# *Biobased films and coatings for different applications*

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TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

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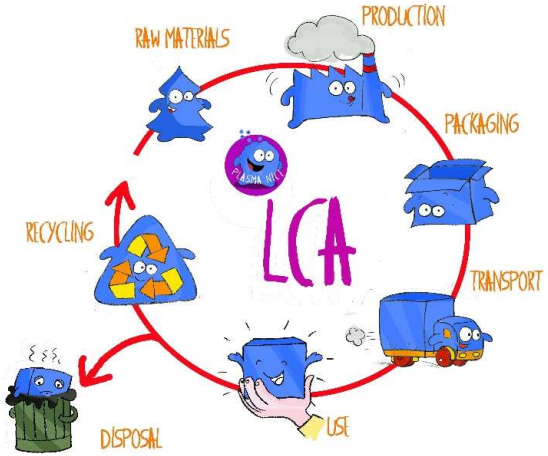
# Research group of **Paper Converting and Packaging Technology**

- The research group offers teaching and research on **paper, paperboard and polymer processing, converting and packaging technology, materials (wood-, fibre- and plastic-based) and products.**
- R&D is focused on **(co)extrusion coating, laminating, dispersion coating, wet and melt spinning and their applications.**
- The development challenges of today include **high-barrier and thin coatings, materials from renewable resources and sustainable packaging materials.**

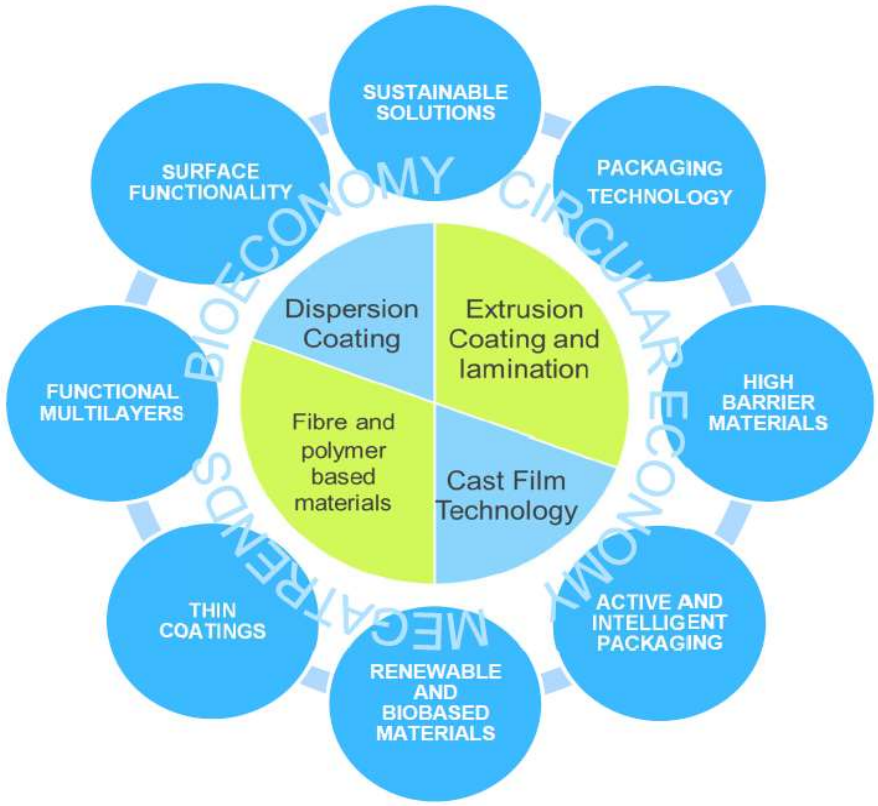
# Today's package development

- Packaging materials are usually **multilayer structures** or **"multimaterials"**
  - "Less is more" – optimisation of materials and material amount
  - Lighter packages save energy and environment
- **Circular economy**: biodegradability, compostability, environmentally friendly, recyclability, re-use…
  - ➢ Renewable alternatives for oil-based (non renewable) materials
- Demands for packaging industry (e.g.):
  - Internet shopping is increasing
  - Supply chains are evolving
  - Food losses should be prevented
  - Product safety/authenticity
  - Etc. Etc.



