EMPA

Materials Science & Technology

Potential applications of Nanofibrillated Cellulose from wood

Dr Philippe Tingaut

Innovation in the Forest-Based Sector - Prerequisite for the Green Economy

Genève, Palais des Nations 22nd April 2013

Applied Wood Materials

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Dü

Wood Technology
Surface Technology

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D. Heer
A. Huch
T. Künniger
W. Risi

Dü

Cellulose
Nanocomposites

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& T. Zimmermann
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C. Gebald[1]
T. Ho[1]
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E. Strub
J. Zhang[1]

Dü, ETHZ

Bio-inspired
Wood Materials

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Biotechnology
Wood Protection

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M. Schubert
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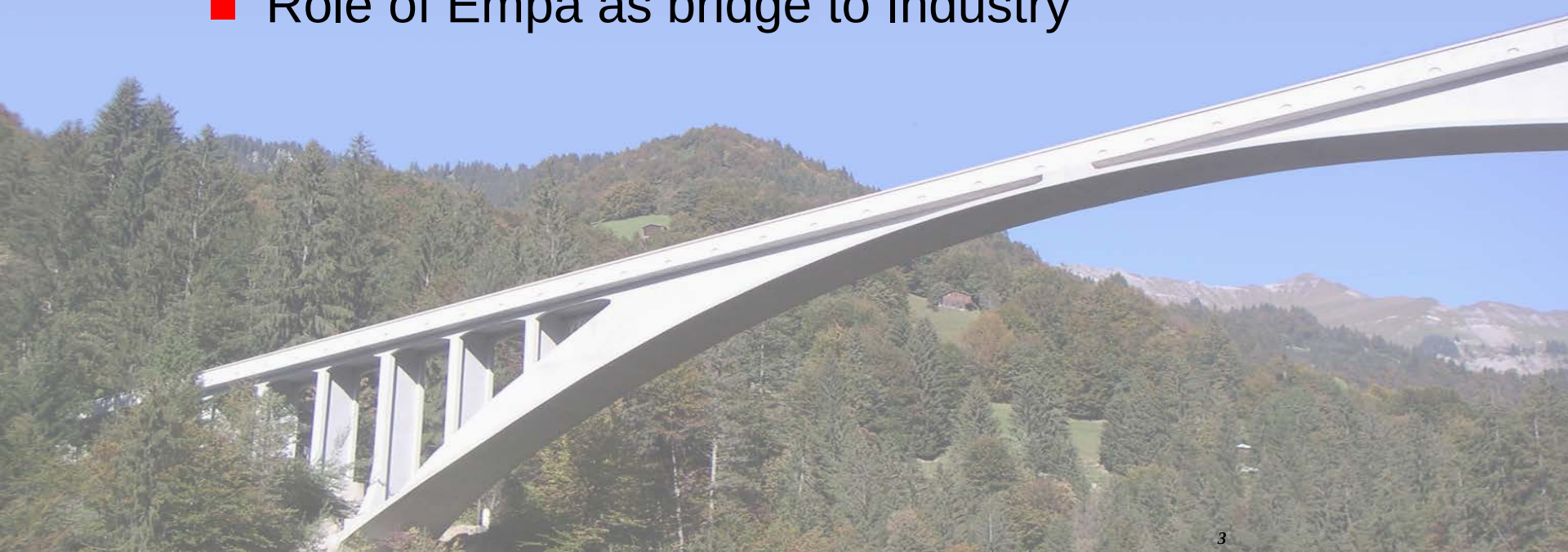
Abbrev.: Grl Group Leader; [1]PhD; [2]Post Doc, [3]Trainee

