FinnCERES Flagship for Materials Bioeconomy

Industry meets FinnCERES

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FinnCERES Materials Cluster

Aalto University

VTT

ACADEMY OF FINLAND

Global challenges

- *Climate change*
- *Resource sufficiency*
- *Quality of life*

Urgent need to transform the existing materials paradigm

Aims of the flagship

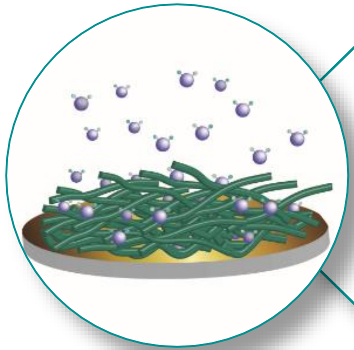
- **Overall aim**
  - To establish a globally recognized Competence Cluster in the area of materials bioeconomy in Finland

- **Specific aims**
  - Research and control the interactions of lignocellulosics
  - Develop methods for lignocellulose disassembly
  - Create disruptive methods for analysis (theoretical, experimental and computational)
  - Develop advanced material solutions and applications
    - Development of e.g. structured and light-weight materials, textiles, biocomposites and food applications
    - Future added-value applications, e.g. energy harvesting, capturing from air and water, nanophotonics and optoelectronics

From fundamental research to industrial implementation and innovations

FinnCERES Materials Cluster

Main research areas



1. Fundamentals

- Interactions (water, cellulose, hemicellulose, lignin, fibre)
- Architecture of lignocellulose and access to the structure
- Modelling

2. Processing

- Biomass fractionation
- Biomass modification

3. Applications

- Development of e.g. structured and light-weight materials, textiles, biocomposites and food applications
- Future added-value applications, e.g. energy harvesting, capturing from air and water, nanophotonics and optoelectronics

Aalto–VTT collaboration - Solving challenges of great importance together

FinnCERES Competence Center

From lignocellulose science to materials bioeconomy

- *1st in the world strategic research of its kind*
- *Unique world-class infrastructure*

Aalto University

- Multidisciplinary science, art, technology and business
- Highly ranked scientific outcome
- Educational aspects

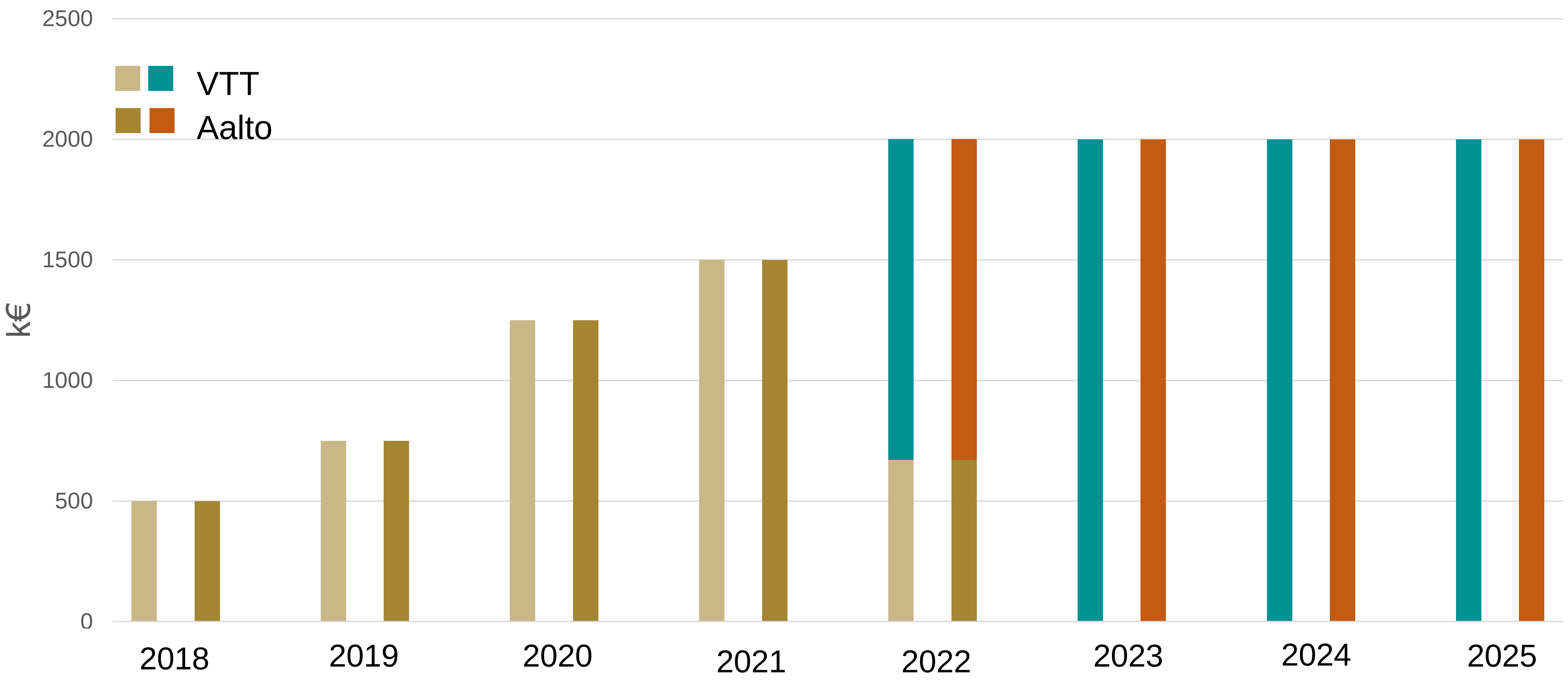
Inspiring innovation and entrepreneurial environment

