



ENFiber

European Network for Valorising Food
Processing Waste into Sustainable Fibers

Cellulose and hemicellulose chemistry Polysaccharide chemistry

Gregor Lavrič



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Pulp and Paper Institute, National Institute of Chemistry





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Alternative raw material sources

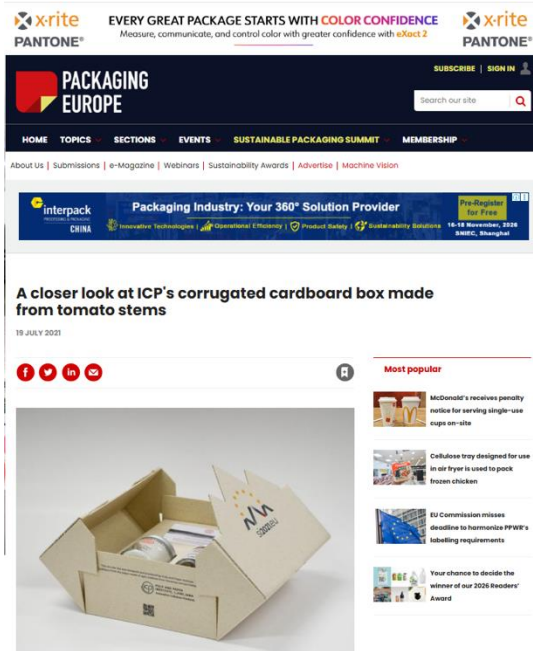
