Materials and Processing Development for Sustainable Packaging Solutions

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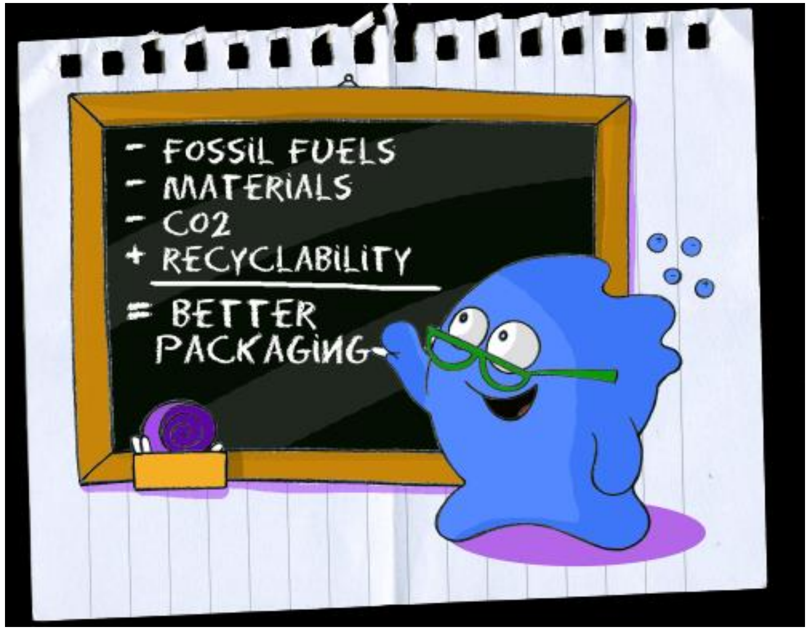
Content

- Research group and facilities
- Packaging development
- Biobased and wood based materials
- Project examples
- Nanocellulose
- Challenges

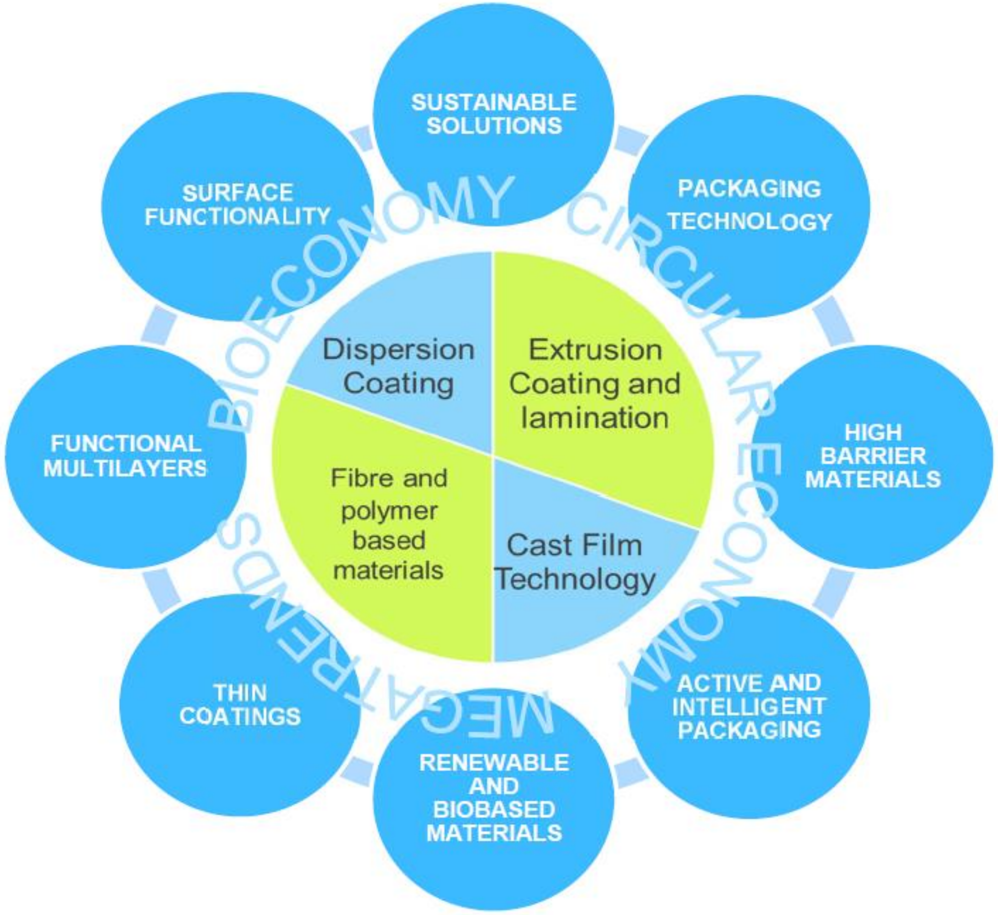
Research group of **Paper Converting and Packaging Technology**

