Title	Foam technologies in production and finishing of nonwoven materials
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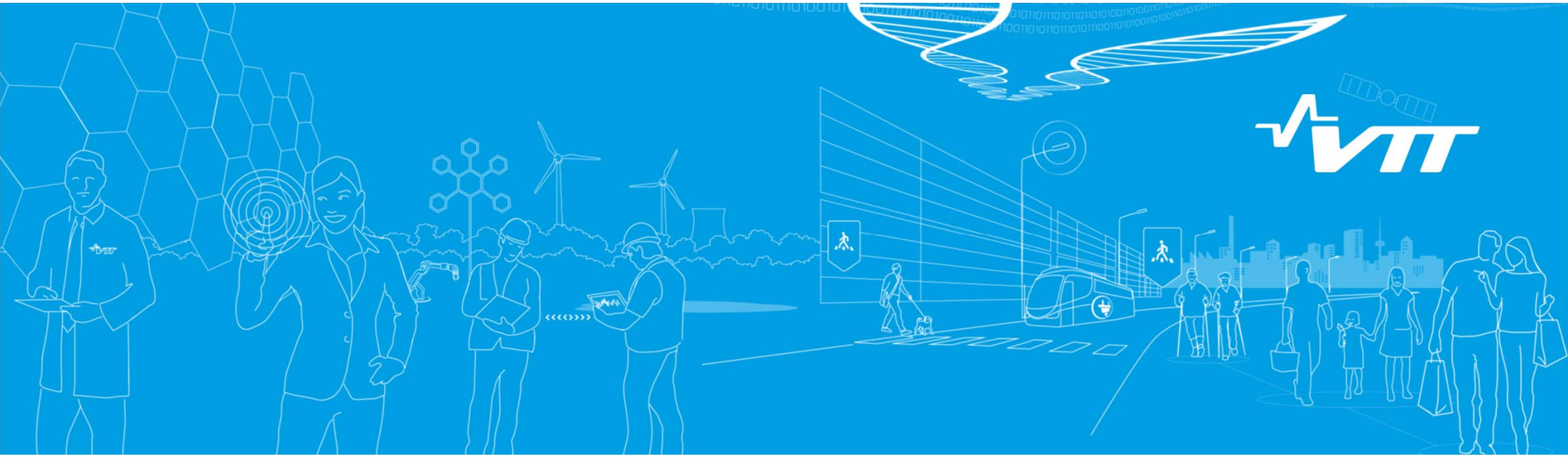

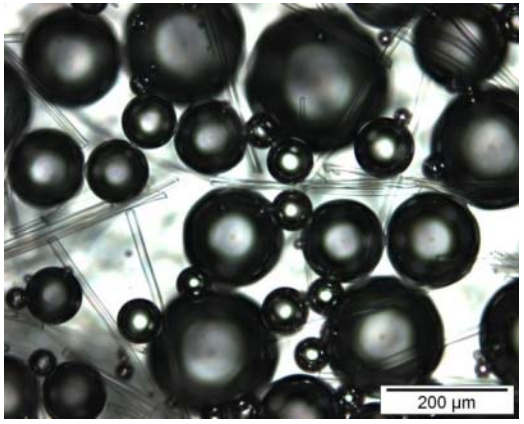

Foam Technologies in Production and Finishing of Nonwoven Materials

Autex 2015 conference, 10th-12th June 2015, Bucharest, Romania,

Pirjo Heikkilä, Petri Jetsu, Tiina Pöhler, Jukka Ketoja, Atsushi Tanaka, Jani Lehmonen, Karita Kinnunen-Raudaskoski, Tuomo Hjelt, Hanna Koskela, Ulla Forsström, Ali Harlin

VTT Technical Research Centre of Finland Ltd

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VTT and Our Foam Technologies

VTT Technical Research Centre of Finland Ltd.

- The biggest multi-technological applied research organisation in Northern Europe

Resources

- Turnover 308 M€ (2013) personnel 2,600 (2015)
- Unique research and testing infrastructure
- Wide national and international cooperation network

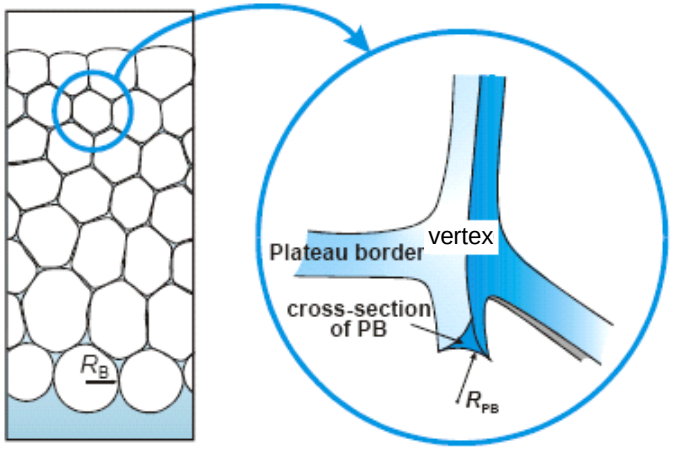
*) Source: Roles, effectiveness, and impact of VTT, VTT & Technopolis Group, 2013.