- reducing **CO₂ emissions**;
- preserving **forests and biodiversity**;
- using **locally available resources**;
- reducing dependence on imported raw materials;
- improving **supply-chain**



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Alternative raw material sources



Wet (and dry) thermoforming

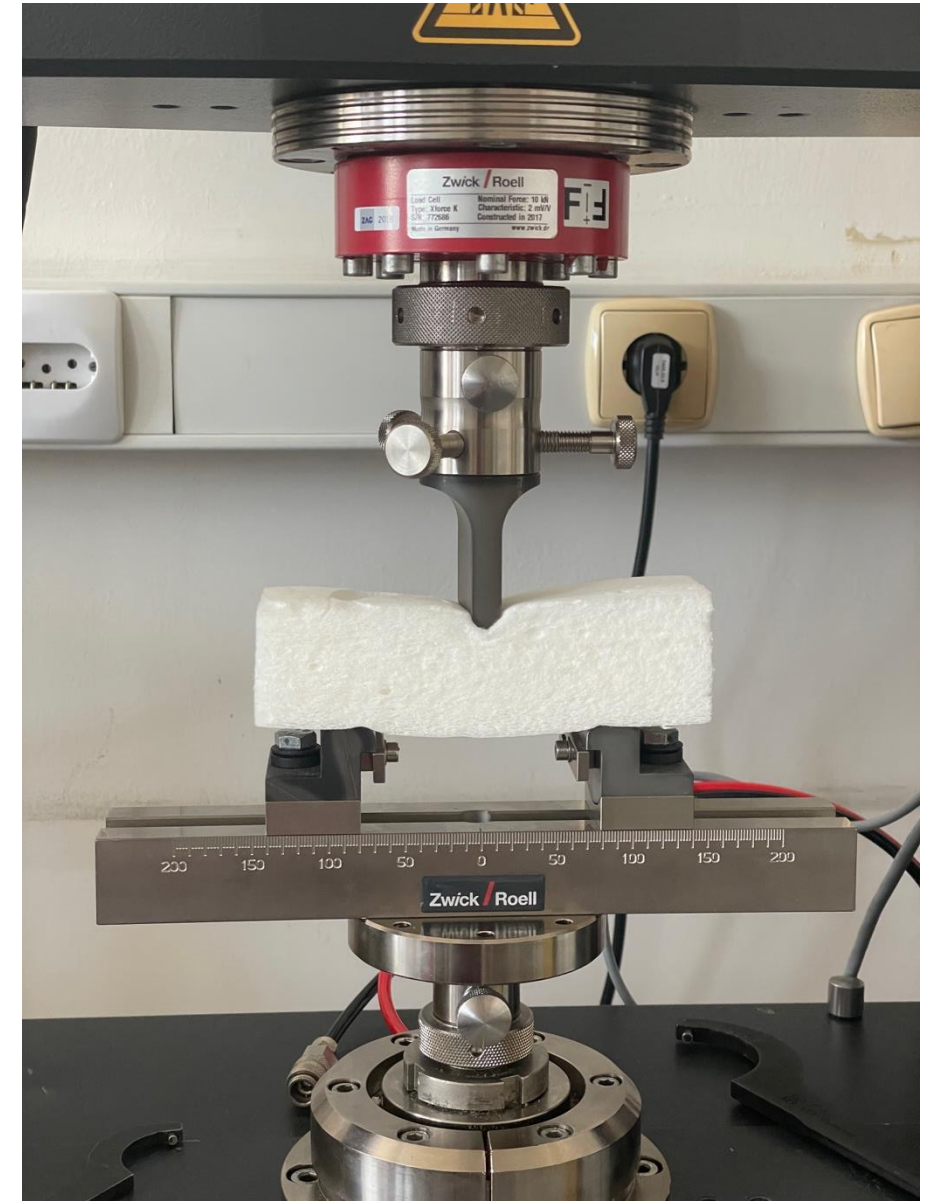
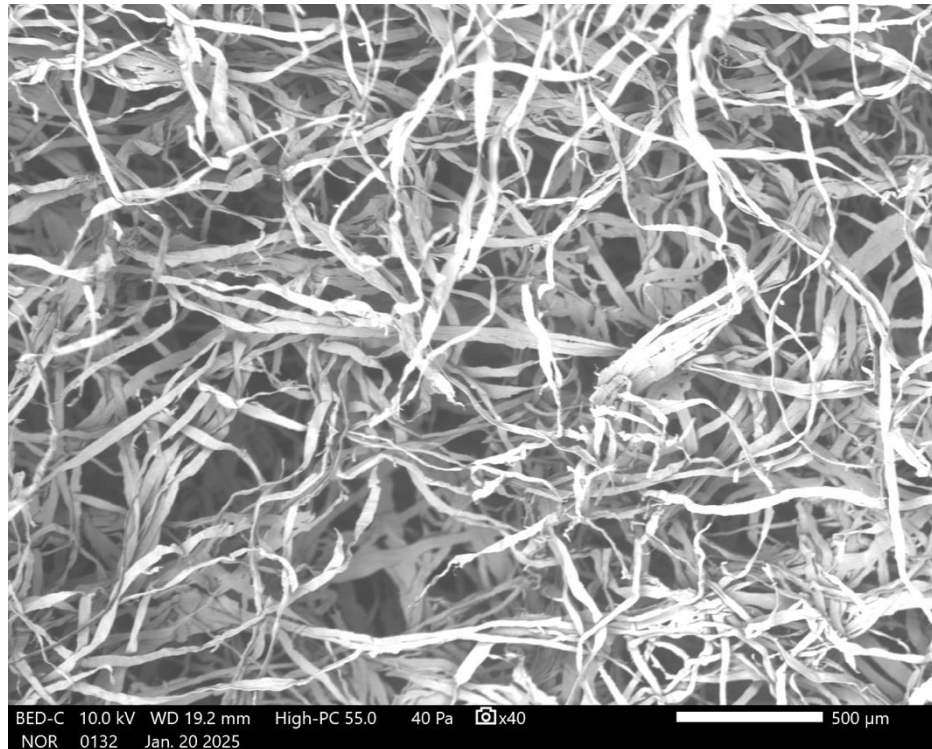