- The research group offers teaching and research on **paper, paperboard and polymer processing, converting and packaging technology, materials (wood-, fiber- 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.**



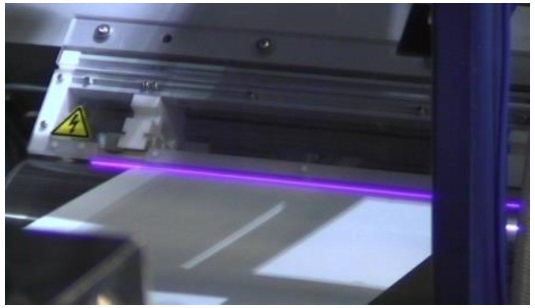
Current research topics

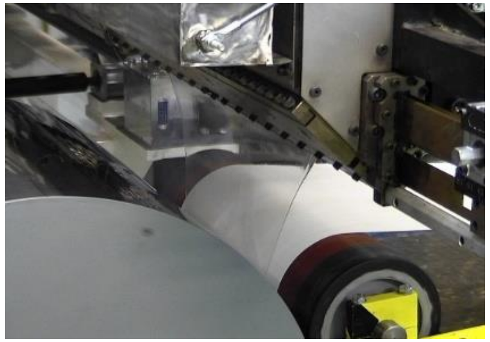
- High-barrier co-extruded coatings and films
- High-barrier paper and paperboard packages
- Biodegradable and bio-based coatings and materials
- Wood-based materials (*e.g.* lignin, cellulose) for various applications
- Active and intelligent packages solutions
- Surface functionalization of plastic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



Facilities

- Production of packaging materials via:
- (co)Extrusion coating and lamination
  - 4 extruders
  - 5-layer technology
  - Encapsulation possibility
- Dispersion coating (blade/rod)
- Cast film (co)extrusion
- Max. line speed 400 m/min, max. substrate width 500 mm
- Surface treatments and functionalisation, e.g. corona, flame, plasma, IR, UV, LFS



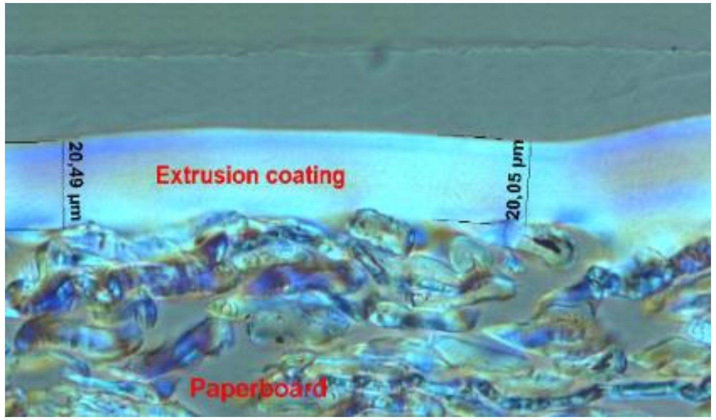


New investment for R2R application of nanocellulose

Tampereen yliopisto
Tampere University

Paper Converting and Packaging Technology Laboratory

- Two environmental test chambers (23-38°C / 50-90%RH, volume 120l)
- Permeability (barrier) measurements:
  - O_2TR: MOCON Ox-Tran 2/21 MH and Ox-Tran 2/21 SS
  - WVTR: MOCON Aquatran 1G and Cup test (ASTM E96-10)
  - CO_2TR: 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