VTT

- Multidisciplinary applied research and innovation
- Global industrial networks
- Piloting capabilities

FinnCERES budgets for eight years

total budget 24 M€ from the Academy of Finland



Research examples

FinnCERES
Materials Cluster

Role of oxygen in fractionation

Hypotheses

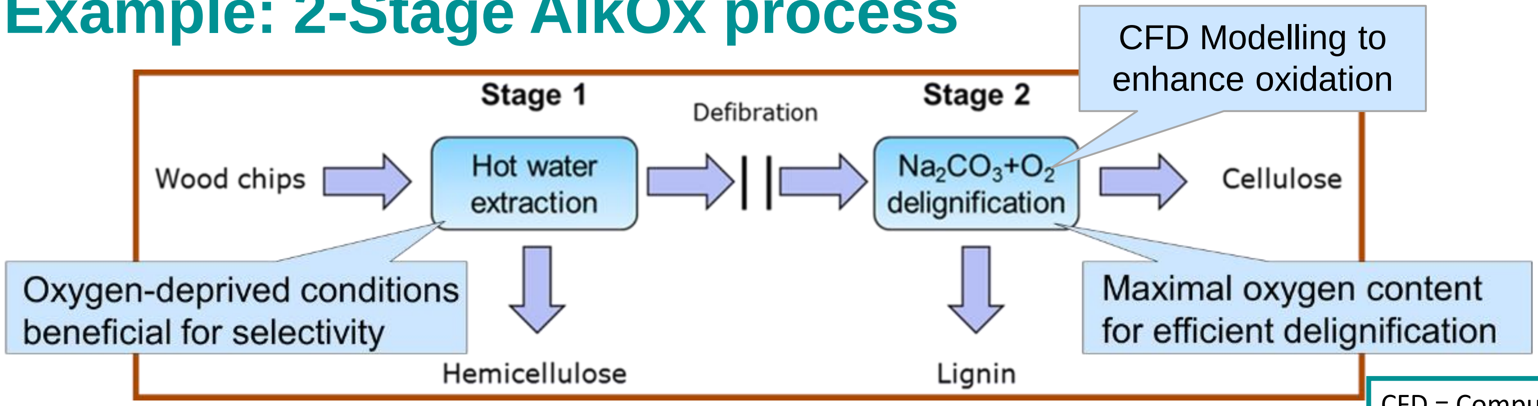
Oxygen induces

- Formation of Lignin-Carbohydrate Linkages (LCC)
- Auto-oxidation of extractives: → polymeric compounds and chromophores hindering fractionation