# Current research topics

- High-barrier co-extruded coatings and films
- High-barrier paper and paperboard packages
- Biodegradable and bio-based coatings and materials
- Wood-based materials (*e.g.* lignin, cellulose) for various applications
- Active and intelligent packages solutions
- Surface functionalization of plastic films and fiber-based materials and their coatings
- Thin coatings and surface modification based on different techniques (ALD, Atomic Layer Deposition; LFS, Liquid Flame Spray; Atmospheric Plasma Deposition)
- Barrier dispersion coating



# Examples of current projects

- **LubISS H2020 ITN** (http://www.lubiss.eu/)
  - Explores the expansive potential of lubricant impregnated surfaces (SLIPS), focusing on three applications of high societal, environmental, industrial and medical impact: anti-icing, easy-to-clean and anti-fouling
- **A&I Packaging** (http://www.actinpak.eu/)
  - COST Action FP1405 ActInPak innovates and introduces fibre-based packaging materials and solutions with active and intelligent features
- **BioBarr H2020** (http://www.biobarr.eu/)
  - Develops new bio-based food packaging materials with enhanced barrier properties. MINERV-PHA™ is based on renewable raw materials, and can be processed with existing extrusion equipment.
- **Eucaliva H2020** (http://www.eucaliva.eu/)
  - Develops and sets-up a fully-integrated, energetically-efficient, scalable, innovative and flexible processing chain based on the valorisation of lignin for producing carbon fibres (CF) and other carbon-based materials.

# Biopolymers from renewable raw materials for packaging applications

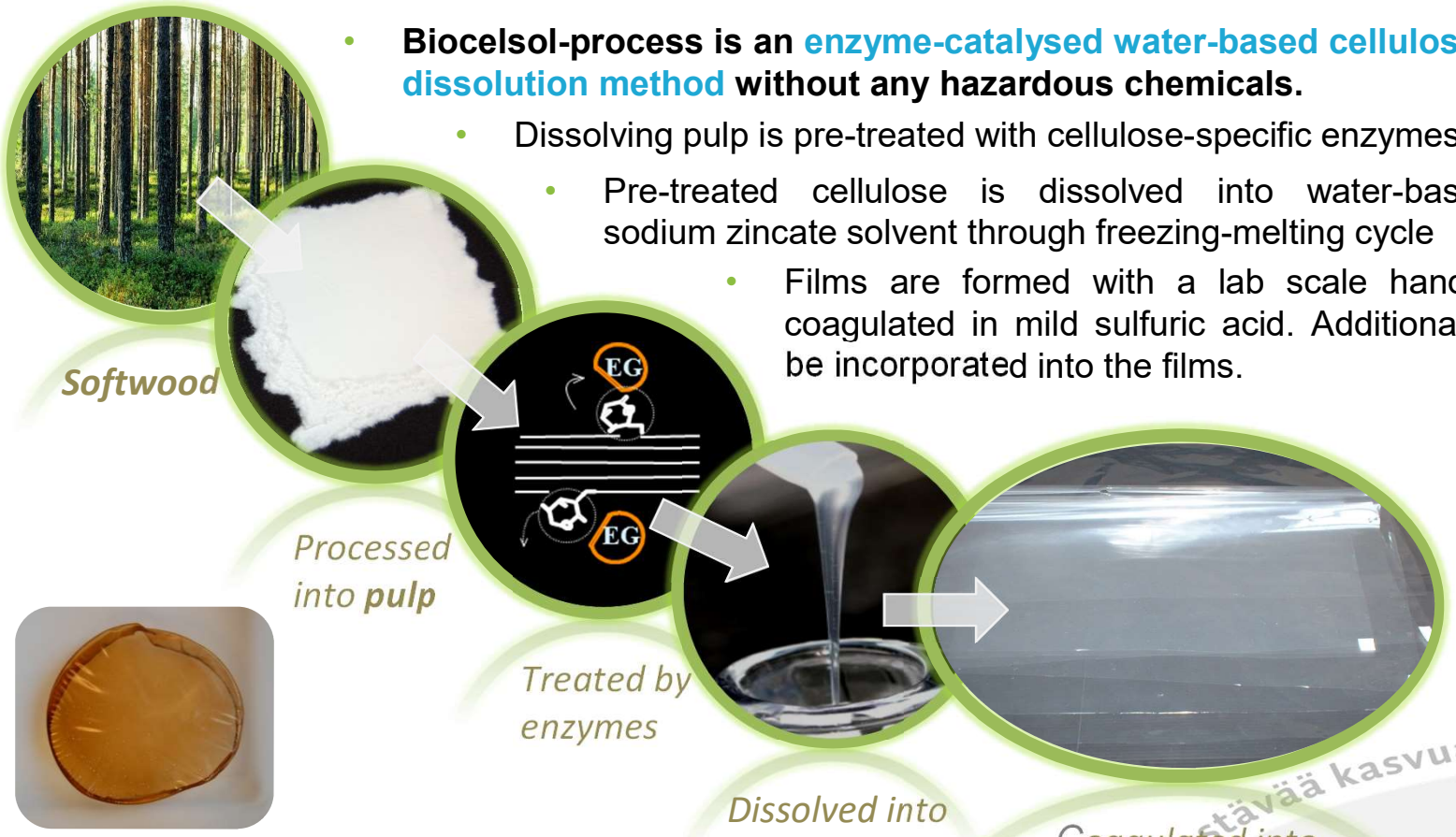
- **Research group has been studying bio-based materials over 20 years (PLA, PHA, starch, etc.)**
- MINERV-PHA™ studied in BioBarr project is based on renewable raw materials, *i.e.* produced from side streams of sugar production (sugar co-products).
- Polymer can be processed with existing extrusion equipment and is suitable for injection and extrusion methods for the production of coatings and objects.