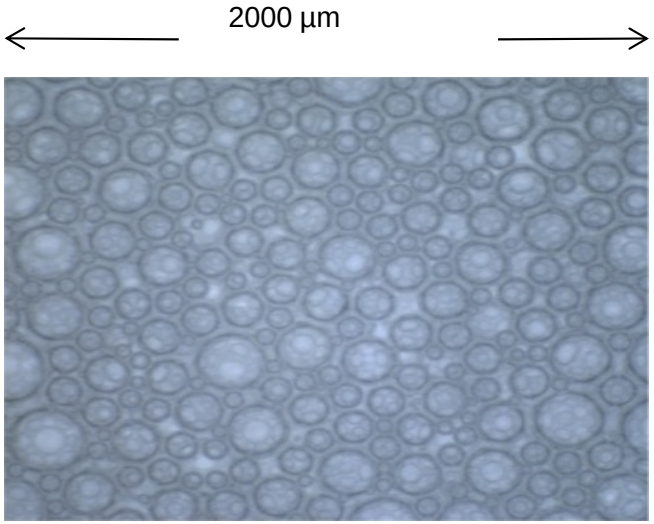
Foam Technologies

Foam as Transport Media Instead of Water

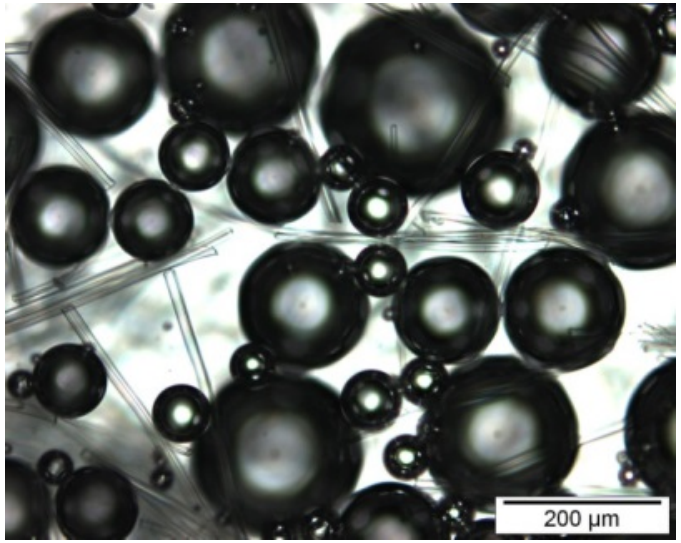
An aqueous foam is an excellent suspending medium:

- Material is located in “bubble pockets” (vertex)
- Pseudoplastic nature allows for the dispersion of relative long fibers under high shear conditions at consistencies of 0.5 to 1.5 w-w-%





Air content 66%



Foam Technologies

Foam as Transport Media Instead of Water

1. **Foam laying** for production of nonwovens
   - Method comparable to wet-laying
   - Wet foam – air content <70%
   - Air bubbles in foam prevent flocculation of fibres → good formation
   - Currently used mostly for rigid fibres such as glass and carbon fibres

2. **Foam coating** for functionalization of nonwovens
   - Dry foam – air content 70-95 %
   - Allows very thin contour coatings, from almost 0 to a few grams per m^2
     - Less coating penetration into the structure
     - Even application of small quantities on large areas: for 1 µm coating amount we make layer of 10 µm (air content 90 %)
   - Common technology used in textile industry for over 20 years, typically low speeds and narrow machines

Foam Laying

Benefits… Over Traditional Forming & Other Textile Methods

Material properties

- Possibility to adjust porosity and bulkiness in forming
- Possibility to use longer fibres compared to wet- and air-laying
- Good formation: more homogeneous compared to other nonwovens and textiles
- Easily adaptable to hydrophilic fibres such as cellulosics, but possibility to use synthetic fibres also
- Extended raw material combinations → tailored product properties

Process

- Higher forming consistency compared to wet-laying → possibility to modify current dilute processes
- Less water → less energy in drying and transport
- Better productivity compared to most other textile processes

Foam Coating
Benefits

Coating properties

- Thin homogeneous coatings
- Coatings from wide range of materials
- Simple ‘coating recipes’ with foaming chemistry, e.g. for nanomaterials no binders required since surface forces enough

Process

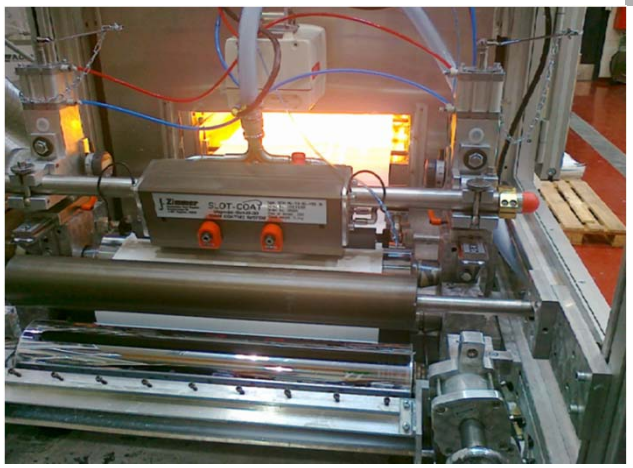
- Versatility
  - Non-contact/contact method
  - Higher concentrations possible compared e.g. to spraying
  - Enables application of high viscous and gel like material, e.g. NFC, MFC
- Simple in use
  - Savings in drying energy
  - No side streams, no recirculation, less maintenance
  - Easy to install into the existing machines
  - Low space demand compared with spray or film transfer
  - Occupationally safe method, no airborne particles

Foam Coating

Research Environments at VTT

- Wet web application SUORA (see next slide)
- Dry web application SUTCO and KCL pilot coater)

SUTCO
R2R surface treatment concept



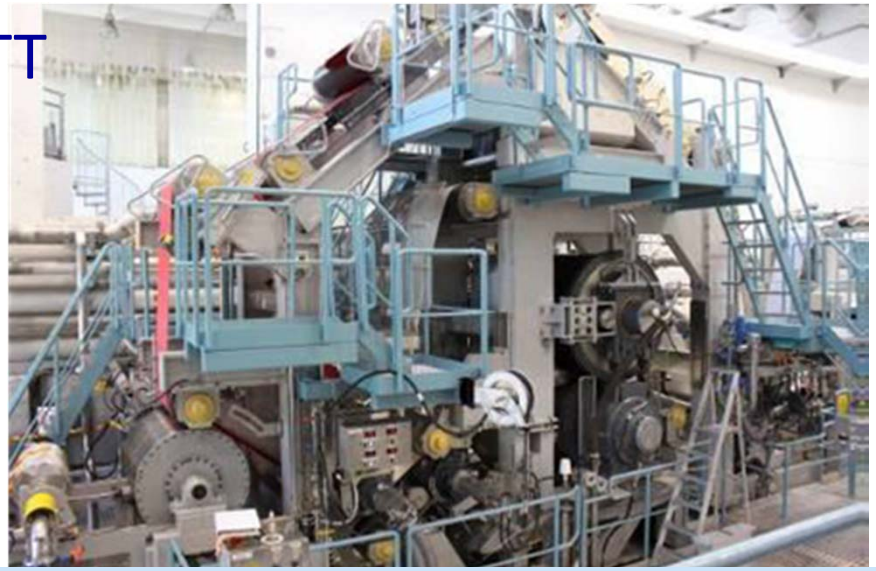
→ Contact application,
foam killing with the nip,
especially for dense surface layers
and nonwovens