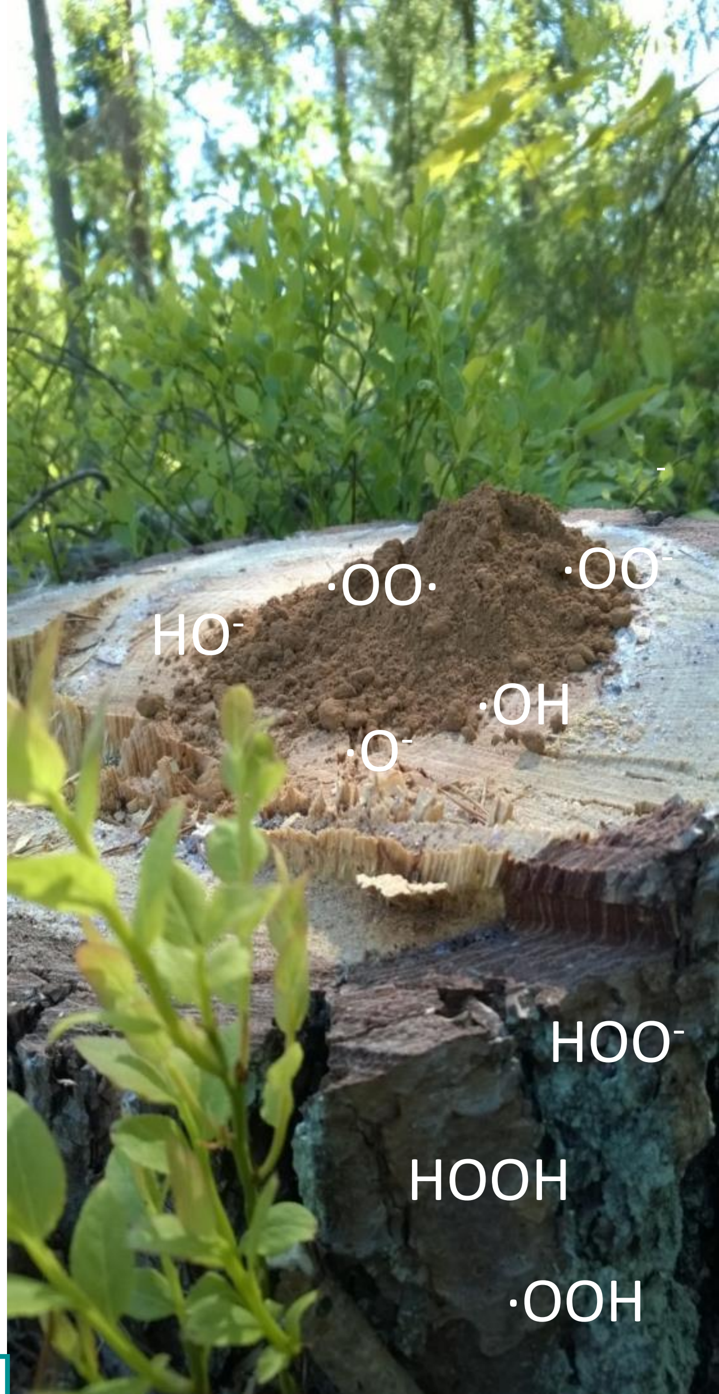
Oxygen induces

- Improved water solubility of lignin and thus delignification
- Surface active properties to lignin, necessary e.g. for dispersant applications

Example: 2-Stage AlkOx process



CFD = Computational Fluid Dynamics



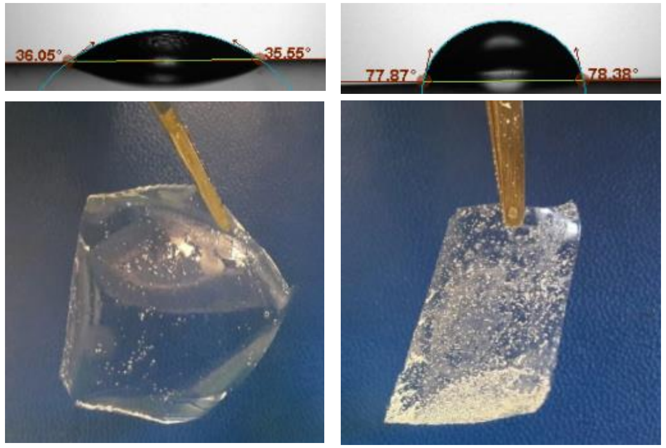
Courtesy: Anna Kalliola

Capturing with cellulose materials

1.

