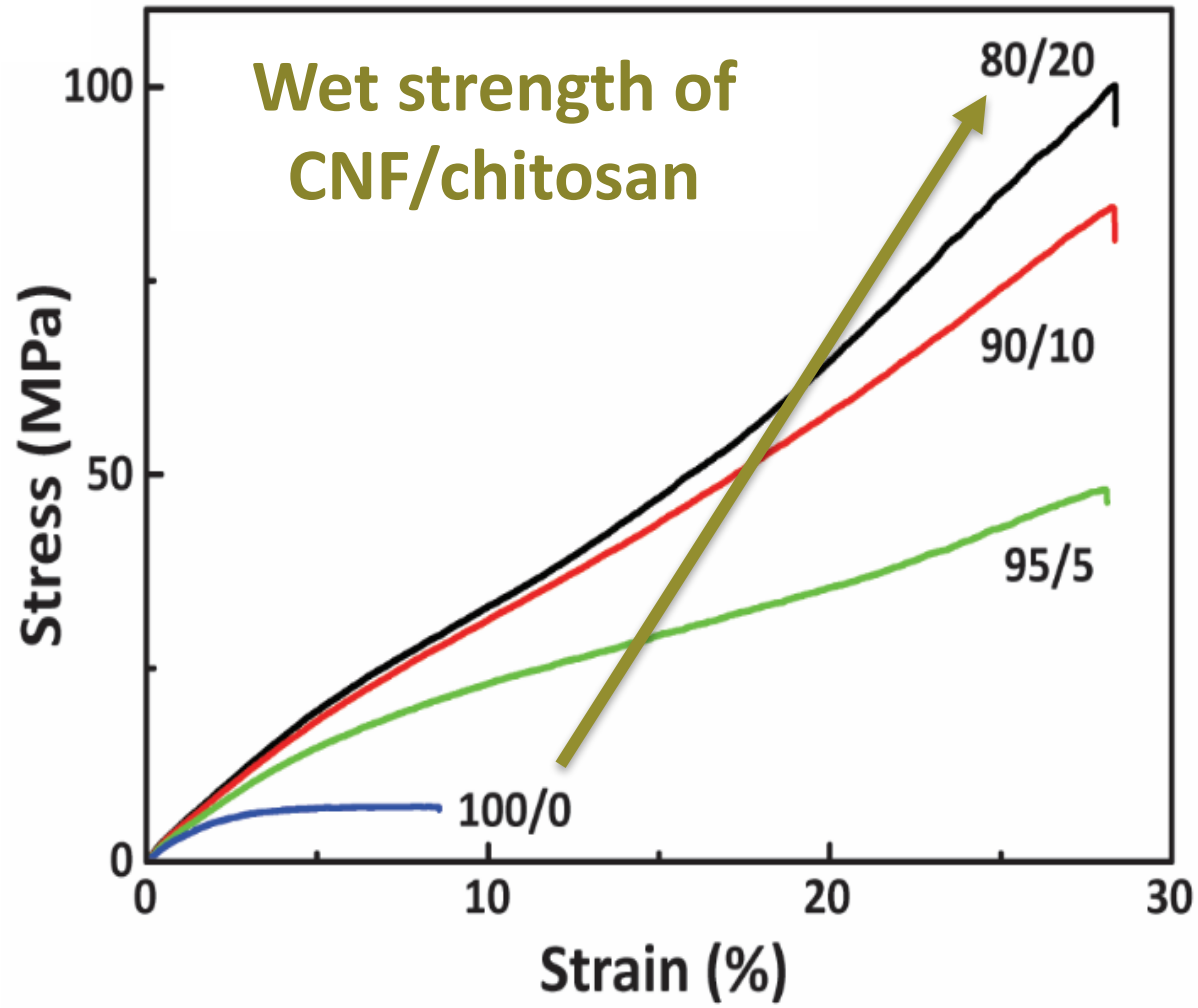




Guo et al. **ACS Applied Materials & Interfaces** 34115 (2016)

What about bulk modification?