Vision of the Applied Wood Materials Lab

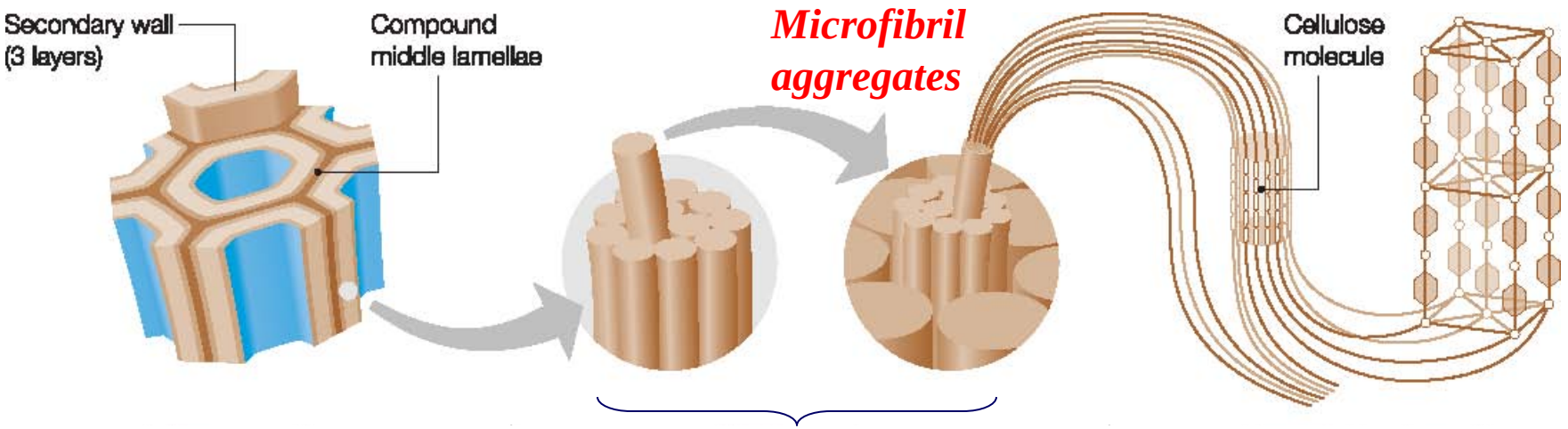
EMPA
Materials Science & Technology

- Development of innovative wood based materials with an economical impact

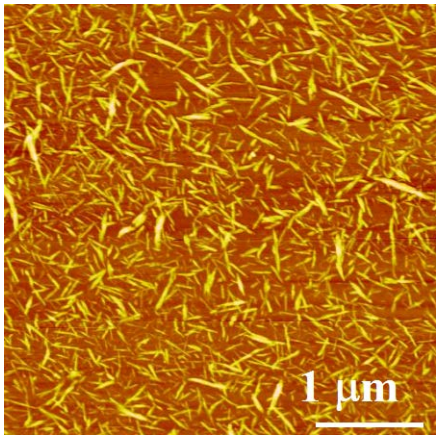
- Role of Empa as bridge to Industry



Isolation of cellulose nanofibers



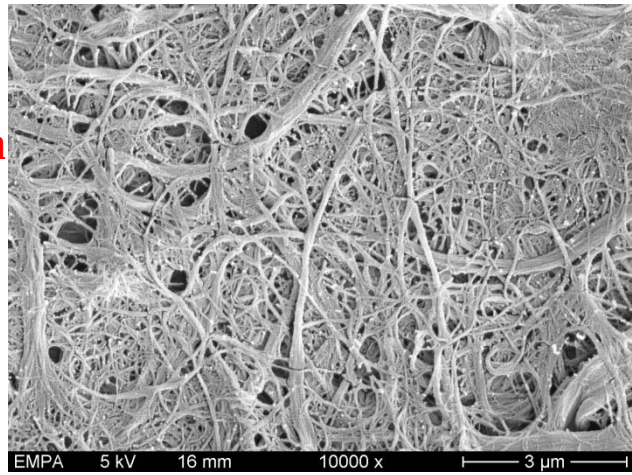
Cellulose Nanocrystals



H_2SO_4

High shear mechanical desintegration

Nanofibrillated cellulose

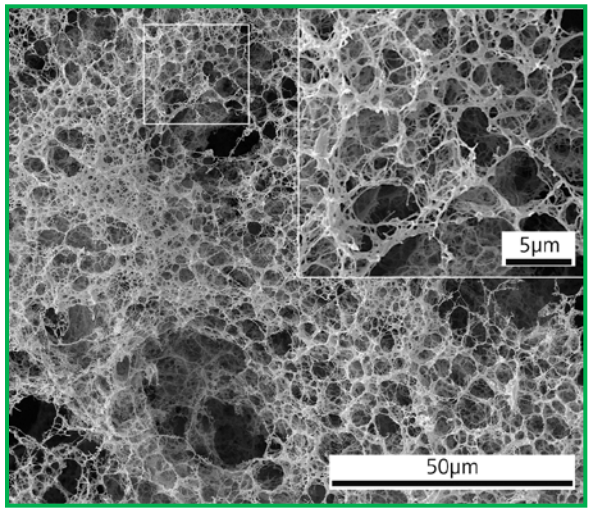


at EMPA

50 nm < L < mm, 4 nm < ∅ < 70 nm

µm < L < mm, 4 nm < ∅ < 70 nm

Advantages of Nanofibrillated Cellulose



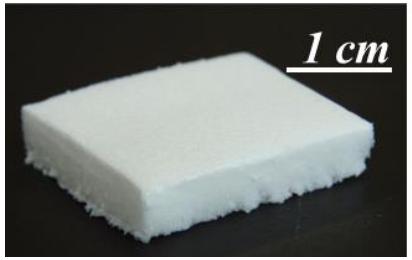
Advantages

- Lightweight material,
  builds network structures
- Renewable resource, biodegradable
- High strength and stiffness
- Transparent, translucent,
  water storage capacity, rheology modifier
- High surface area and aspect ratio
- High reactivity, barrier properties

Transparent gel (1.5 % w/w)

powder

Translucent films
(Nogi, 2009)