Particle size ~ 250 μm
Density = 1.1 g/cm^{3}[15]

Nanocellulose | Nanocellulose +poly(styrene)

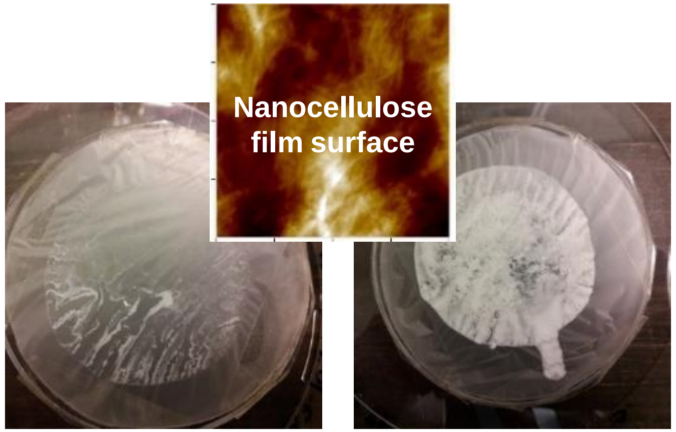


Using intrinsic properties of cellulosic materials we can for example:

1. Capture submerged microplastic beads by hydrophobic interactions
2. Capture floating microplastic beads by cohesion
3. Capture small molecules by specific and non-specific interactions

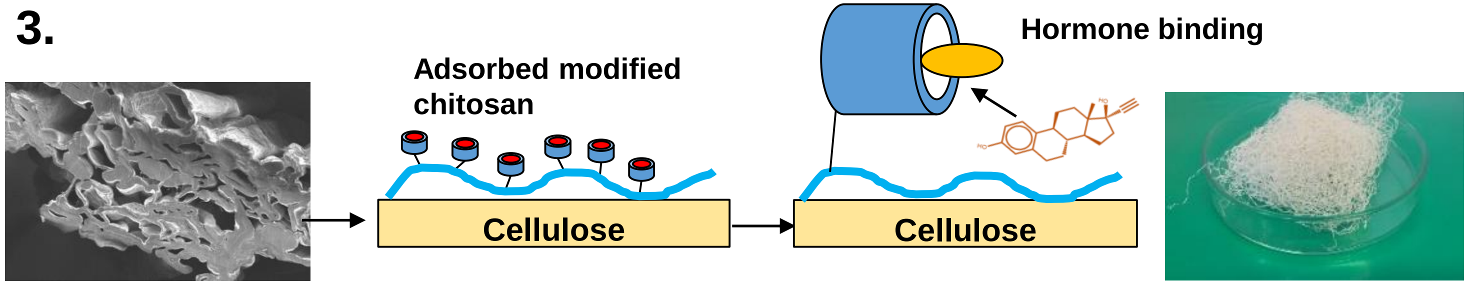
2.

Particle size ~ 48 μm
Density = 0.94 g/cm^{3}



0.1% PE in water | 1% PE in water

3.



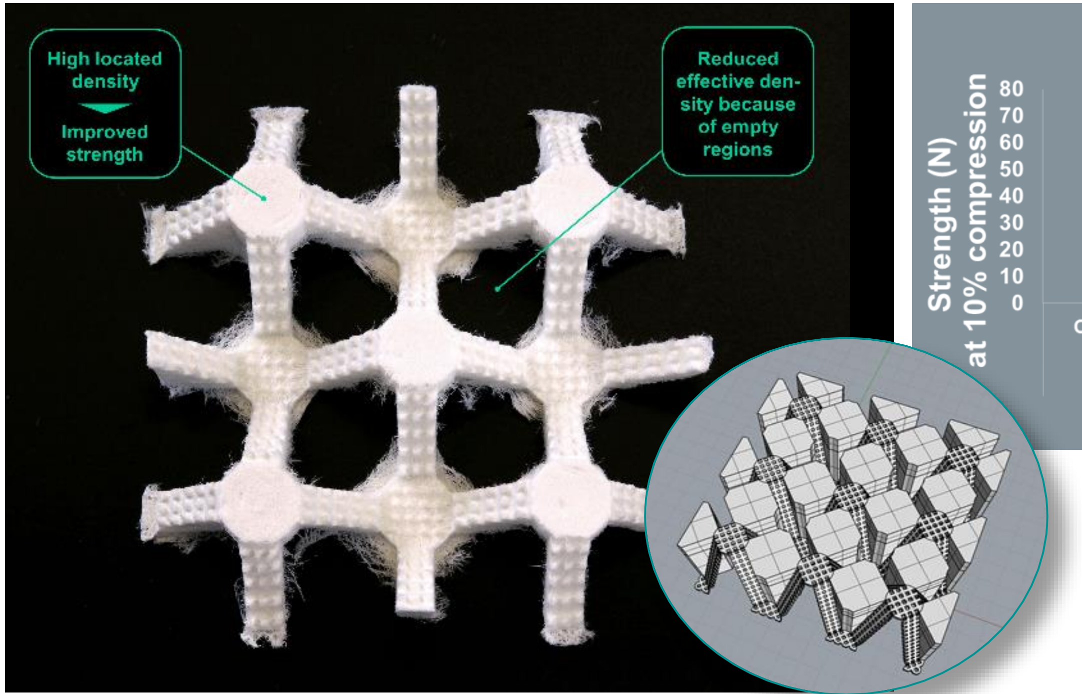
Cellulose fiber yarn | **Functionalized yarn** | **Hormone capturing yarn**