← Non-contact application
with curtain coating,
foam killing by absorption,
especially for small application amounts

Foam Laying

Research Environments at VTT

VTT paper making research environment
SUORA
Foam generation
Fourdrinier hybrid and gap former
Pressing with shoe press upto 2000 kN/m
Speed up to 2000 m/min



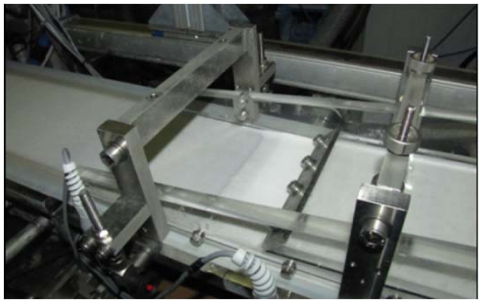
2011 → 2016

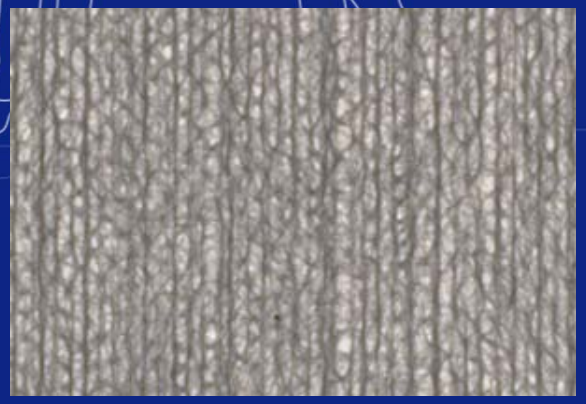
Foam laid tissue and nonwovens in laboratory scale

Foam laid tissue and nonwovens in semi-pilot scale at speed of 210 m/min

Pilot-scale foam forming facilities tissue and nonwovens

Next generation fibre foam research environment for special grades and long fibre usage

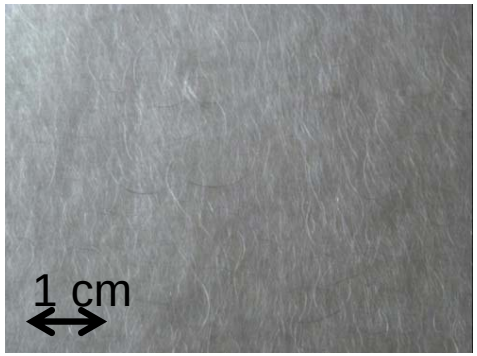




Nonwoven Materials from Cellulose Fibres by Foam Laying

Foam Laid Nonwovens from Cellulosic Fibres

Lab Scale - Different Fibre Compositions



"Novel Emerging of Fibre Web Products (Neoweb)"
2012-2013
VTT internal project

Sheet (60 g/m^2)

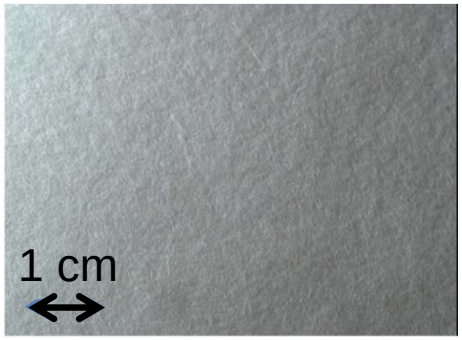
- 9 mm viscose fibres
- Viscose mixture with
  - cellulose pulp (pine kraft)
  - binder fibres (bi-component PES/PE)

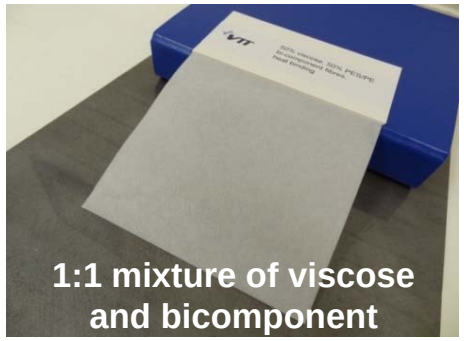
Formation

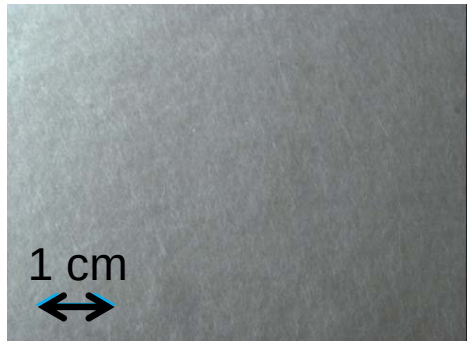
→ Excellent, very homoeneous

Chemical (latex) or thermal bonding

→ Stiff, paper like products







Foam Laid Nonwovens from Cellulosic Fibres

Lab Scale - Different Fibre Compositions

Foam laid sheets from cellulose carbamate (CCA)

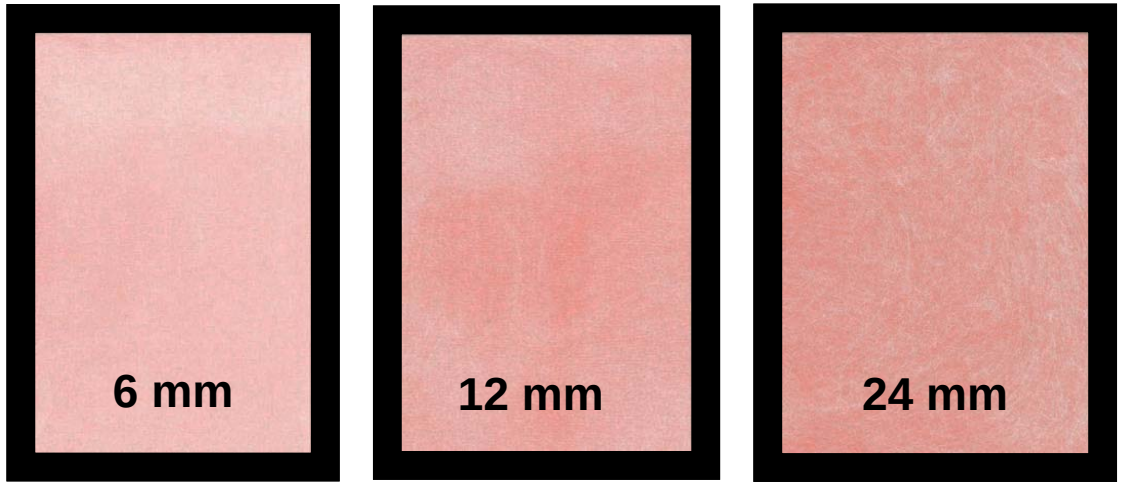
- Fibres made from recycled fibre at VTT
- Fibres were cut to 13 mm or 25 mm length
- Bundles opened using laboratory scale carding device
- The quality of the sheets formation depends on how well the opening i.e. carding was done