Ref: www.tut.fi, www.bio-on.it


http://www.biobarr.eu/

# From wood to cellulose and cellulose/lignin films

- **Biocelsol-process is an enzyme-catalysed water-based cellulose dissolution method without any hazardous chemicals.**
  - Dissolving pulp is pre-treated with cellulose-specific enzymes
    - Pre-treated cellulose is dissolved into water-based sodium zincate solvent through freezing-melting cycle
      - Films are formed with a lab scale hand coater and coagulated in mild sulfuric acid. Additionally, lignin can be incorporated into the films.






Cellulose/lignin film

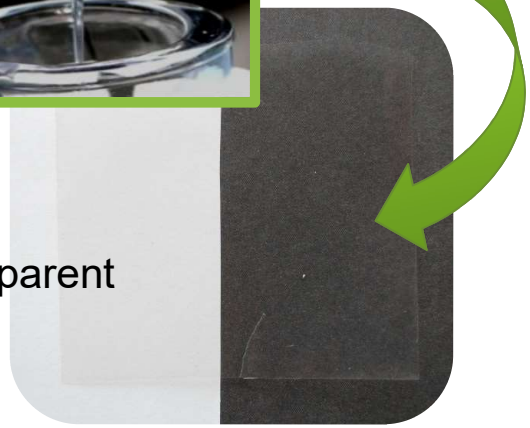
# From wood to fibres by Biocelsol-process

- Dissolving pulp is pre-treated with cellulose-specific enzymes
  - Pre-treated cellulose is dissolved into aqueous alkaline solvent
    - Fibres are regenerated by wet spinning (utilizing the same machinery as the viscose process)
      - Regenerated cellulose fibres are suitable for nonwovens and yarns and further for textile products

# From wood to cellulose and cellulose/lignin films

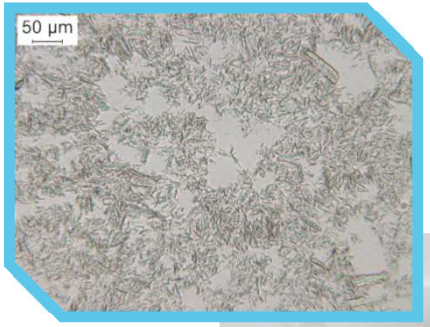
**Biocelsol film**

Cellulose is dissolved and coagulated into film



Transparent film

**MFC film**




MFC is dried and dehydrated into film

Opaque film

| Cellulose as raw material: | Cellulose films are: | Applications |
|---|---|---|
| • Abundant<br>• Renewable raw material<br>• Biodegradable | • Biodegradable<br>• Non toxic<br>• Barrier to oxygen | • Packaging etc. |