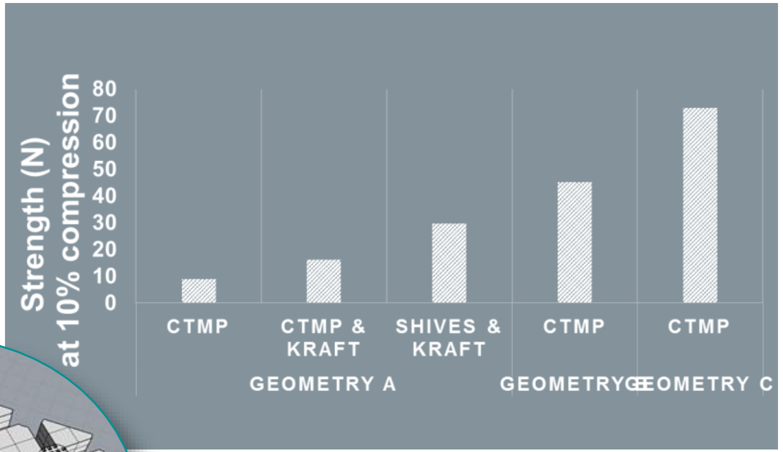
Orelma *et al.* 2018. Cyclodextrin-Functionalized Fiber Yarns Spun from Deep Eutectic Cellulose Solutions for Nonspecific Hormone Capture in Aqueous Matrices. *Biomacromolecules* **19,** 652–661.

Light-weight structures

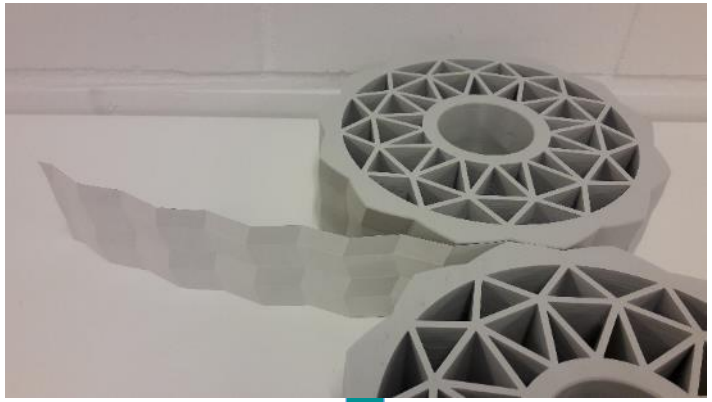
- Complex geometries and functional structures by disruptive technologies e.g. foam forming and additive manufacturing
- Intelligent design of the multi-scale structure
- Understanding of interactions of lignocellulosic materials
- Enhanced mechanical and functional properties (like fire retardant , thermal insulation and moisture tolerance) for construction, packaging and other end-use applications

Enhancing mechanical performance of cellulose materials with designed structural complexity