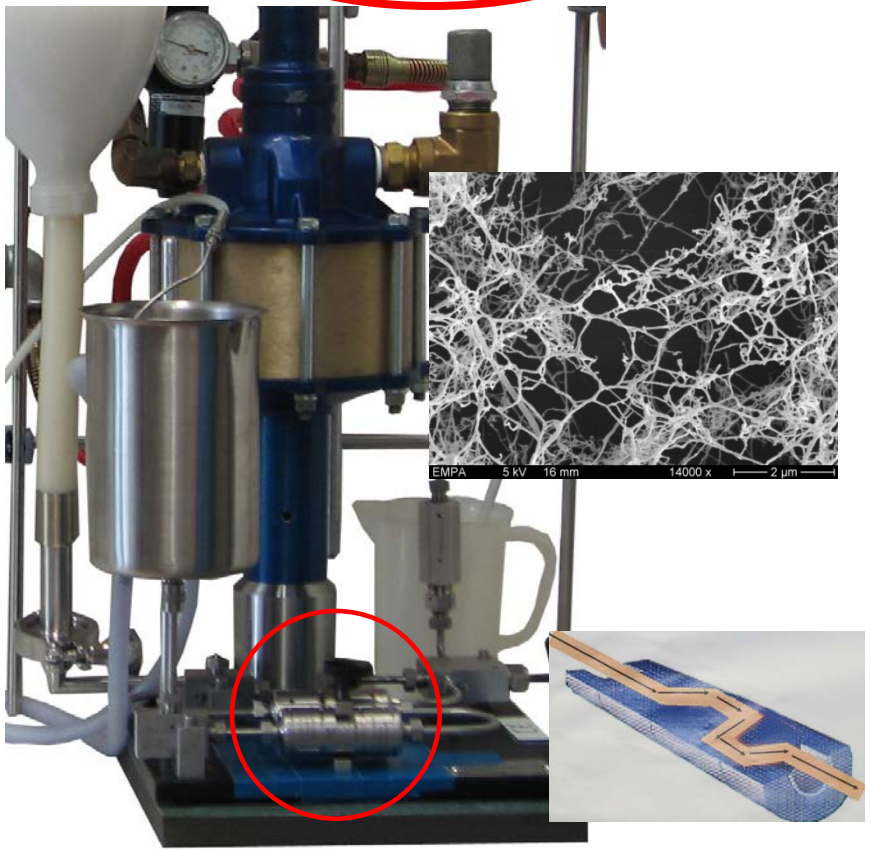
Porous material
(porosity ~ 99%)

Isolation possibilty 1: High shear homogenisation

Starting material: bleached pulp fibers (wood, agricultural crops)

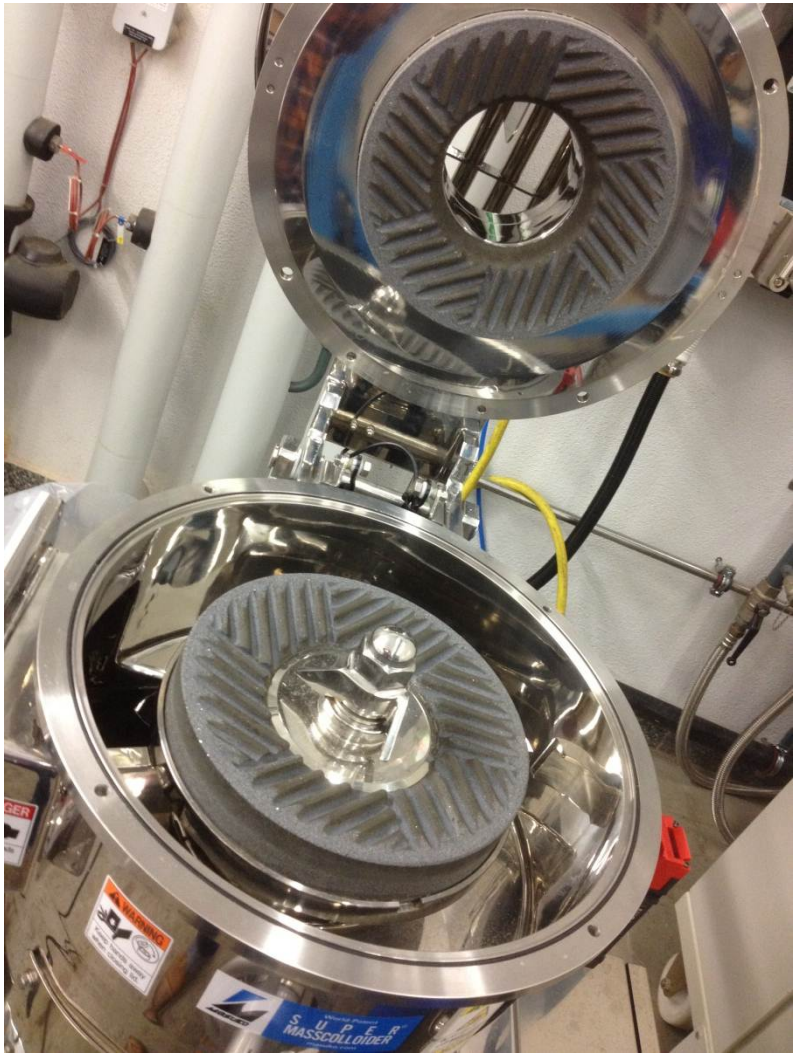
Resulting material: nanofibrillated cellulose (NFC) – **100 g scale**