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Cellulose foams

- alternative to expanded polystyrene (EPS)
- applications: protective packaging and thermal insulation in the construction sector

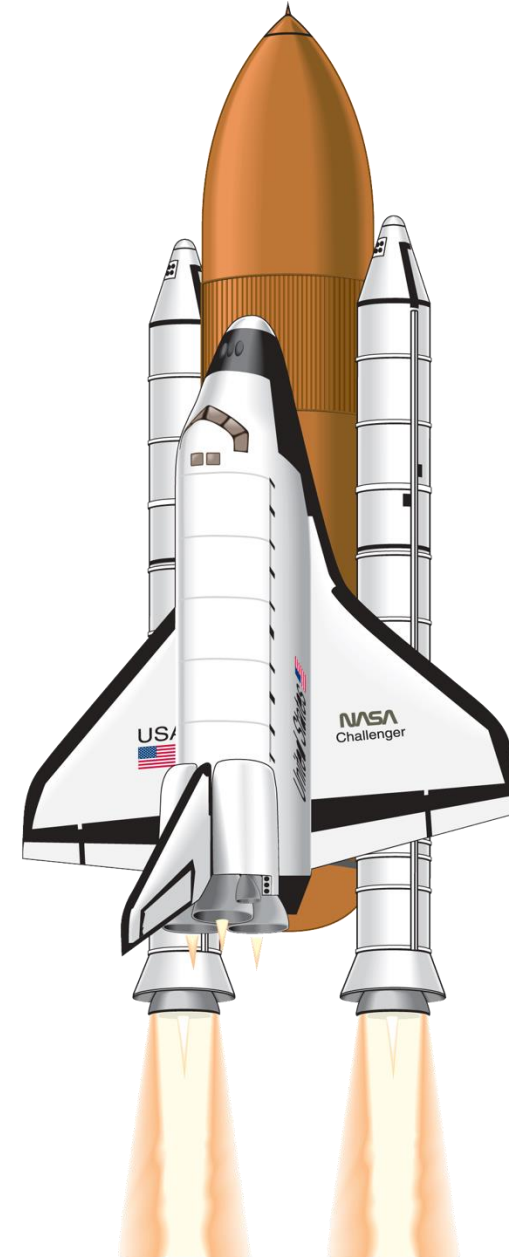


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Nanocellulose

- nanomaterials: one or more external dimensions in the 1–100 nm range
- nanocellulose: bio-based material with high added value
- main groups: **nanofibrillated cellulose (NFC)**, **nanocrystalline cellulose (CNC)** and **bacterial nanocellulose (BNC)**
- wide application potential in paper, coatings, films, 3D structures and adhesives



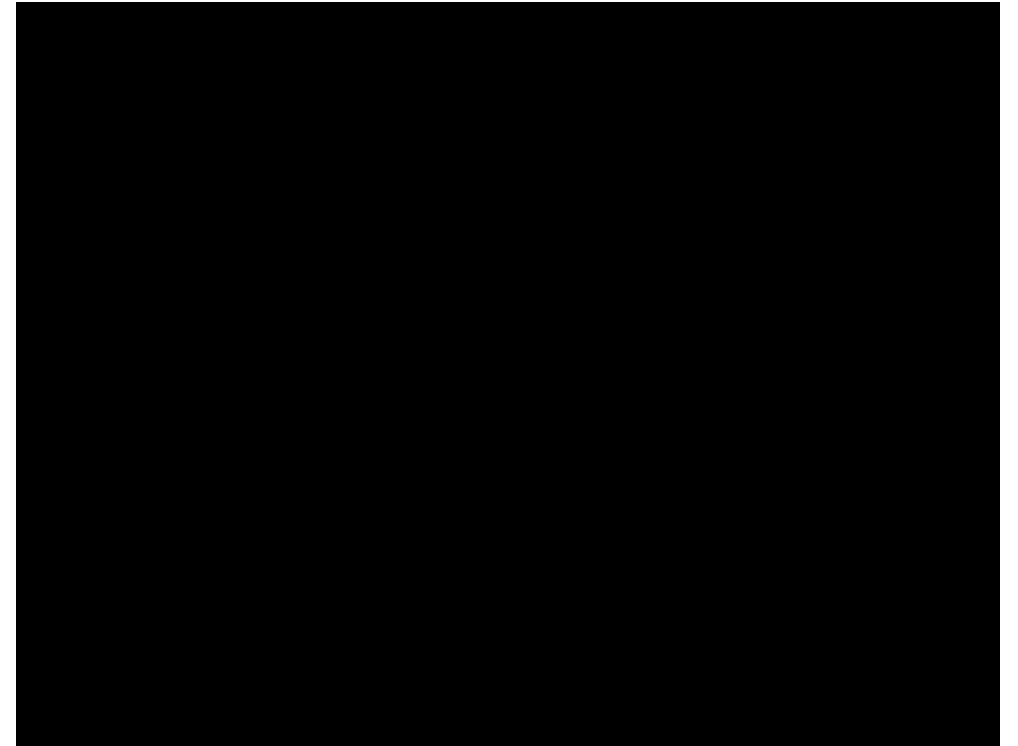
Nanocellulose – preparation

- high-quality NFC and CNC require preliminary processing of cellulose fibres
- key steps: **delignification and bleaching**