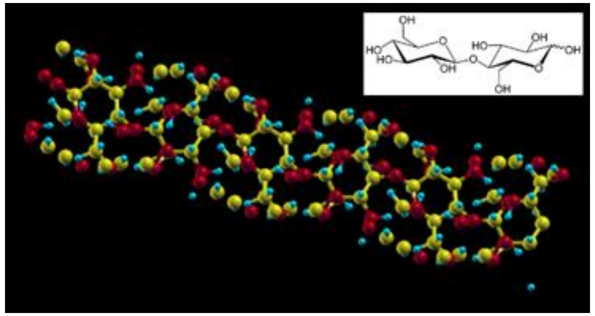




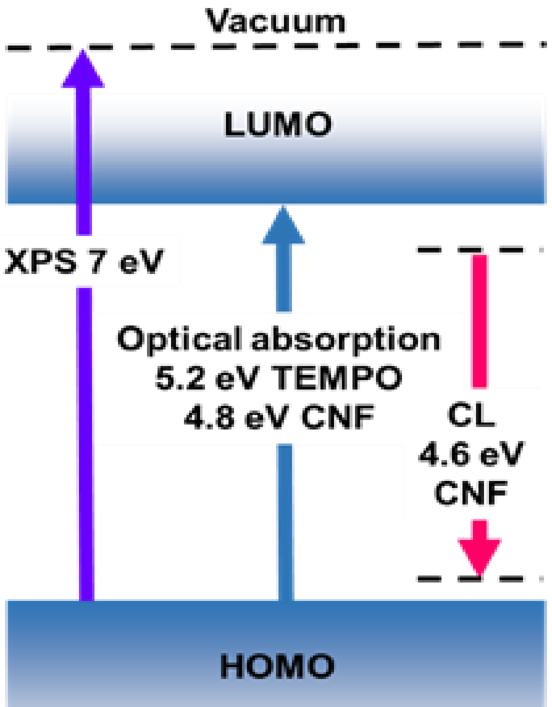
Finely assembled structures (origamis) modelling structures



Photonics, optoelectronics and electronics

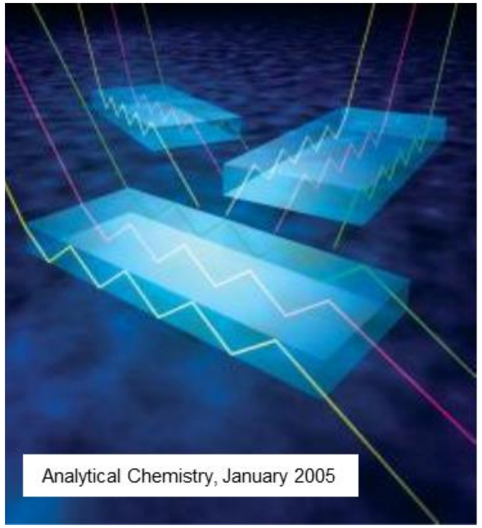


Cellulose nanocrystals are single crystalline with translational symmetry → Dispersive band structure, and consequently <u>nanocellulose is a wide band gap semiconductor</u>

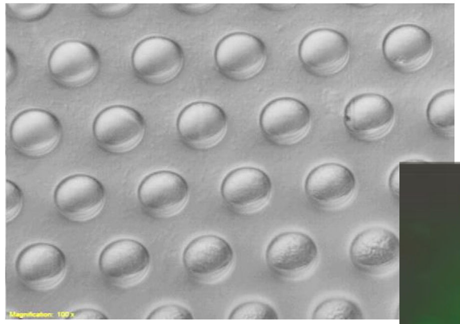


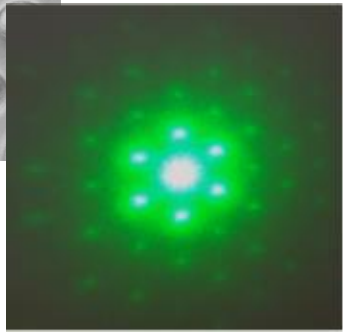
Simao et al., 2015. Optical, mechanical, and vibrational properties of nanofibrillated cellulose: towards a robust platform for next-generation green technologies. Carbohydr. Polym. 126, 40.

Nanocellulose has a large **optical** band gap and low absorption, is transparent down to 235 nm wavelength, emits light, can be dyed, and patterned by casting or nanoimprinting → <u>Very interesting material for photonics</u>



Broad band waveguides





Mäkelä et al., 2016. Fabrication of micropillars on nanocellulose films using a roll-to-roll nanoimprinting method, Microelectr. Eng. 163, 1-6.

Next step is to investigate the **electrical** properties, doping and contacting → Nanocellulose is a new **green** material for <u>electronics and optoelectronics</u> (?)

Thank you for your attention!