Inline disperser with Ultra-Turrax



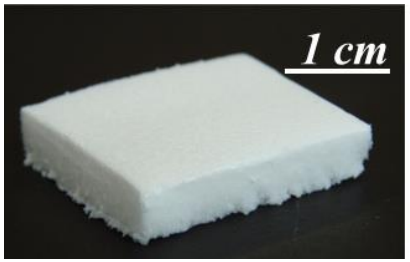
High pressure homogenizer
(Microfluidizer)

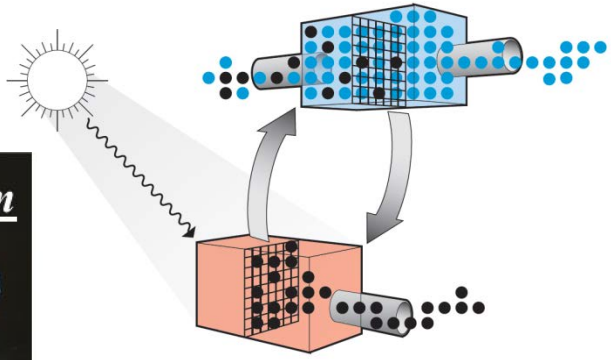
Isolation possibility 2: Masuku grinder – kg scale

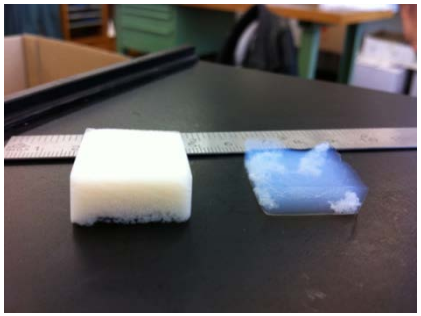


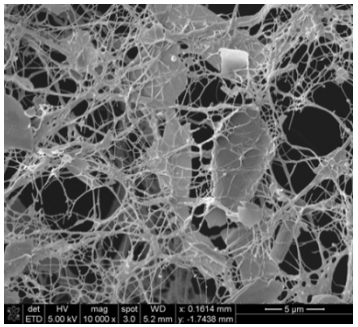
Applications of Nanofibrillated Cellulose @ Empa

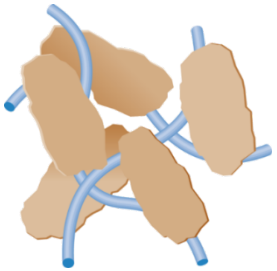
- Hydrogels (e.g. biomedicine)
- Aerogels, Foams (e.g. gas separation, functional insulating materials)
- (Bio)polymers (e.g. PLA, adhesives, sealants, coatings)
- Nanopapers, membranes (e.g. as barrier layers in packaging, functional papers, filters)
- Bicomponent polymer fibers
- Inorganic matrices

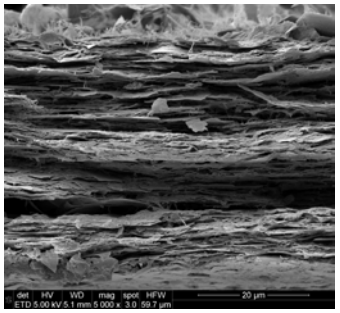


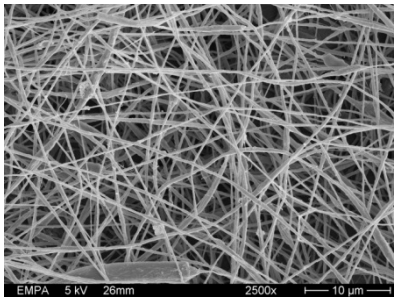










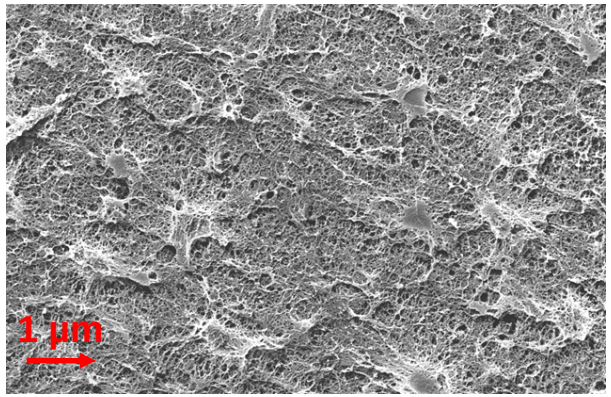


Health and Performance - Hydrogels

- Biocomposite hydrogel for the replacement of the *nucleus pulposus* in the intervertebral discs; crucial are the swelling and mechanical properties
  - UV-cross-linked N-vinyl pyrrolidone/ trimethacrylate hydrogel
  - NFC and carboxymethylated NFC (c-NFC) as filler