Fire retardancy (Cellulose 177, 13-21, 2017)

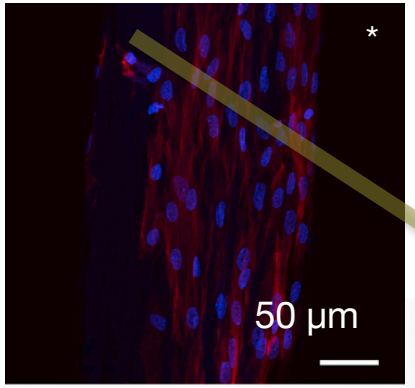
Toivonen, *Biomacromolecules*, 16, 1062-7 (**2015**)

DESIGN DRIVEN VALUE CHAINS IN THE WORLD OF CELLULOSE DWoC

Filaments & functions

High price, low volume

First applications



1. Bioactive textiles

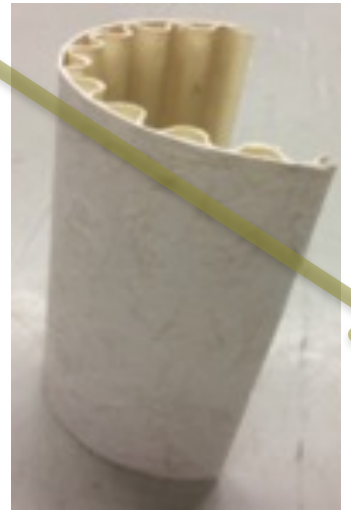
1D diagnostics

Wearable electronics

2. Composite reinforcement for automotive / sports

3. Textiles

Packaging, Disposables



Low price, high volume

*Mertaniemi et al. *Biomaterials* 82 (2015) 208-220.

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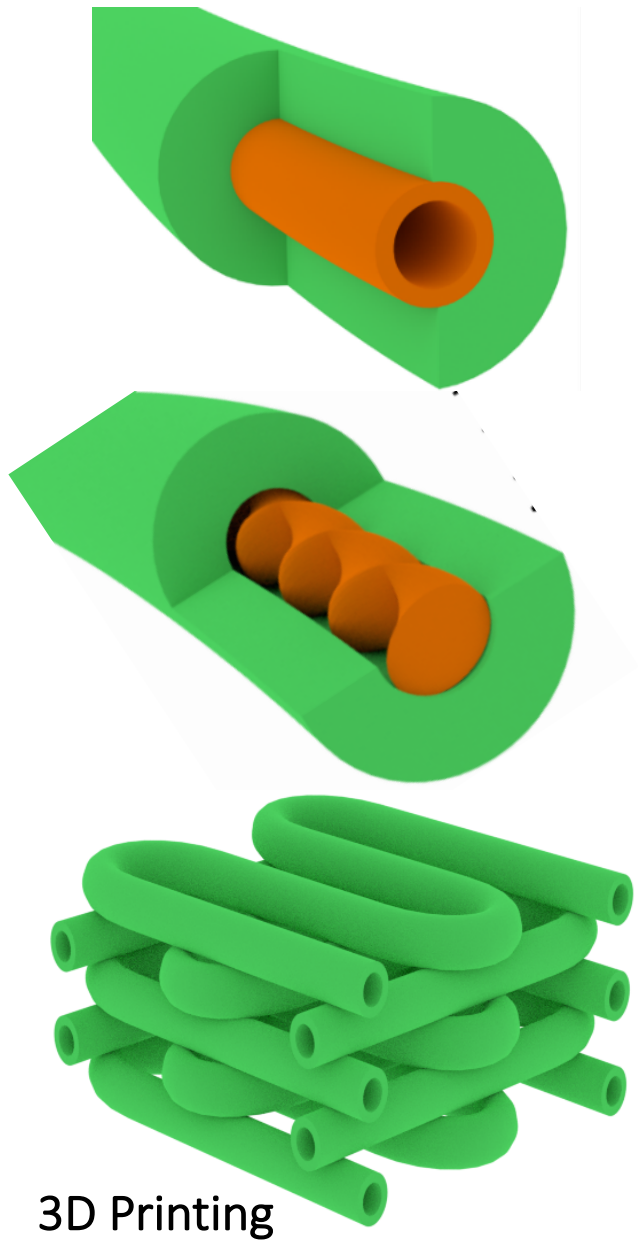
DESIGN DRIVEN VALUE CHAINS IN THE WORLD OF CELLULOSE DWoC 2.0

Huge opportunities to develop functions

(Photos: ChemArts2014)