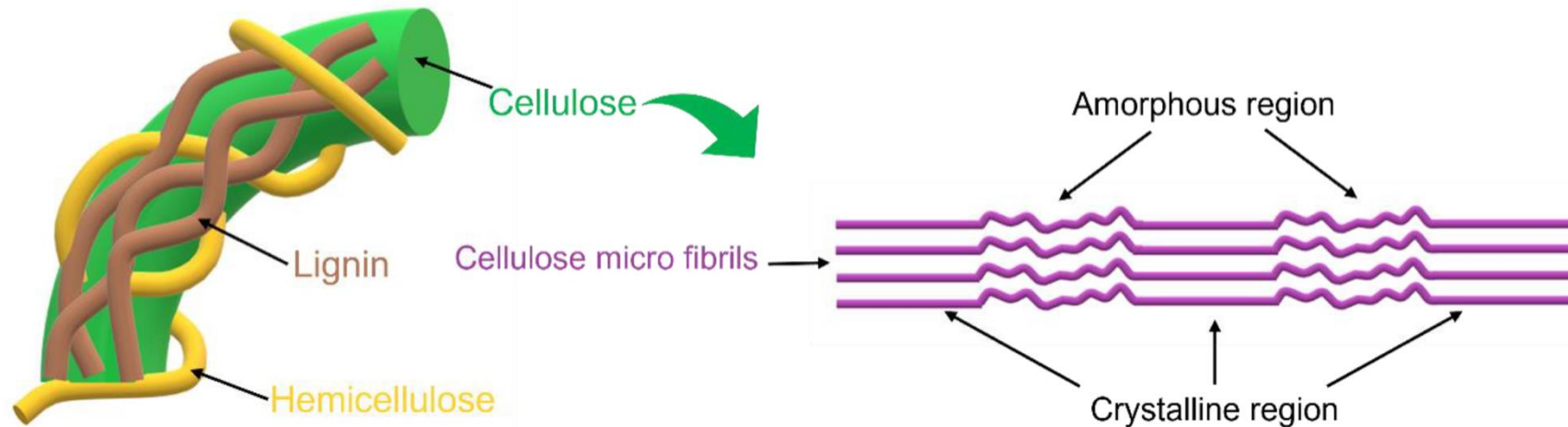
Nanofibrillated cellulose – NFC

- wood-derived cellulose fibres
- annual plants, including Japanese knotweed and other alternative raw material sources
- mechanical treatment, chemical treatment (e.g. TEMPO oxidation) or enzymatic pre-treatment
- the goal is to open the fibre structure and enable controlled fibrillation
- **a transparent gel is formed; average width: 20–40 nm**



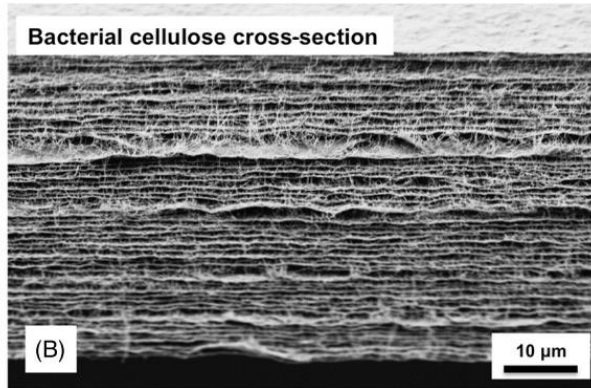
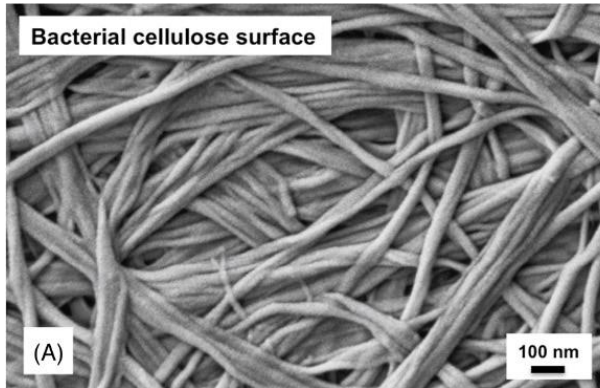
Nanocrystalline cellulose – CNC

- prepared from wood-derived cellulose fibres or annual plants, such as cotton
- acid hydrolysis cleaves microfibrils transversely, mainly in amorphous regions
- **rod-shaped cellulose crystals: 2–20 nm**
- fewer amorphous regions, high crystallinity and 20–50% yield
- (significant) environmental burden?



Bacterial nanocellulose – BNC

- production differs completely from NFC and CNC production
- produced by bacteria such as *Acetobacter xylinum* through polymerisation of glucose
- average width: 2–100 nm
- **does not contain lignin or hemicelluloses**
- also, a by-product of conventional vinegar production