P. Heikkilä, P. Jetsu, K. Kinnunen, M. Määttänen, K. Valta & A. Harlin, Sustainable Nonwoven Materials by Foam Forming Using Cellulosic Fibres and Recycled Materials, ADITC 2013, 27.-28.11.2013, Aachen, Germany

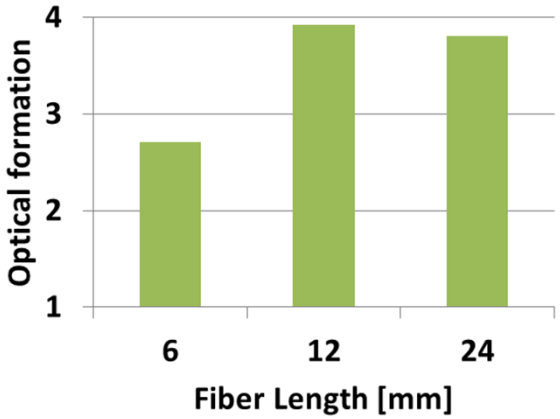
Foam Laid Nonwovens from Cellulosic Fibres

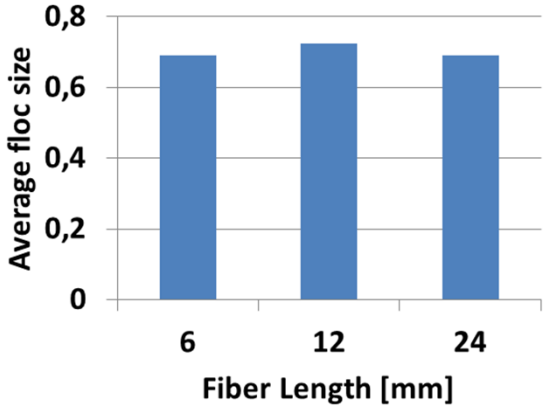
Lab Scale - Different Fibre Lengths

- Visually 6 mm web most homogeneous, 12 mm sheet had real differences in homogeneity and 24 mm sheet has more fibre bundling



- Optical formation slightly weakened with fibre lengths 12 mm and 24 mm
- Floc size remained constant



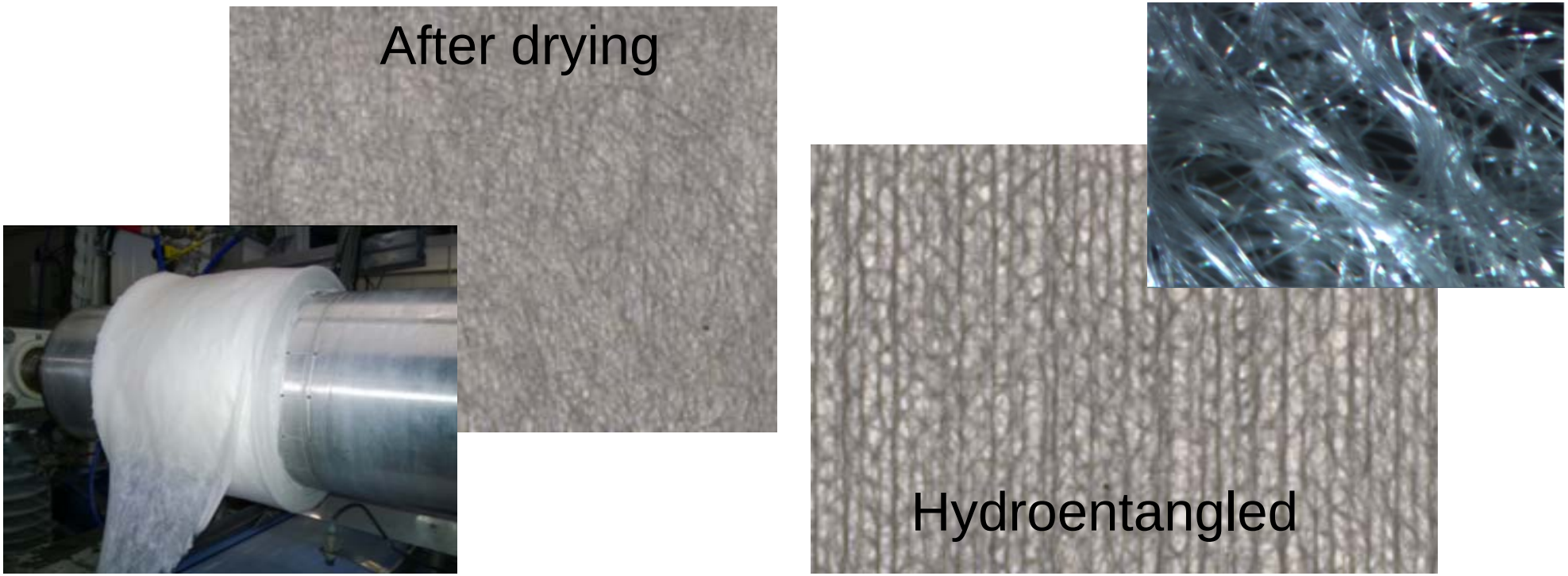


Lehmonen et al. Foam forming for Tissue and Nonwovens" PaperCon 2015 April 19 – 22, 2015, Atlanta
Design Driven Value Chain in the World of Cellulose (DWoC), Finnish national project funded by TEKES, 2013-2015
Mechanical bonding of foam laid nonwovens (MECBO), VTT internal project, 2014