3D Printing

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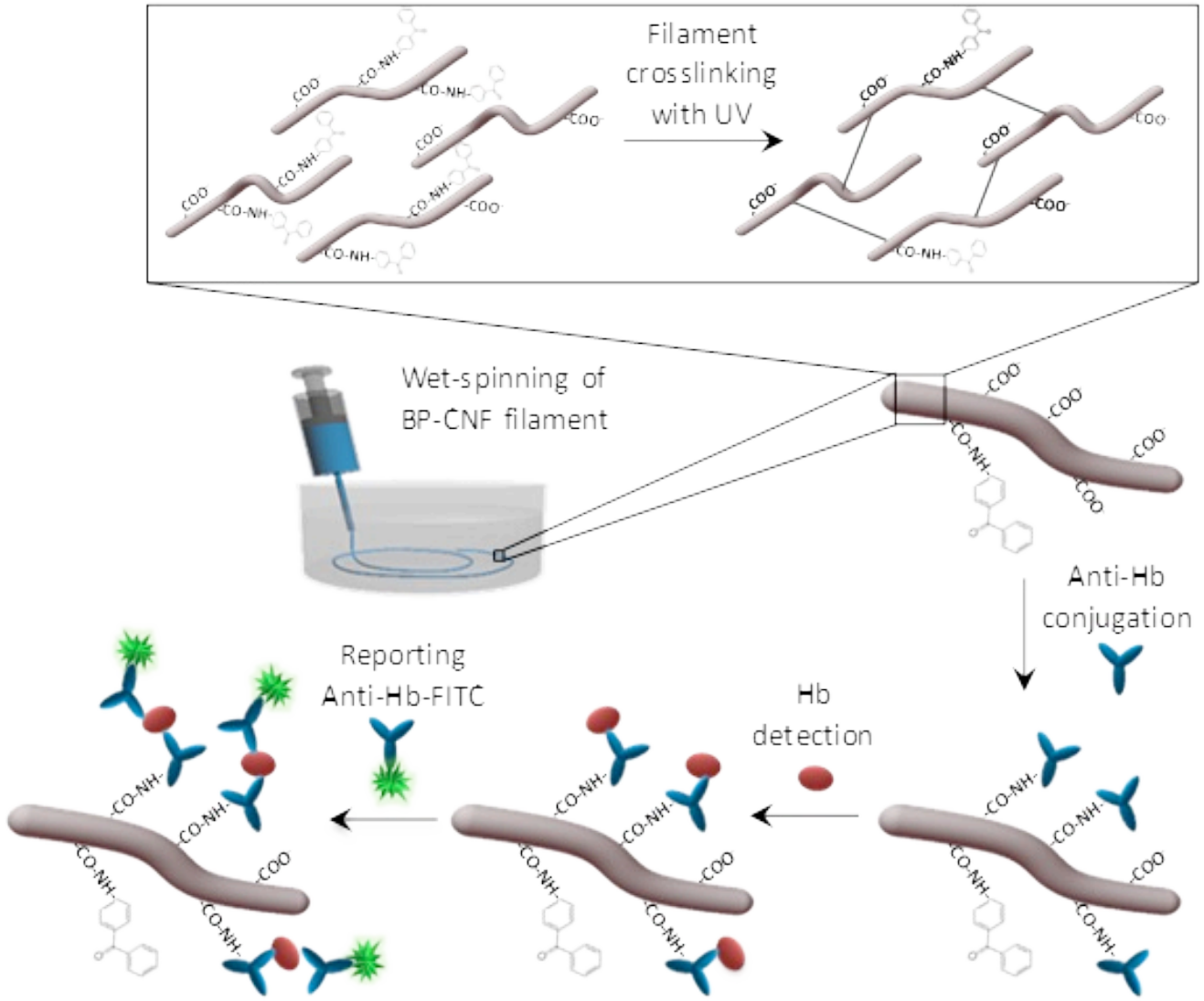
DESIGN DRIVEN VALUE CHAINS IN THE WORLD OF CELLULOSE DWoC

Bifunctional filaments
bioactivity and wet strength



RSC Advances 6, 85100-85106 (2016)
ACS Applied Materials & Interfaces 8, 15607-15614 (2016)
ACS Applied Materials & Interfaces 8, 5668-5678 (2016)
ACS Applied Materials & Interfaces (2017)