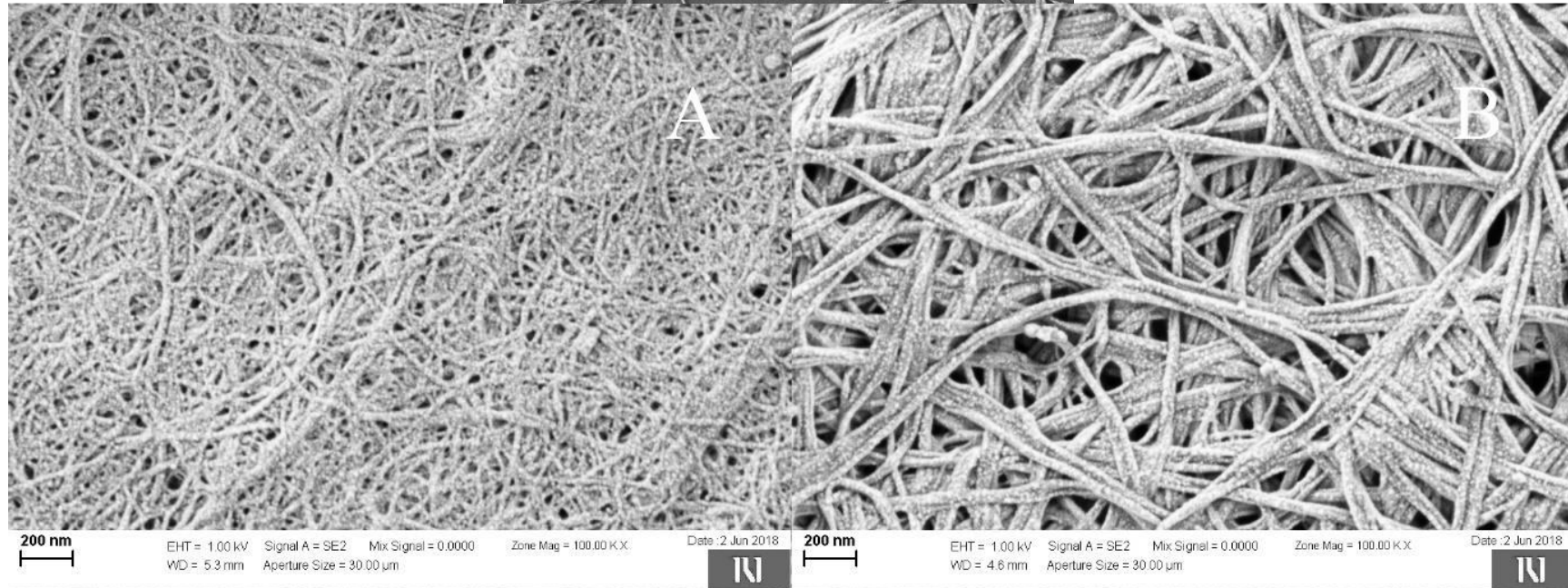
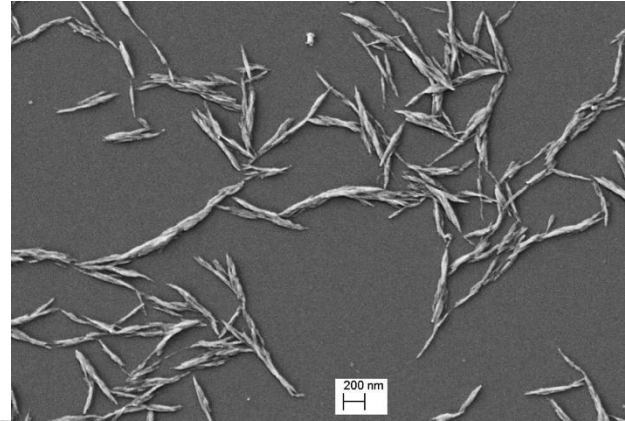
Bacterial nanocellulose – BNC