# Oxygen permeability

| Sample | Thickness, µm | OTR, ml $m^{-2}$ $day^{-1}$ | Ref. |
|---|---|---|---|
| Cellulose | 32 ± 2 | 8* | This work |
| Cellulose | 32 ± 2 | 1** | This work |
| MFC | 58 ± 6 | 3** | This work |
| Cellophane | 21 | 3 | a |
| MFC | 21 | 17 | b |
| Polyester | 25 | 50 – 130 | c |
| EVOH | 25 | 3 – 5 | c |
| Polyethylene LD | 25 | 7800 | c |
| Polyethylene HD | 25 | 2600 | c |

Measurement conditions:
*23°C / 50% RH / 10% $O_2$
**23°C / 0% RH / 100% $O_2$


References:

This work, studies by Kamppuri T. & Lahti, J.

a) ´Kjellgren and Engström (2006) Influence of base paper on the barrier properties of chitosan-coated paper. Nordic Pulp Pap Res J 21(5):685–689. DOI 10.3183/NPPRJ-2006-21-05-p685-689

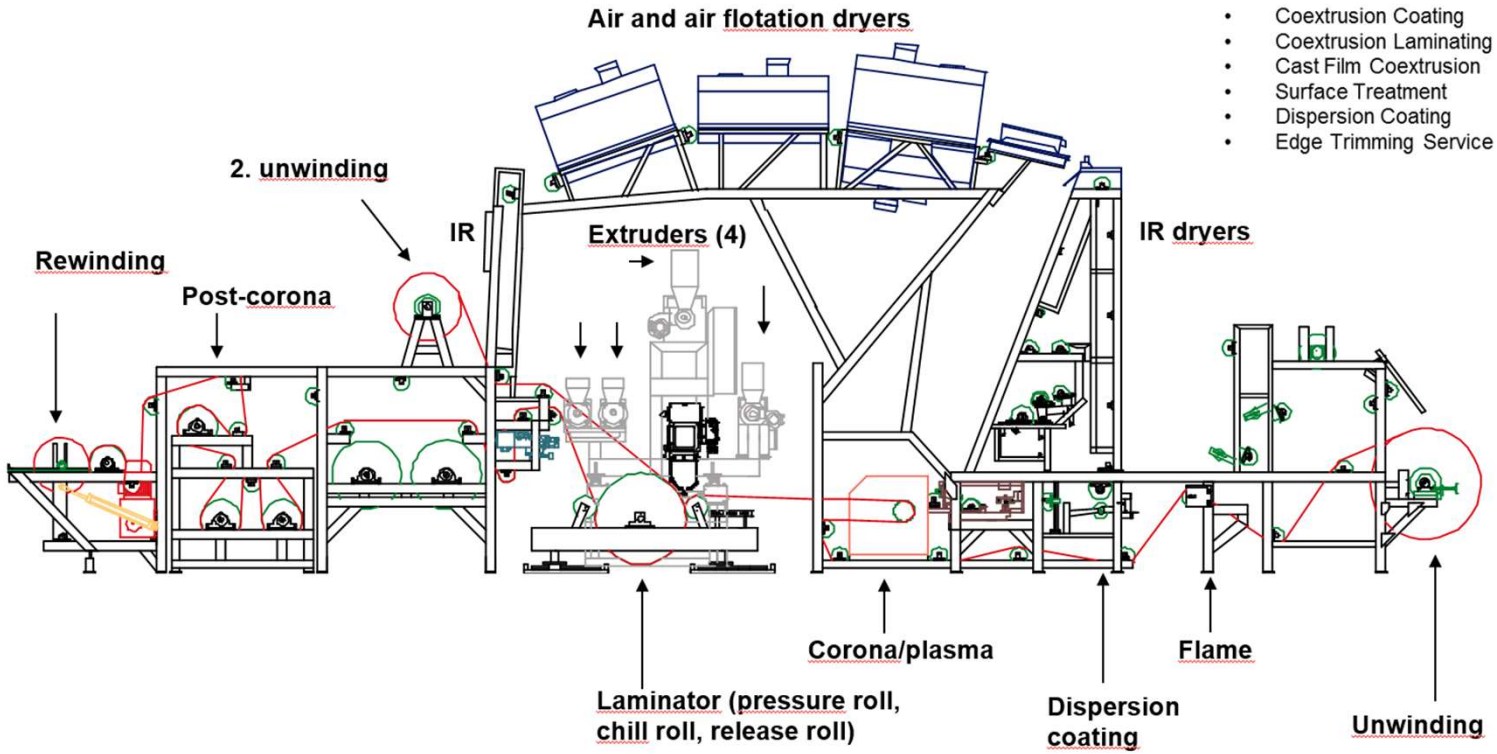
b) Syverud and Stenius (2009) Strength and barrier properties of MFC films. Cellulose 16:75-85. DOI 10.1007/s10570-008-9244-2