⇨ Higher swelling ratio, higher MOE values in compression + lower strain values during relaxation tests (creep) as compared with the NP

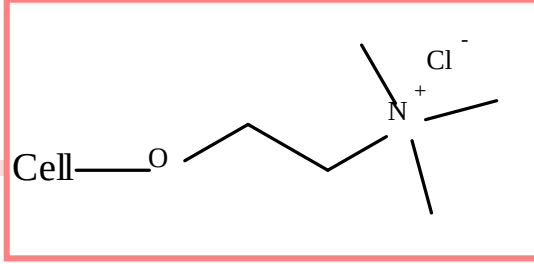
Nucleus pulposus (NP)



Collaboration with Technical University Lausanne (EPFL)

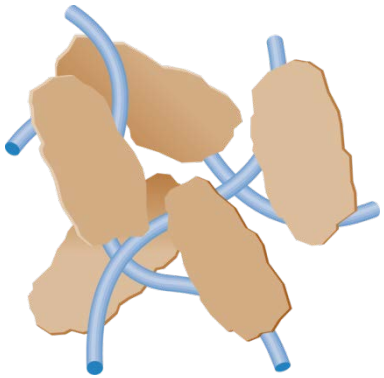
Borges et al. 2010. Patent application
Borges et al. 2011. Acta Biomaterialia
Eyholzer et al. 2011. Biomacromolecules

Functional films for packaging



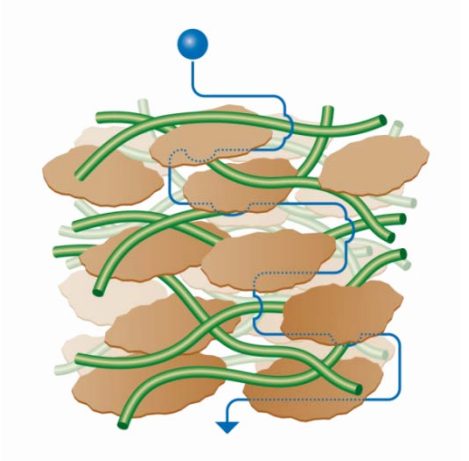
- Ammonium functionalized NFC

CTI project CEBAS, PhD thesis Thi Thu Thao Ho

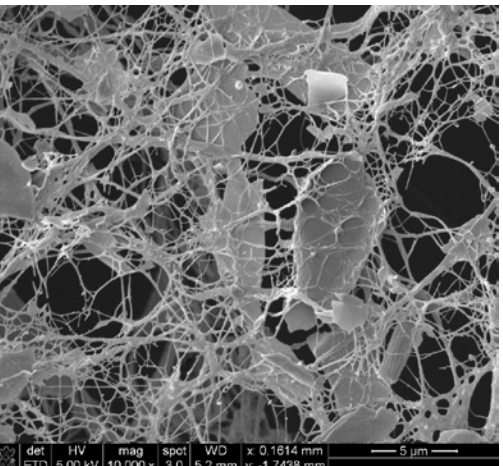


Strong adhesion

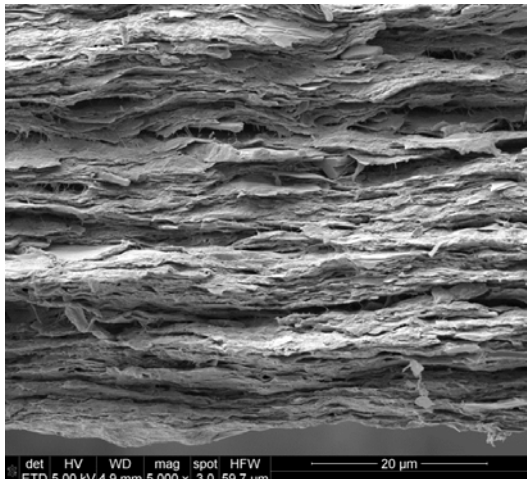
Combination of NFC (barrier against oxygen) **and clay** (barrier against vapor)



Efficient barrier system

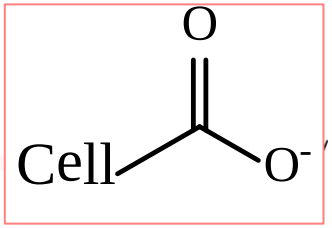


Acceptable vapor and oxygen transmission rates for packaging applications (confidential, Cham Paper Group)