Foam Laid Nonwovens from Cellulosic Fibres

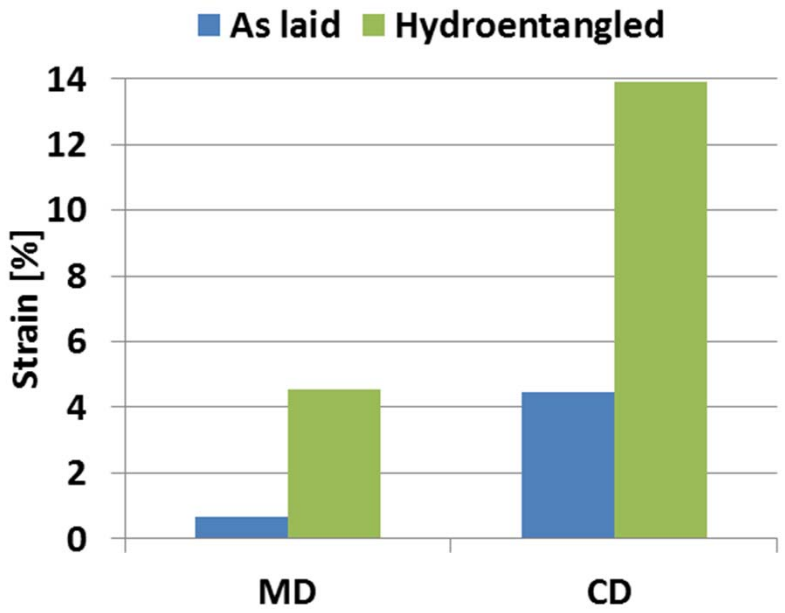
Semi Pilot Scale - Hydroentanglement

- Brilliant formation in the case of long fibres, even though high forming consistency applied
- Mechanical bonding instead of chemical bonding → aspect for sustainability
- Widening of raw material combinations → process simplifying

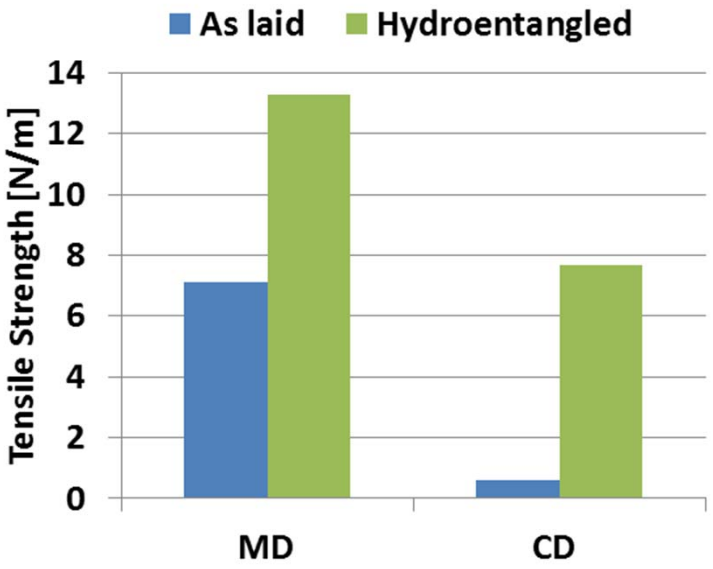


Foam Laid Nonwovens from Cellulosic Fibres

Semi Pilot Scale - Hydroentanglement



← Clear increase in **strain** after hydroentanglement leading to more textile-like structures



→ Tensile **strength** was also improved after hydroentanglement

Mechanical bonding of foam laid nonwovens (MECBO), VTT internal project, 2014

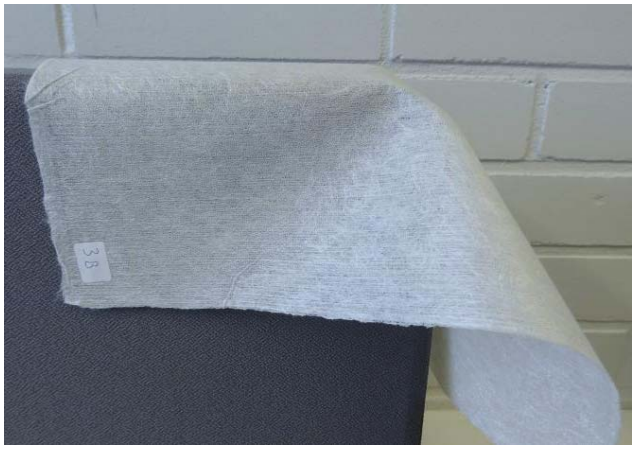
Foam Laid Nonwovens from Cellulosic Fibres

Hydroentangled Textile-Like Nonwovens

100% 24 mm viscose fibres
150 g/m^2
Tensile strength 128 N/m
Strain at max force 10%

100% 12 mm viscose fibres
100 g/m^2
Tensile strength* 834 N/m
Strain at max force 36%

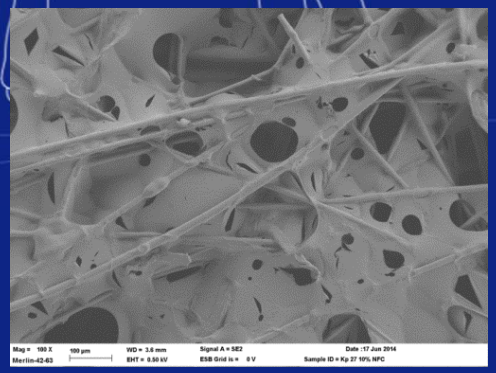
70% 12 mm viscose fibres,
30% softwood kraft pulp
50 g/m^2
Tensile strength 207 N/m
Strain at max force 26%



Foam Laid Nonwovens from Cellulosic Fibres

Summary of Experimental Results

- Foam laid nonwovens with good formation were obtained
- Formation dependent of many factors e.g.:
  - Fibre length: Shorter fibres easier; currently good formation obtained with fibre lengths up to 24 mm
  - Adding fibre:
    - Opening of fibres (in lab scale done with carding)
    - Mixing fibres into foam
  - Foam characteristics
- Foam laying suitable for paper-like products, but also textile-like products possible especially when using mechanical bonding