c) Parry (1993) Principles and applications of modified atmosphere packaging of foods. Chapman & Hall, Suffolk

# TUT Facilities


YouTube video:
“NanoMEND pilot line”

# (co)Extrusion coating and lamination pilot line (TUT)

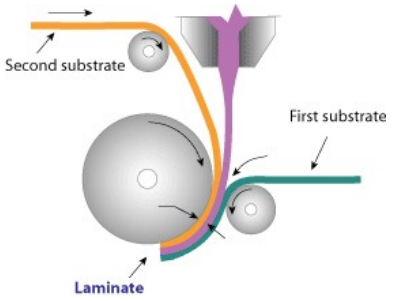


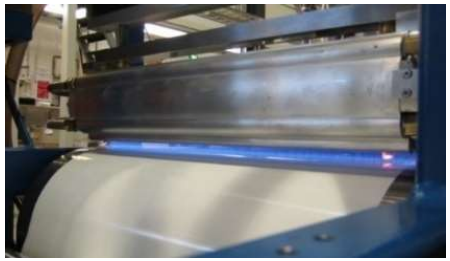

- Coextrusion Coating
- Coextrusion Laminating
- Cast Film Coextrusion
- Surface Treatment
- Dispersion Coating
- Edge Trimming Service

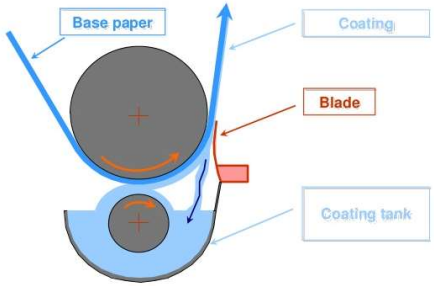
# Processes available at the pilot line

Versatile roll-to roll pilot-lines:

- (co)Extrusion coating and lamination
- 4 extruders, 5-layer technology, encapsulation possibility
- Dispersion coating (rod/blade)
- Surface treatments (flame, corona, plasma etc.)
- Max. line speed 400 m/min, max. substrate width 550 mm