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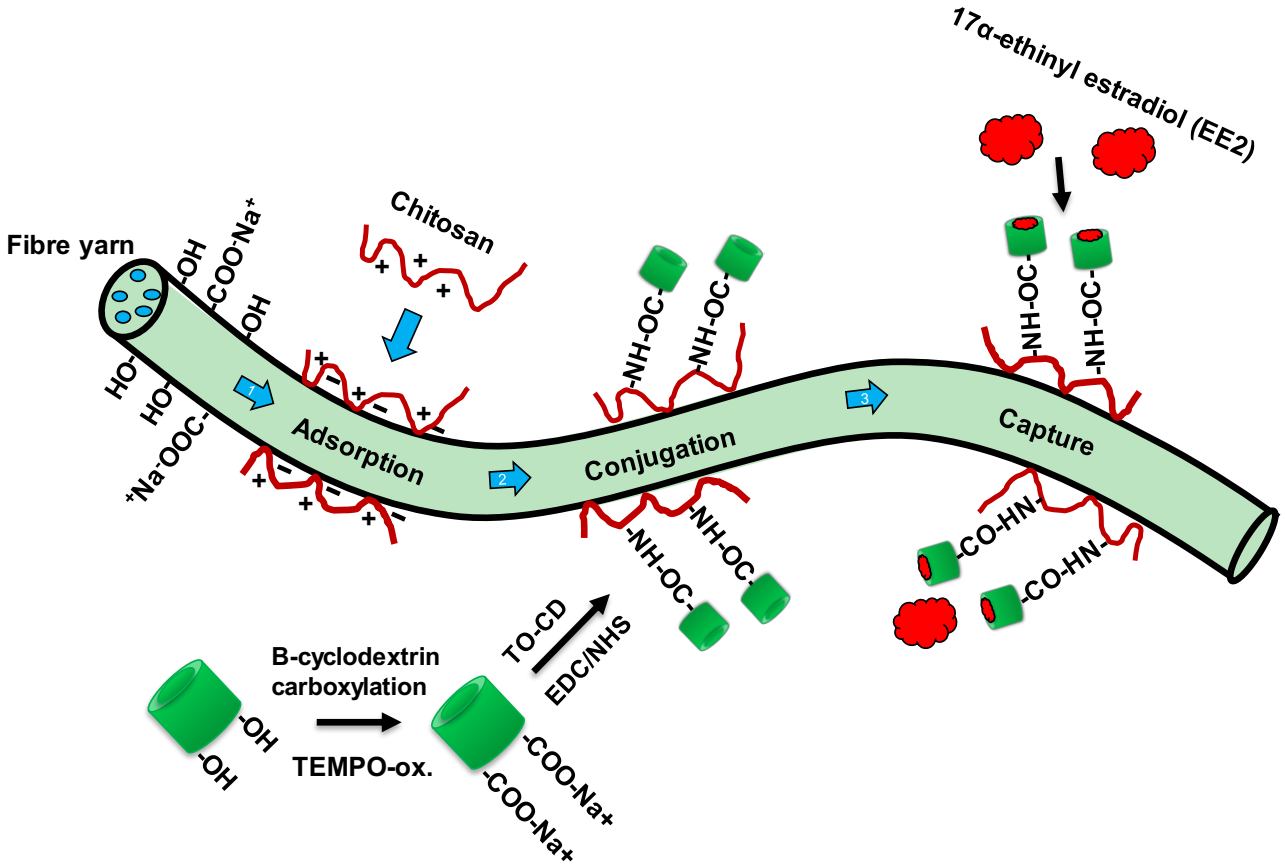

- Cyclodextrin-functionalized fiber yarns for non-specific hormone capture in aqueous matrices
- Antibody-functionalized filaments for human plasma protein detection, removal or affinity separation.