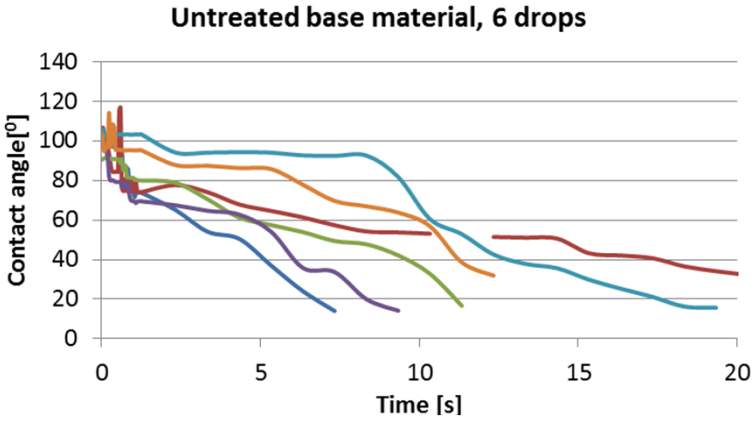


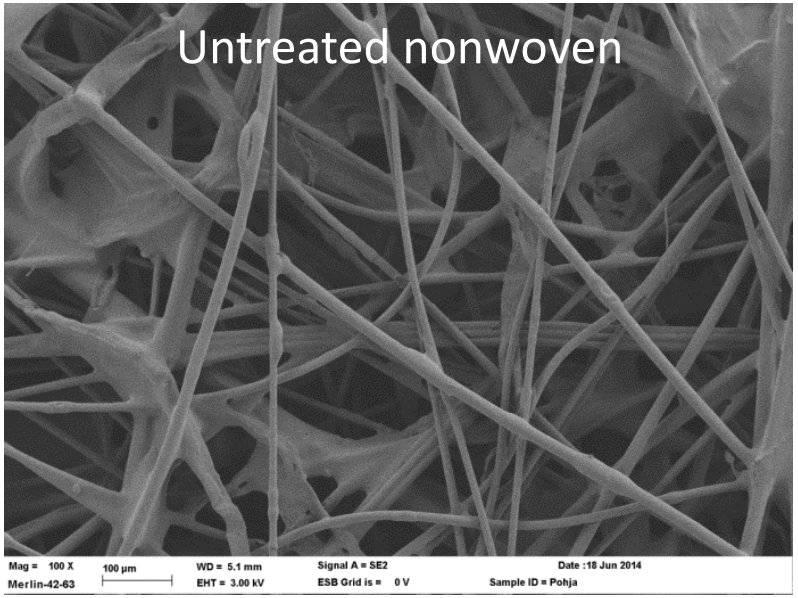
Functionalization of Nonwoven with Nanofibrillated Cellulose Utilizing Foam Coating

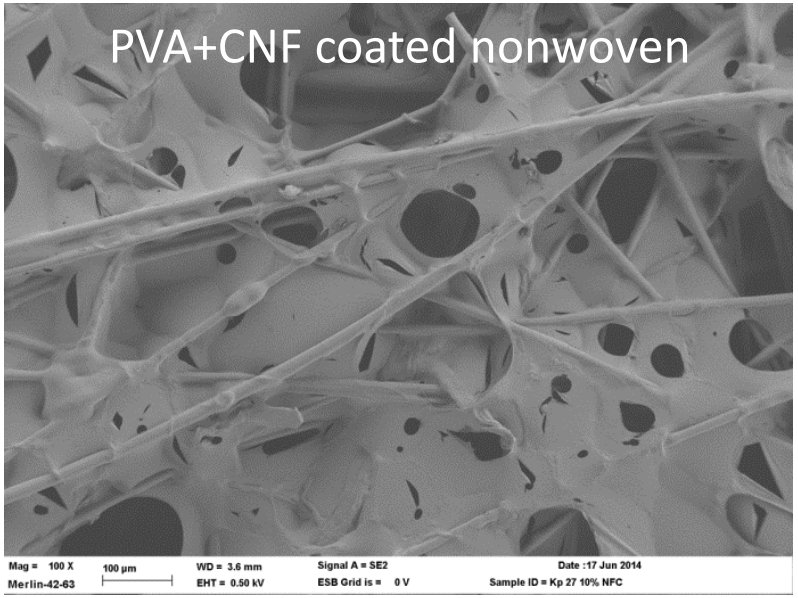
Foam Coated Nonwoven

Surface Properties and Wetting

- Materials
  - Base mixture of cellulosic and synthetics, chemically bonded
  - Coating with CNF (< 0.4 g/m^2) with PVA as foaming agent
- Effects of coating
  - Closing the surface
  - Increased hydrophilicity (WCA measurement not possible for coated) and faster wetting