Cellulose, 2011

Functional membranes for water purification

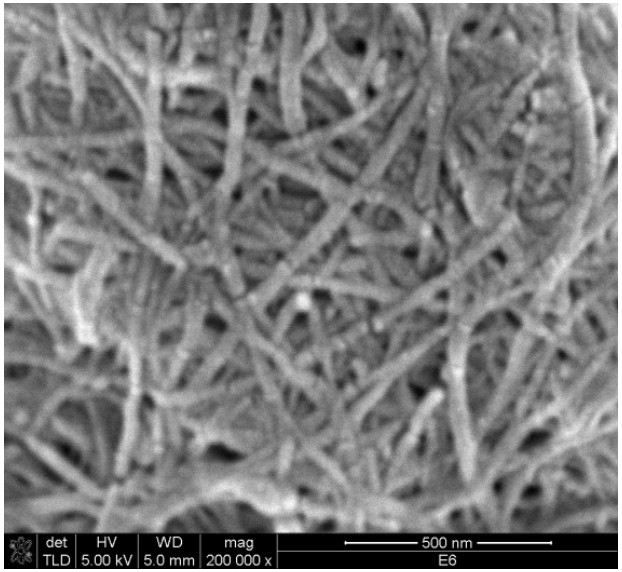


Oxidized NFC

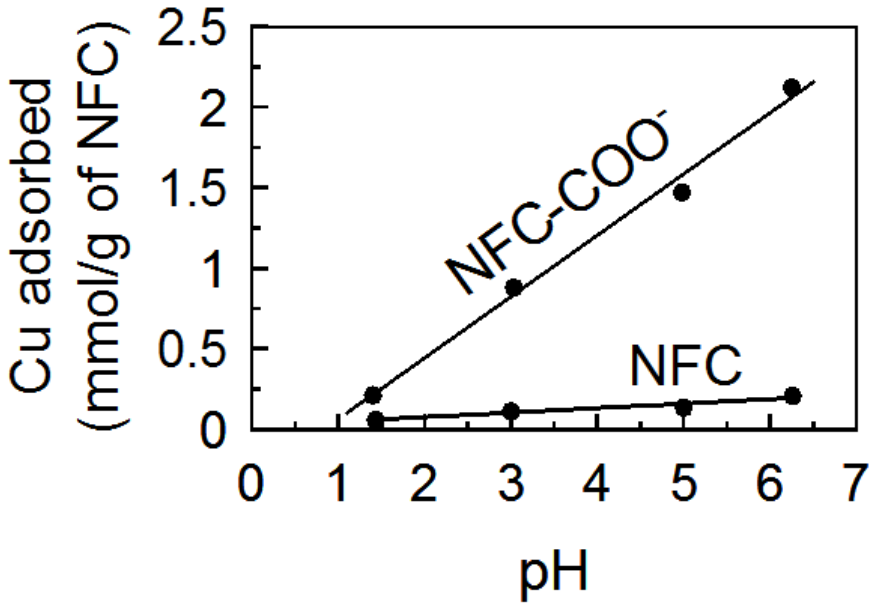
- Removal of metal ions in water using biobased membranes