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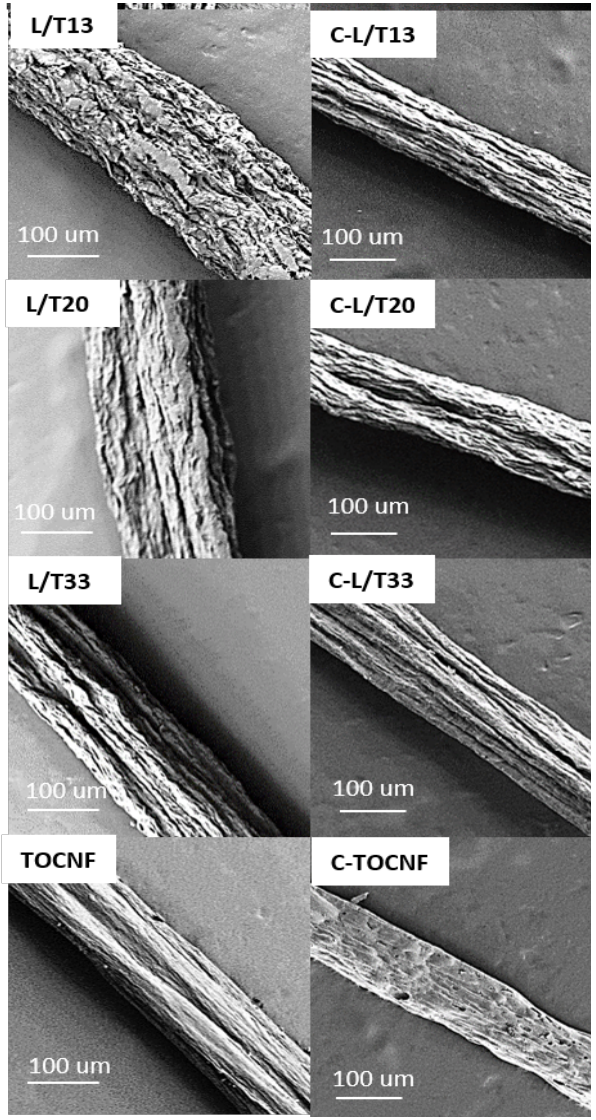
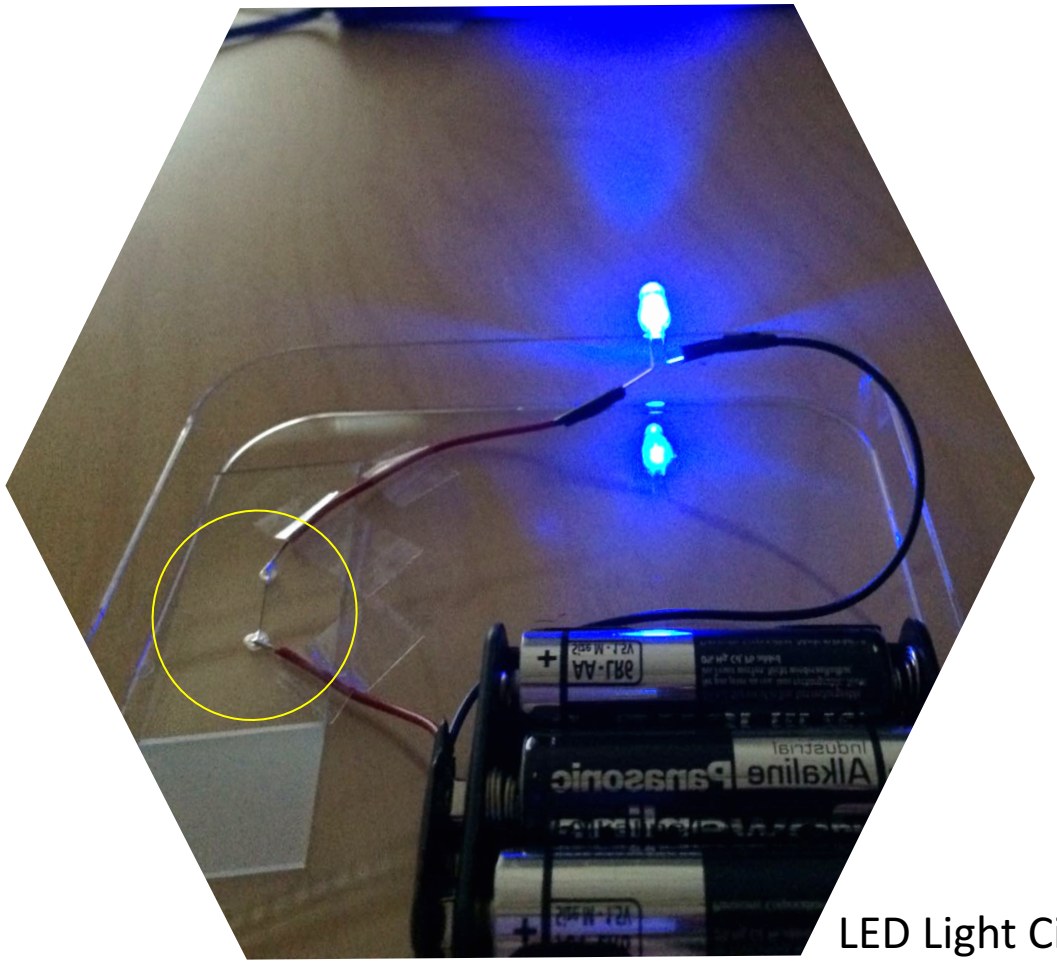
Conductive and super-capacitive filaments