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NFC, CNC, BNC



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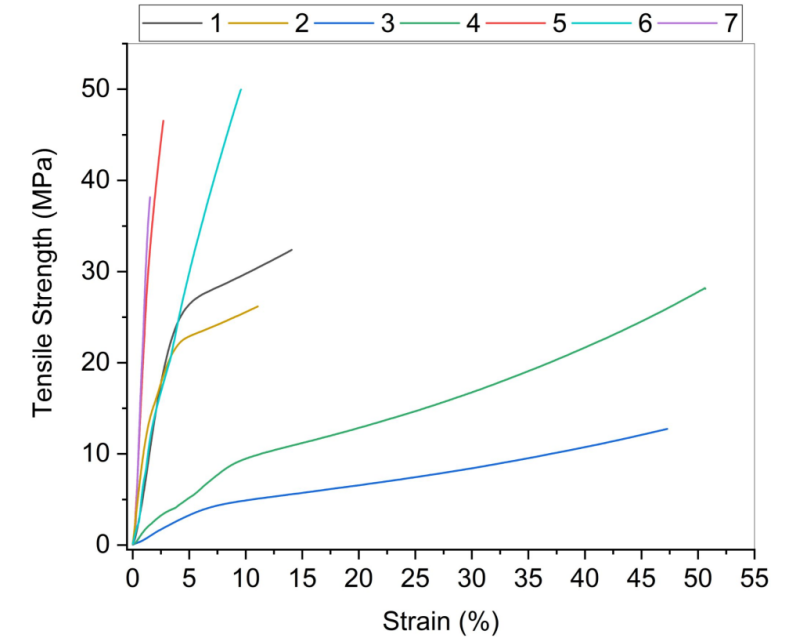
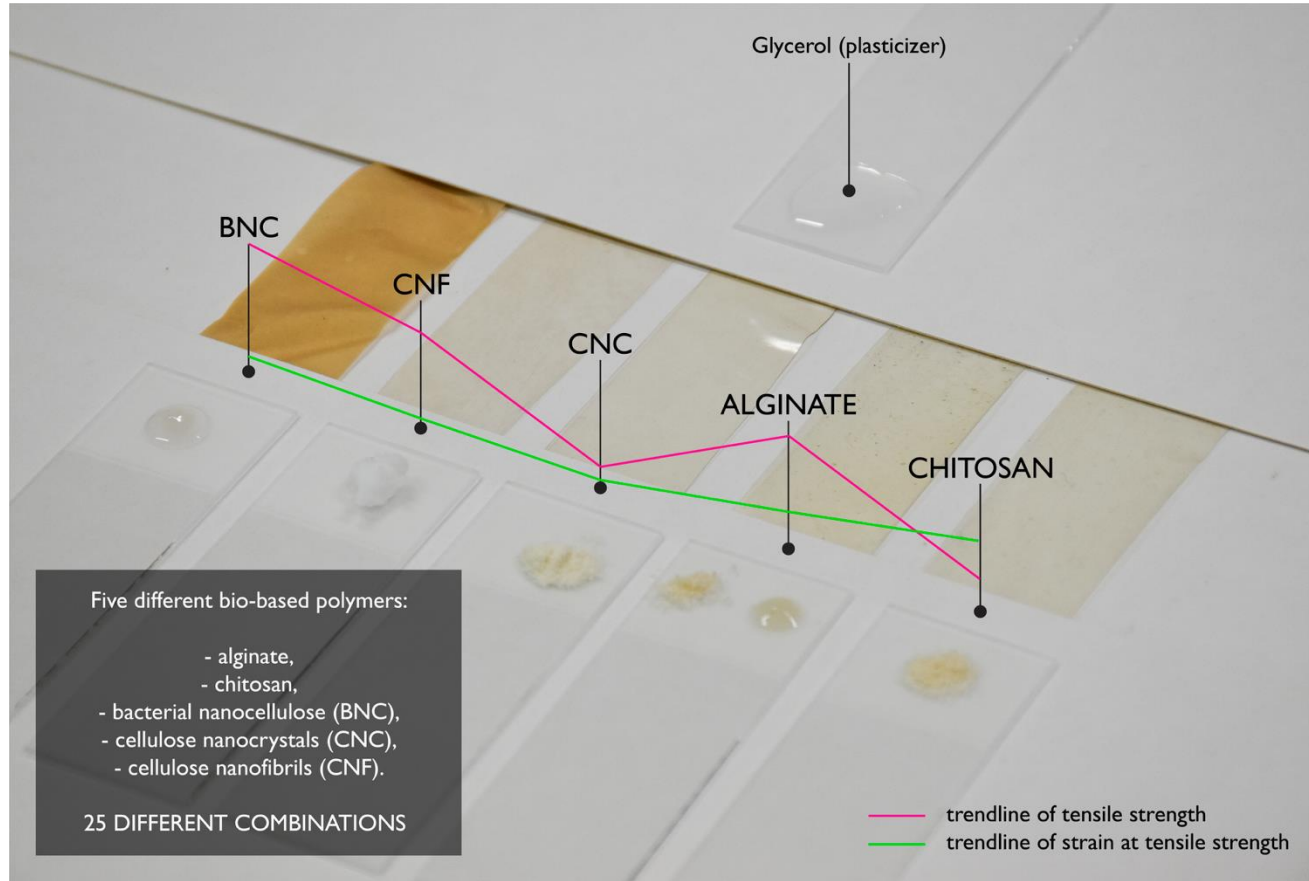
Nanocellulose in papermaking – coatings

- **improved barrier properties**
- improved graphic properties
- replacement of components based on petroleum derivatives
- rheology?