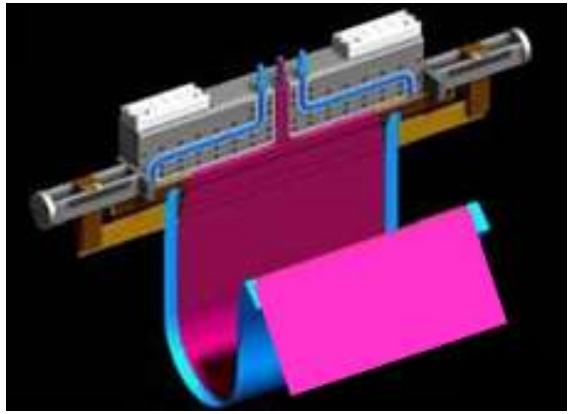


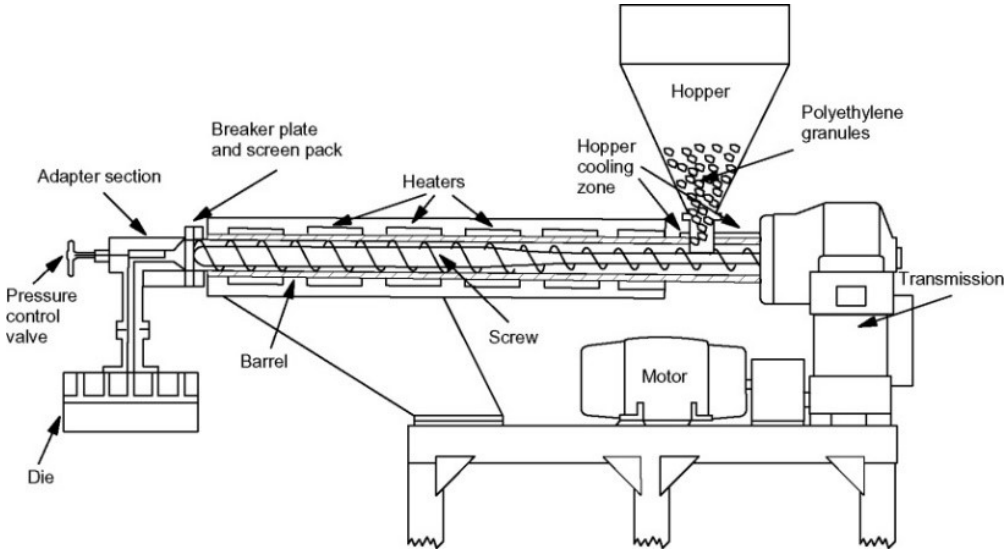



New process being installed this year:
**R2R application of nanocellulose**

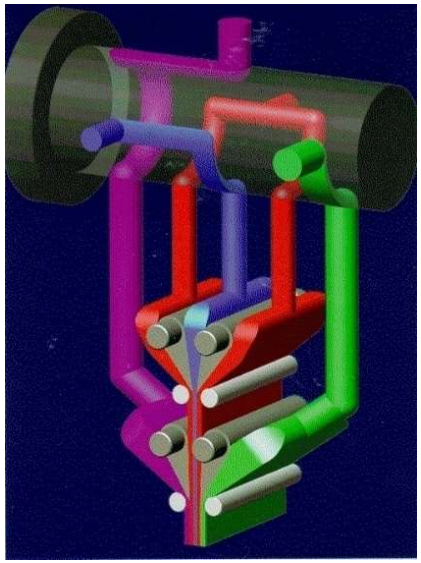
# Processes available at the pilot line



T-die with encapsulation possibility

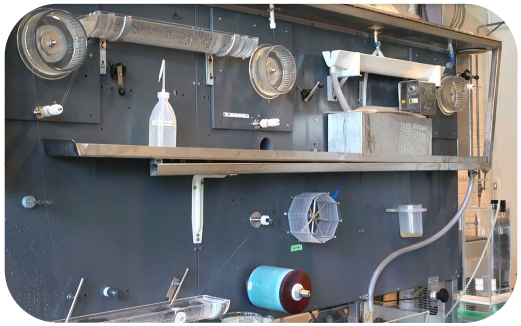



5-layer technology: Selector plug and Cloeren-feedblock



Plastics as pellets, dry blending is possible

# Prototyping for melt-, wet- and electrospinning in lab scale

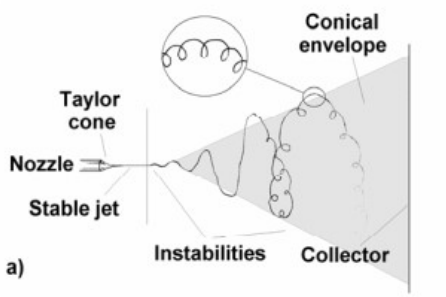


Wet spinning:

- For polymers that need to be dissolved in a solvent to be spun → not suitable for lignin as such; but suitable for example lignin/cellulose mixtures
- Capacity 10 – 1000 g fibres/day
- Several different spinnerets (e.g. 100X51µm; 2100x51 µm)