EU project NanoSelect

Dr Houssine Sehaqui

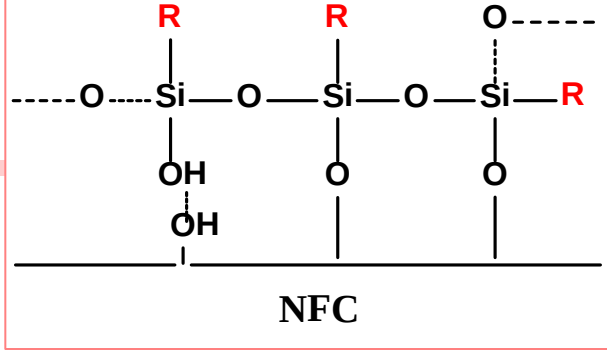


SEM of a NFC membrane



Cu(II) adsorption onto unmodified and tempo-oxidized NFC

Functional aerogels/foams

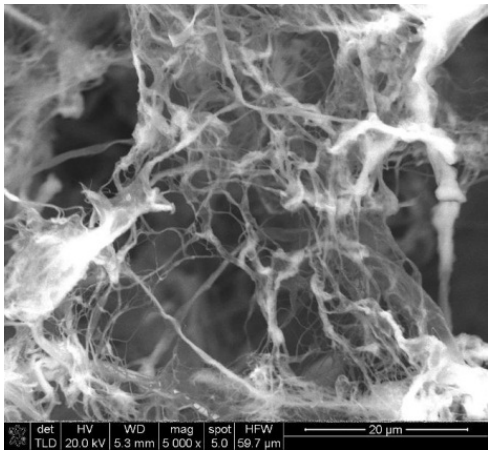


- Elaboration of (multi)functional porous materials

  PhD Thesis Zheng Zhang

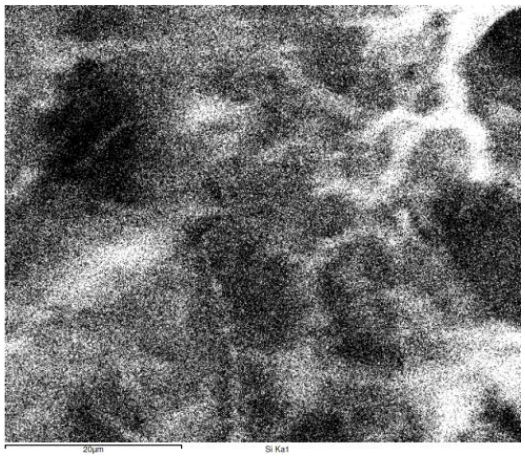
  KTI project SICEPO

SEM micrograph



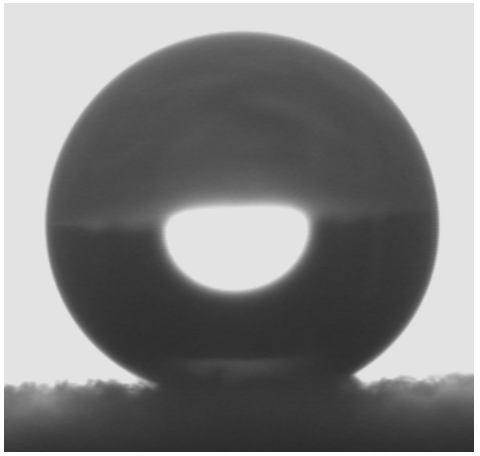
Nanoscale fibers

EDX



Homogeneous Si distribution

Water contact angle

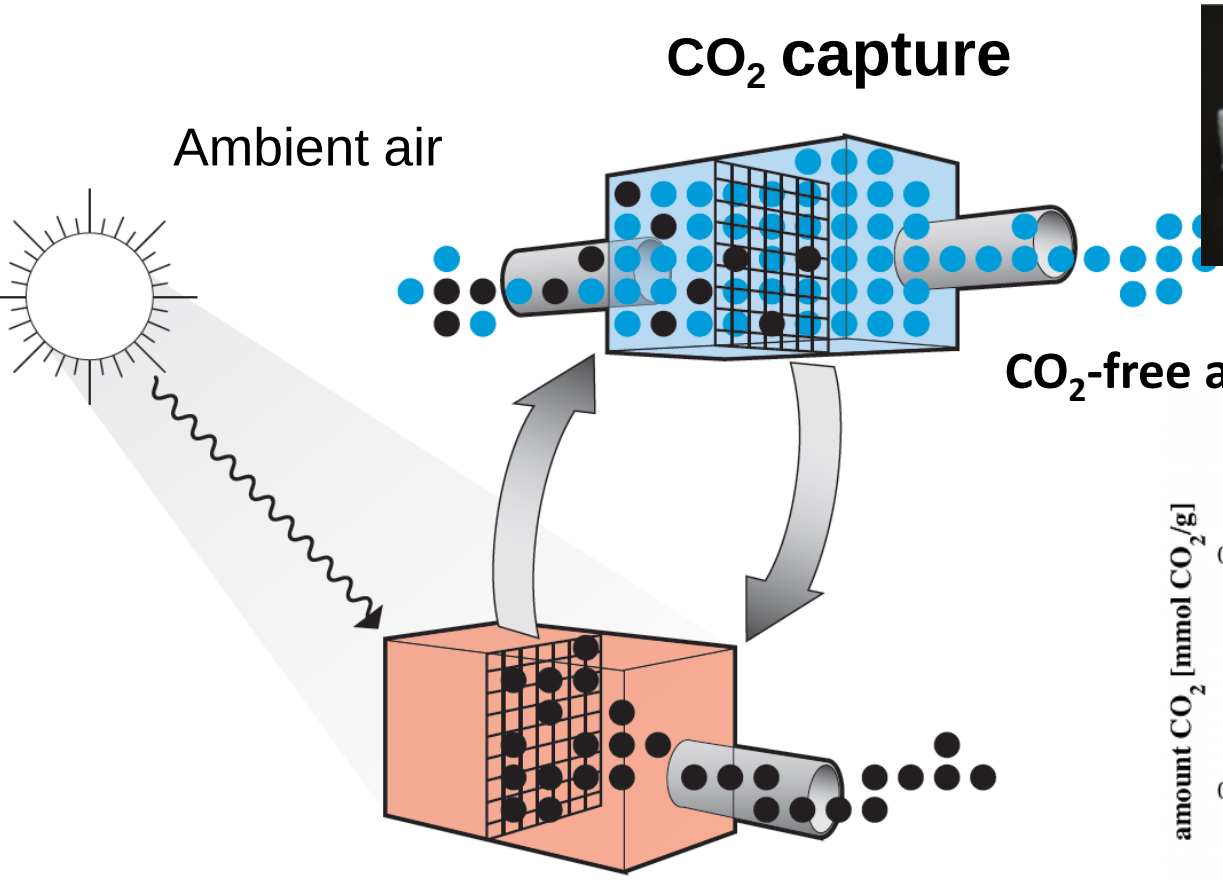


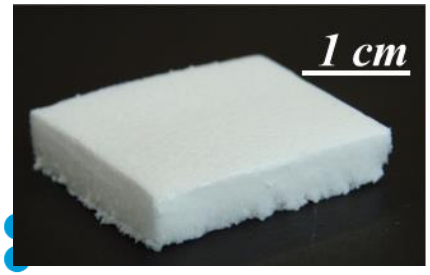
Θ ~ 135°

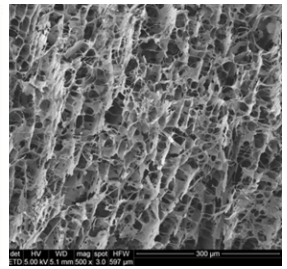
⇨ Properties of the foams tuned with the R group

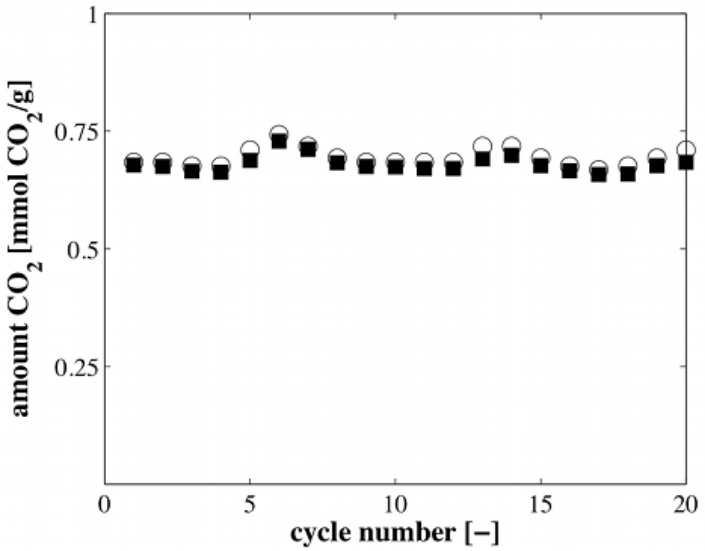
⇨ Applications in purification technologies (oil/water separation, etc.)

Energy / Pollution – Aerogels/ Foams (gas capture)









Stability of CO_2 capture capacity over 20 sorption/desorption cycles