LED Light Circuit

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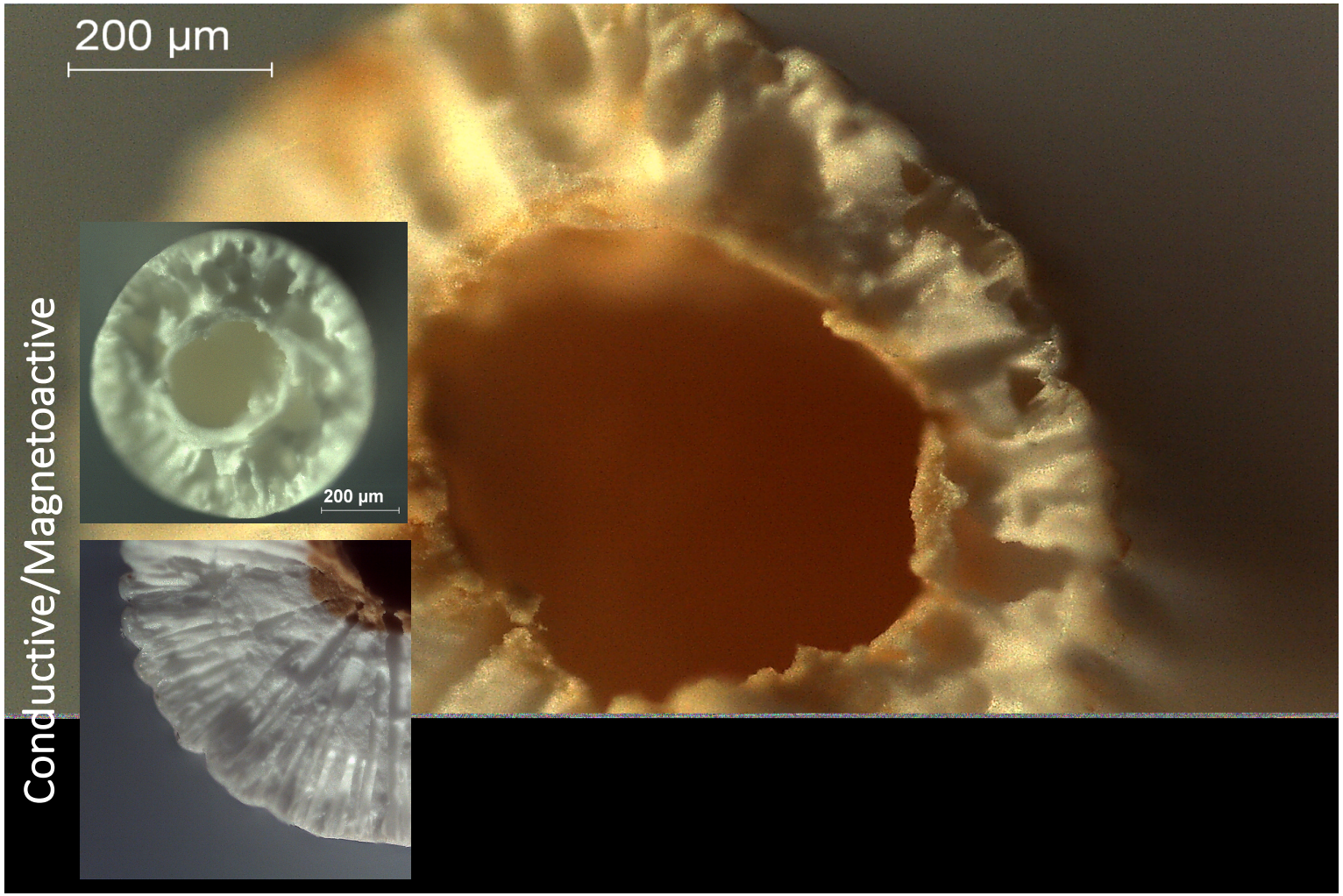
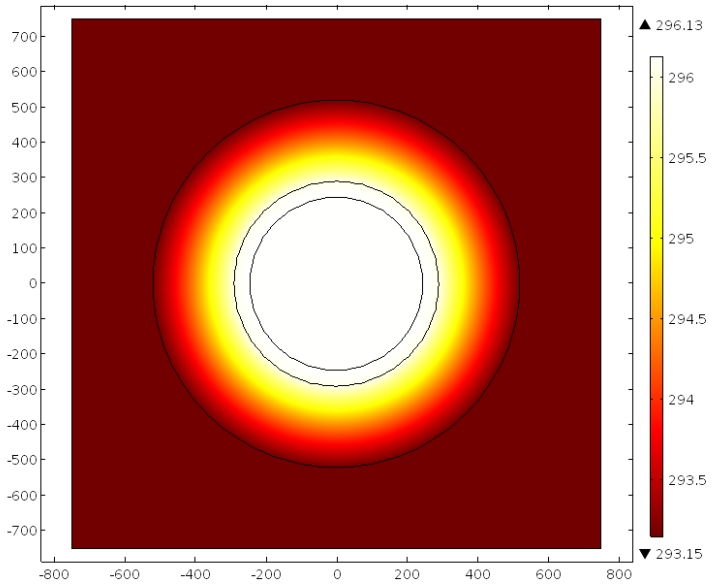
Magnetic, thermo-electric, thermo-chromic filaments