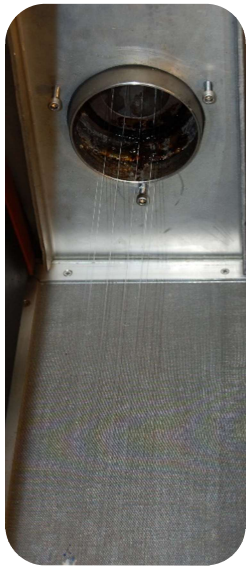
Electrospinning:

- For polymer solutions
- Horizontal electric field, Luer needle, copper collector
- Syringe pump can be used to control output
- Capacity 1-10 ml/day



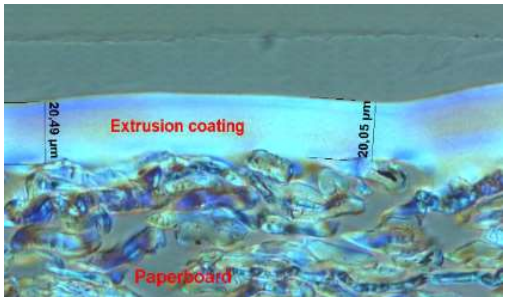

Melt spinning:

- For thermoplastic polymers that can be melted
- Capacity 200 – 5000 g fibres/day
- Spinning velocities 10-800 m/min
- Max. spinning temperature 350 °C

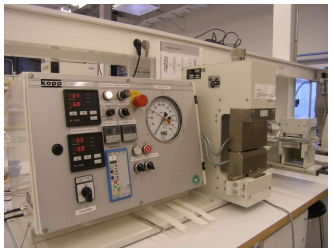


# TUT Paper Converting and Packaging Technology Laboratory

- Two environmental test chambers (23-38°C / 50-90%RH, volume 120l)
- Permeability (barrier) measurements:
  - $O_2$TR: MOCON Ox-Tran 2/21 MH and Ox-Tran 2/21 SS
  - WVTR: MOCON Aquatran 1G and Cup test (ASTM E96-10)
  - $CO_2$TR: MOCON Permatran-C 4/41
  - Grease resistance (ASTM F119-82)
  - HVTR
- Dual column material testing machine: Strength properties and adhesion measurements (90°and 180°peel)
- Contact angle and surface energy
- Heat sealability:
  - Hot bar sealing and hot tack (KOPP SGPE 20 laboratory sealer)
  - Hot air sealing
  - Ultrasonic sealing





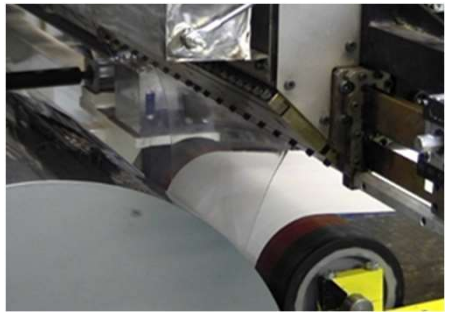


- Coefficient of friction (Qualitest FX7100-V)
- FTIR with ATR unit
- Optical microscope with polarisation contrast + microtome
- Extrusion rheometer
- Lab-scale sheet coater
- Brookfield viscometer
- Creasing – perforating machine (Cyklos GPM4 50)
- Package testing:
- Hydrogen leak detector H2000
- PBI Dansensor CheckPoint O2/CO2

# MOL/PCPT in BioÄly-project

**Challenges**

- Alternatives for fossil-based materials
- Use of renewable raw materials
- Reduction of resources and material costs
- Consumer awareness and circular economy



**Results**

- New materials and material combinations with enhanced and optimised properties
- Bio-based and sustainable products
- Source reduction and cost-effectiveness


**Solutions**

- Bio-based materials
  - Fiber-based (paper, board), wood-based (MFC, lignin), biopolymers (PHA, PLA, etc.), multilayer structures of these
- Development of sustainable processing methods and materials
- Laboratory testing and analysis of materials
  - Substrates, polymers, coatings
- Optimisation of processes (roll-to-roll pilot-line)
  - Coating, lamination and surface treatment trials

# *Thank You! Kiitos!*

**Project's Principal investigators:**

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