Gebert Rüf, ETH spin-off Climeworks LLC, ETH Zürich, Professorship of Renewable Energy Carriers

Gebald et al. 2011. Patent application
Gebald et al. 2011. Env. Sc. and Techn.

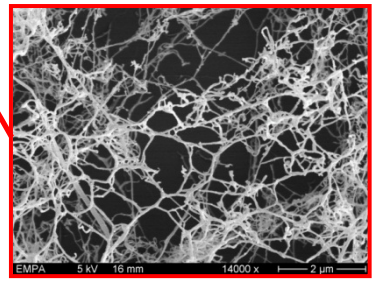
Sustainable Built Environment - Super insulating materials

Reinforcement of silica aerogels with NFC

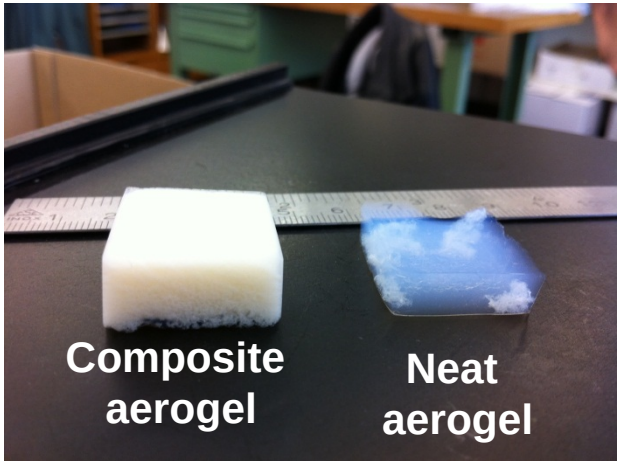
European project AEROCOINs
Collaboration with Building Technologies at Empa

Challenges:
- Homogeneous dispersion of nanofibers
- Reinforcement without loosening neat aerogel insulating properties

Silica aerogel



Functionalized NFC
(different polarities,
dispersion properties)



PhD Thesis Zheng Zhang

Industrial project SICEPO

Recent (very) promising result

Acknowledgments

EMPA
Materials Science & Technology

- Members of the Cellulose Nanocomposites group

- The Applied Wood Materials laboratory

- The EMPA institute for his support


Thank you very much for your attention!
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