COMSOL simulation

- Porosity 82 %
- Heating power 400 W/g
- MNP 30 wt%

Mark 2009; Westrum & Gronvold 1969; Slack 1962

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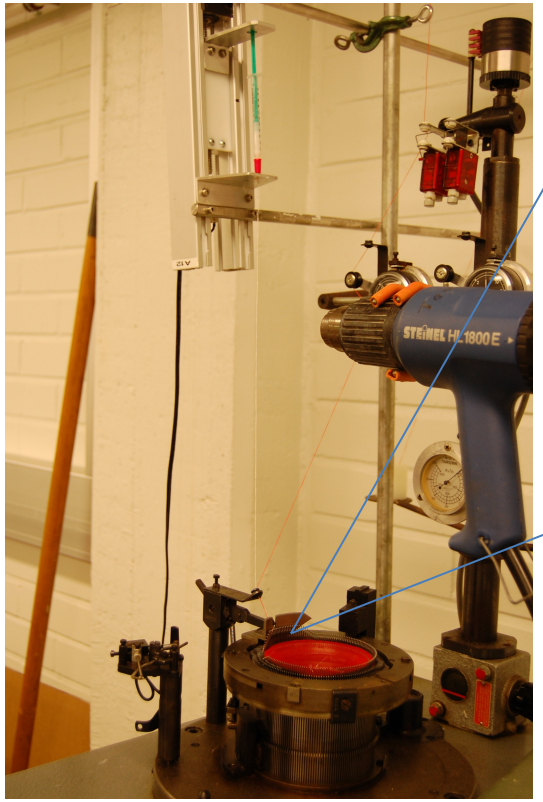
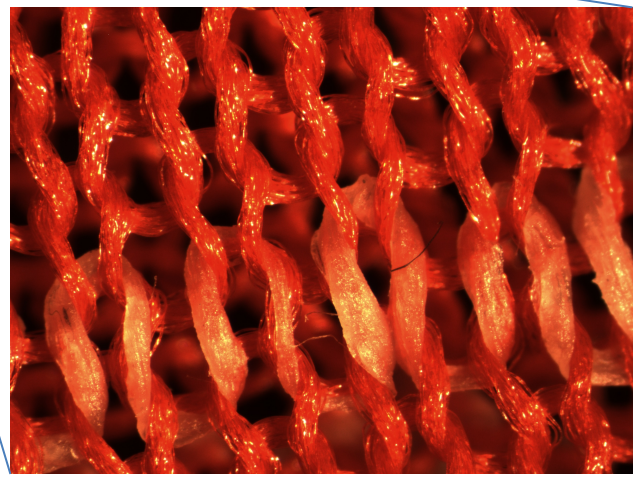
DESIGN DRIVEN VALUE CHAINS IN THE WORLD OF CELLULOSE DWoC

Towards a combined spinning-knitting process





Closing remarks

Dilution

High shear

Slender CNF

Strong & functional filaments

Extension

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