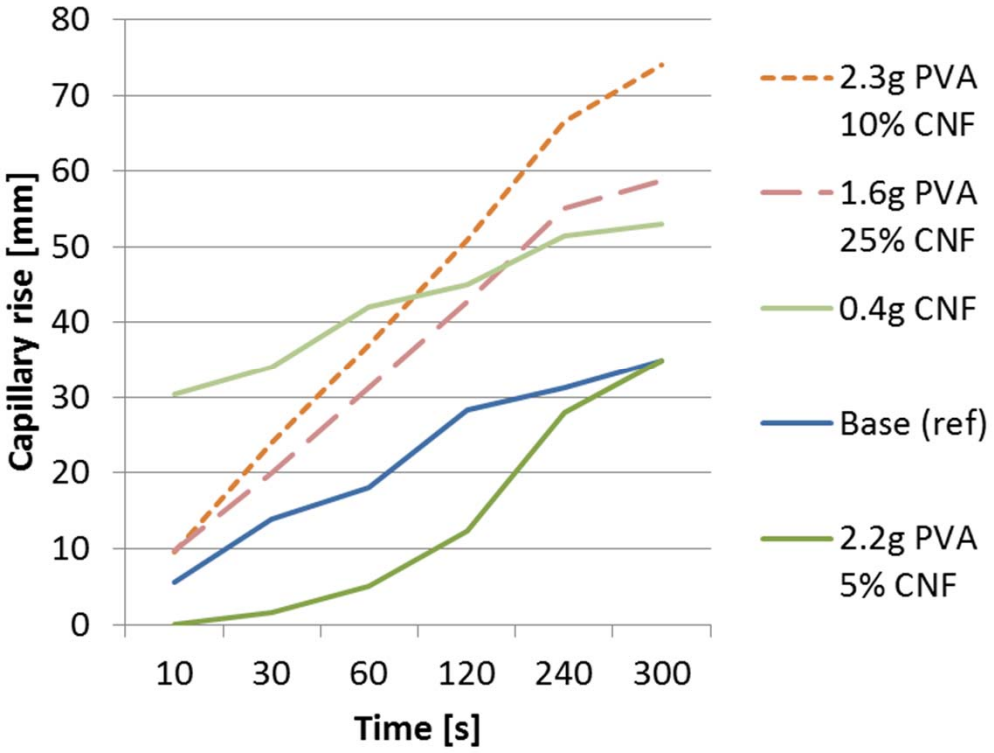


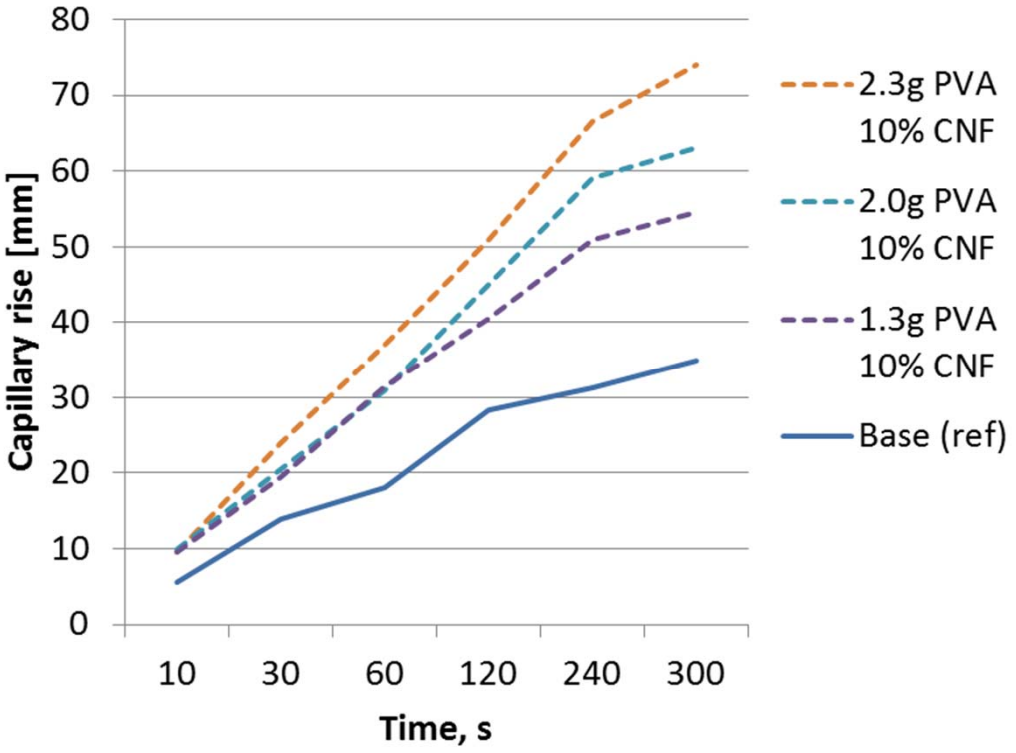




Foam Coated Nonwoven

Surface Properties and Wetting

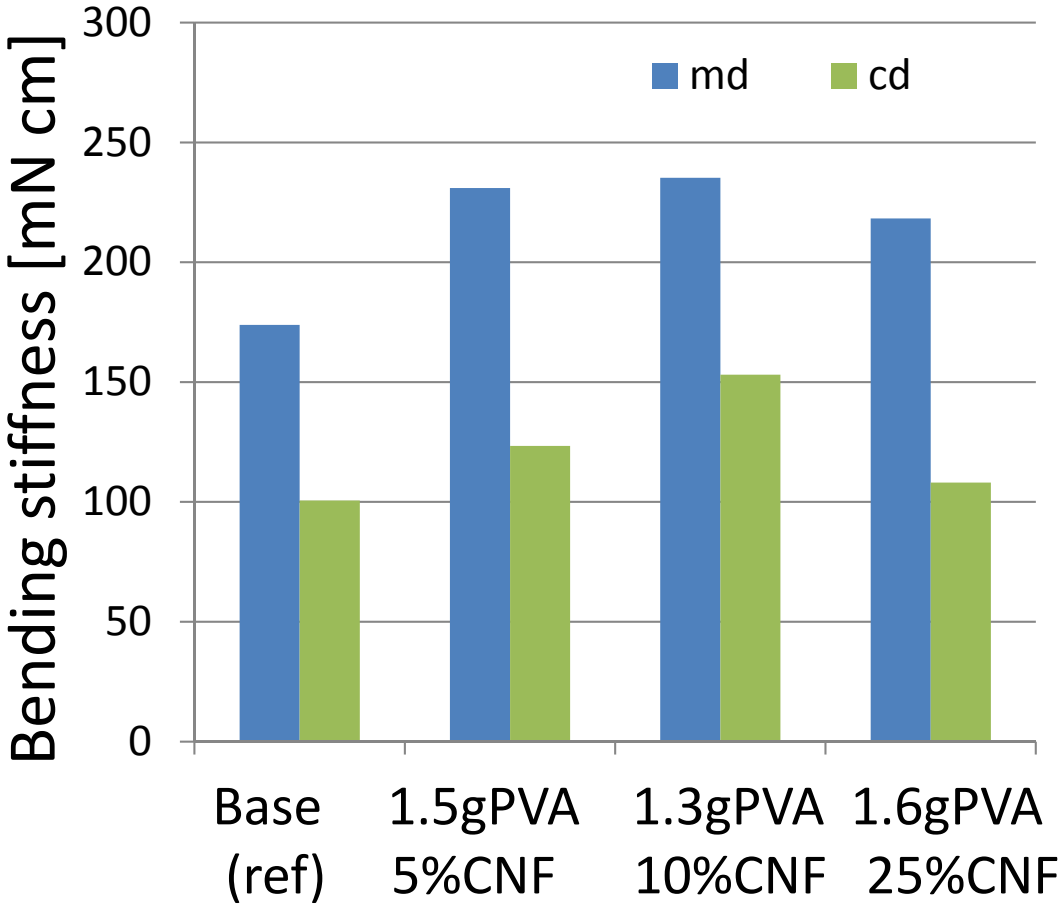


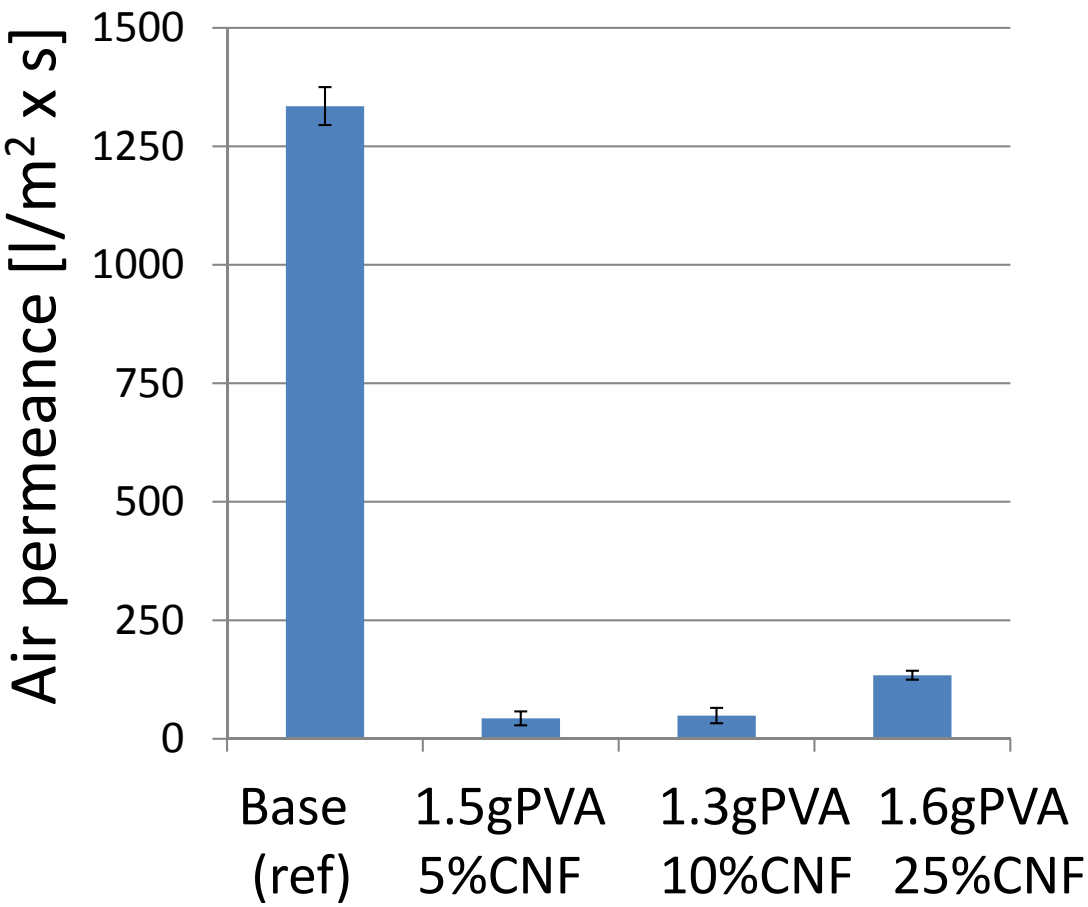


PVA and CNF both hydrophilic by nature, but wetting also affected by capillary structure

Foam Coated Nonwoven

Bending Stiffness and Air Permeability

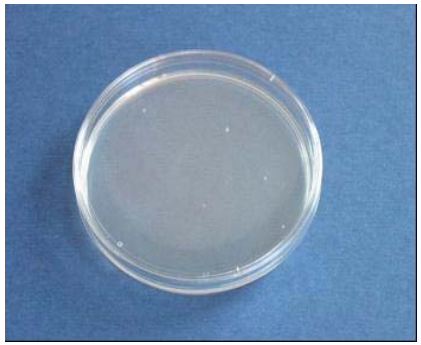




Foam Coated Nonwoven

Functionalization Option

- TiO_2 and ZnO have photo-oxidative and antimicrobial activities
  - Inhibition to grow (bacteriostatic)
  - killing (bactericidal)



- Functionalization of CNF by the addition of inorganic TiO_2 and ZnO nanoparticles and then application with foam technology
- We have done such coatings on paper, similar approach suitable for nonwoven

K. Kinnunen-Raudaskoski, T. Hjelt, H. Koskela, U. Forsström, P.a Sadocco, J. Causio, G. Baldi, Thin Barrier and Other Functional Coatings for Paper by Foam Coating, Papercon 2015, 19-22 April 2015, Altanta, US

Foam Coated Nonwoven

Summary of Experimental Results

- Thin coatings with CNF and its compounds
  - More hydrophilic nature and changed capillary structure speed up the wetting of the sample
  - A very small amount of pure CNF (0.4 g/m^2) and increased CNF amount of PVA+CNF-coatings promote faster wetting compared to the original base material.
  - Possibility to achieve functionalities such as antimicrobial activity

Summary and Conclusions

Summary and Conclusions

- Foam laying
  - Excellent formation
  - Development work on-going to enable use of longer fibres → More textile like structures possible, especially hand and drapability
  - Next generation fibre foam research environment under development for special grades and long fibre usage
- Foam coating
  - Thin layers coated evenly
  - Adjustment of properties with very small amount of functional material
- Foam technologies beneficial not only for product, but also from processing point of view due to reduced water use!

TECHNOLOGY FOR BUSINESS

Thank you for your attention, and
meet me after this session to see the samples!

For more information contact: pirjo.heikkila@vtt.fi