Nanocellulose in packaging

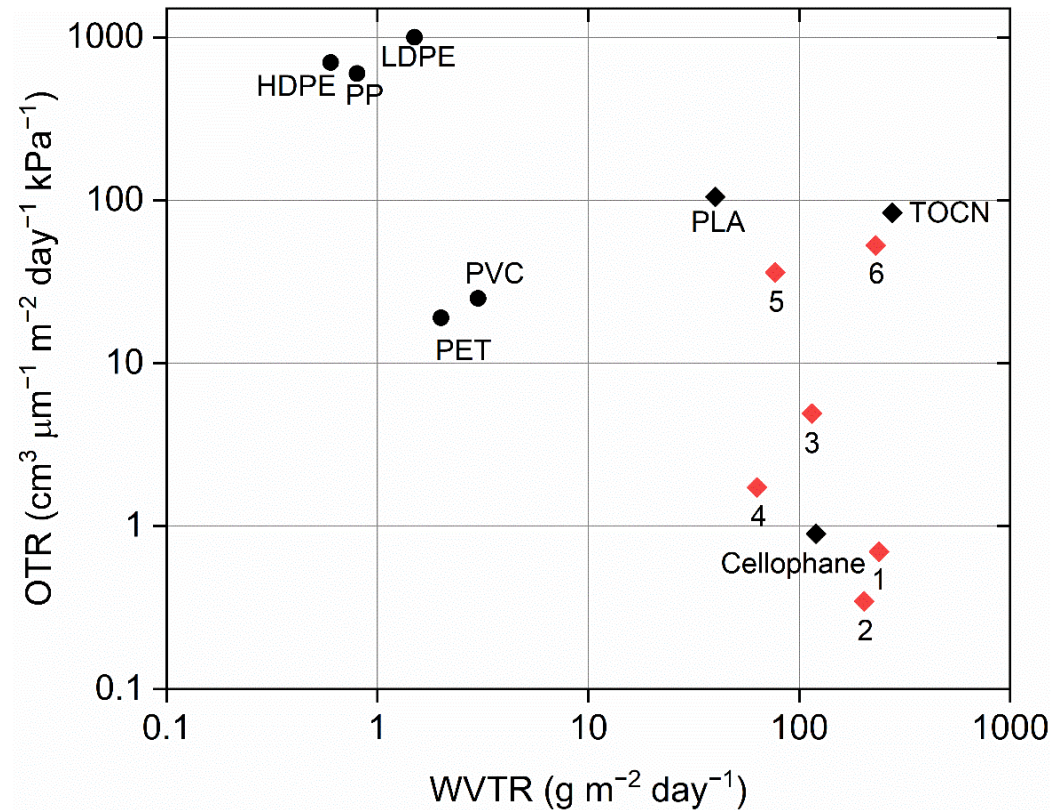
- thin, flexible, (partly) translucent films



Sample Name	Film Composition
Film 1	Alginate
Film 2	Alginate + 5% CNC
Film 3	Chitosan
Film 4	Chitosan + 3% CNC
Film 5	BNC
Film 6	BNC + 30% glycerol
Film 7	CNF + 30% glycerol

Nanocellulose in packaging

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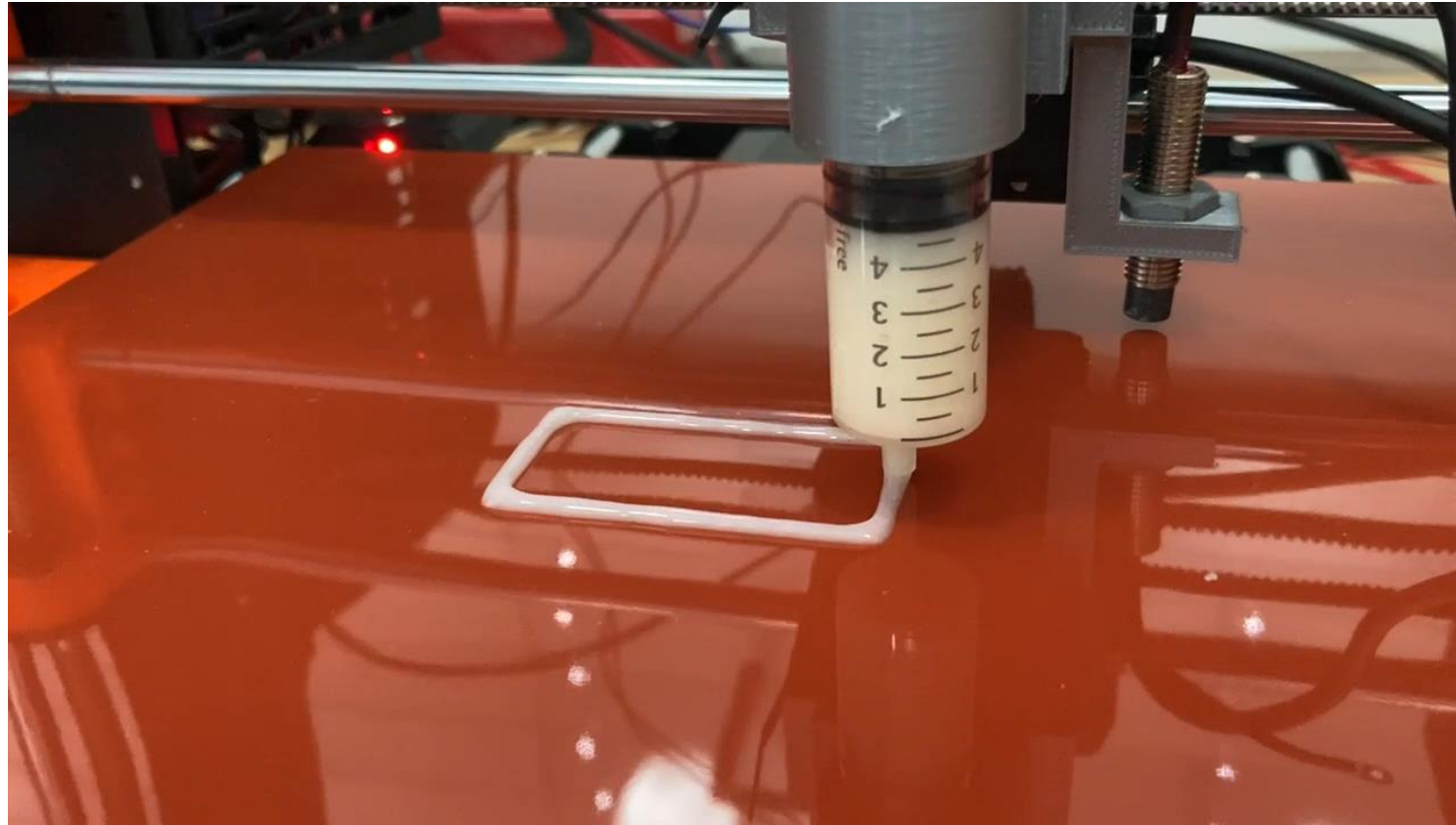


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Nanocellulose in packaging

- 3D printing of hydrogels

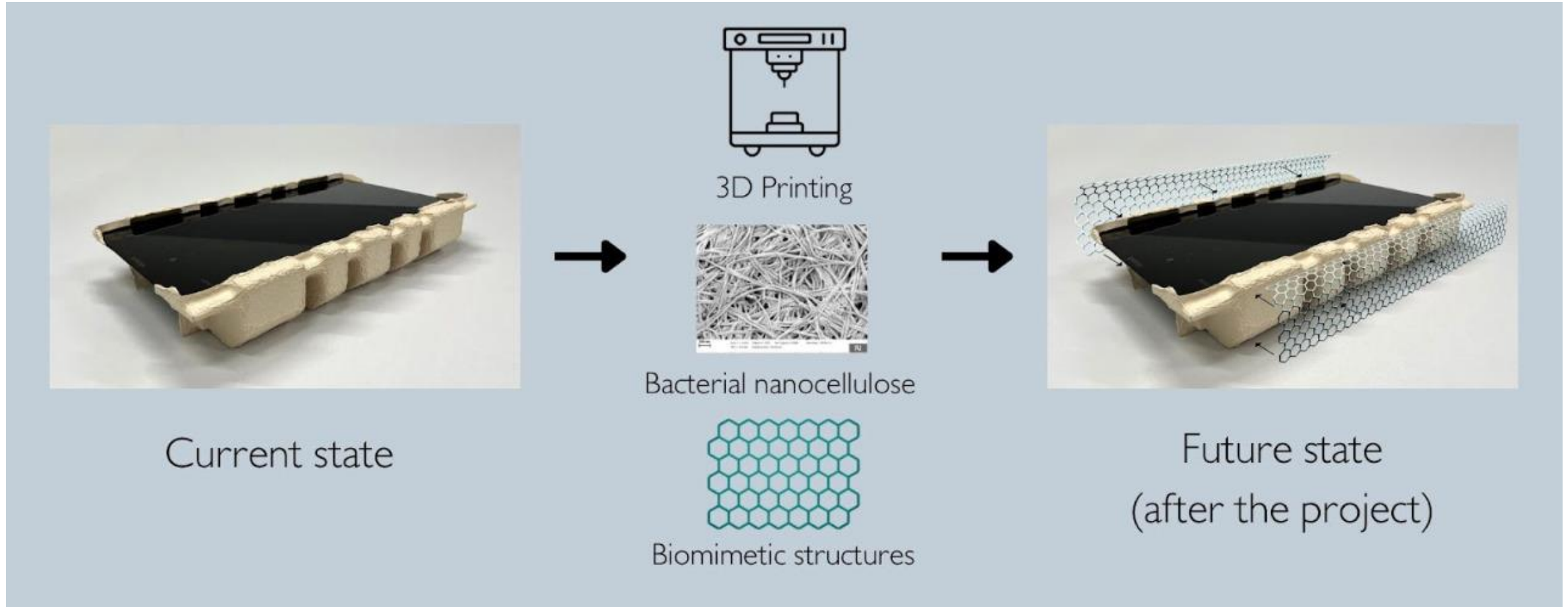


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Nanocellulose in packaging

- 3D printing of hydrogels



Nanocellulose in packaging

- combination with other polymers
- drying/crosslinking?
- structures of arbitrary shape – protective elements
- 4D packaging?



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Acknowledgement



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