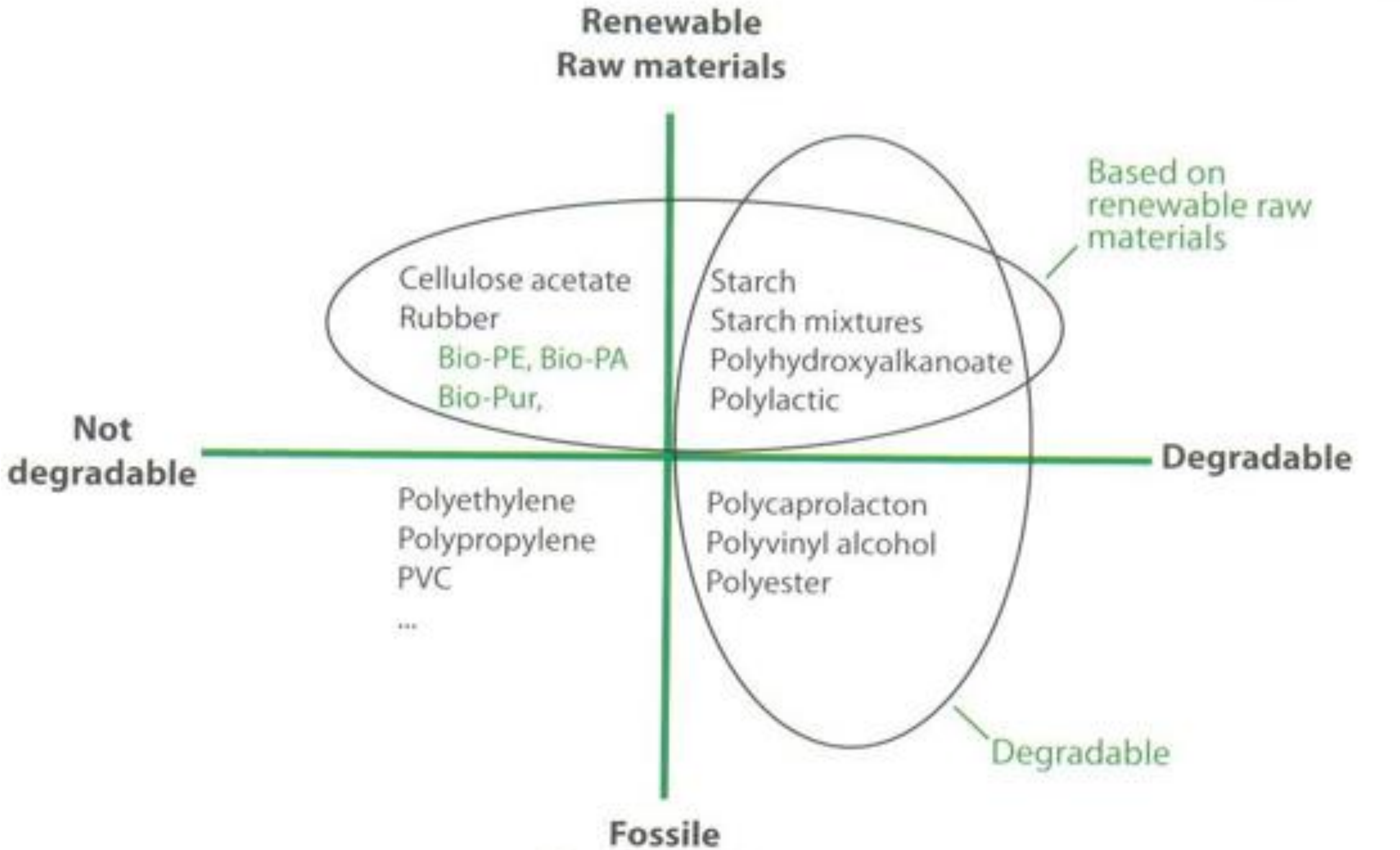


- Coefficient of friction (Qualitest FX7100-V)
- FTIR with ATR unit
- Optical microscope with polarisation contrast + microtome
- Extrusion rheometer
- Lab-scale sheet coater
- Brookfield viscometer
- Creasing – perforating machine (Cyklos GPM4 50)
- Package testing:
- Hydrogen leak detector H2000
-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

Package development

- **Packaging materials are usually multilayer structures**
  - “Less is more” – optimisation of material selection and amount
  - Lighter packages save energy and environment
- **Circular and bioeconomy: biodegradability, compostability, environmentally friendly, recyclability, re-use….**
  - Materials that are easier to recycle or re-use
  - Renewable alternatives for petroleum-based (non renewable) materials
- **Trends in packaging industry (e.g.):**
  - Internet shopping is increasing
  - Delivery chains are evolving
  - Food losses should be prevented
  - Product safety/authenticity
- The demand for **high quality (active and intelligent) packaging concepts** is constantly increasing.

Classification of polymers based on raw materials



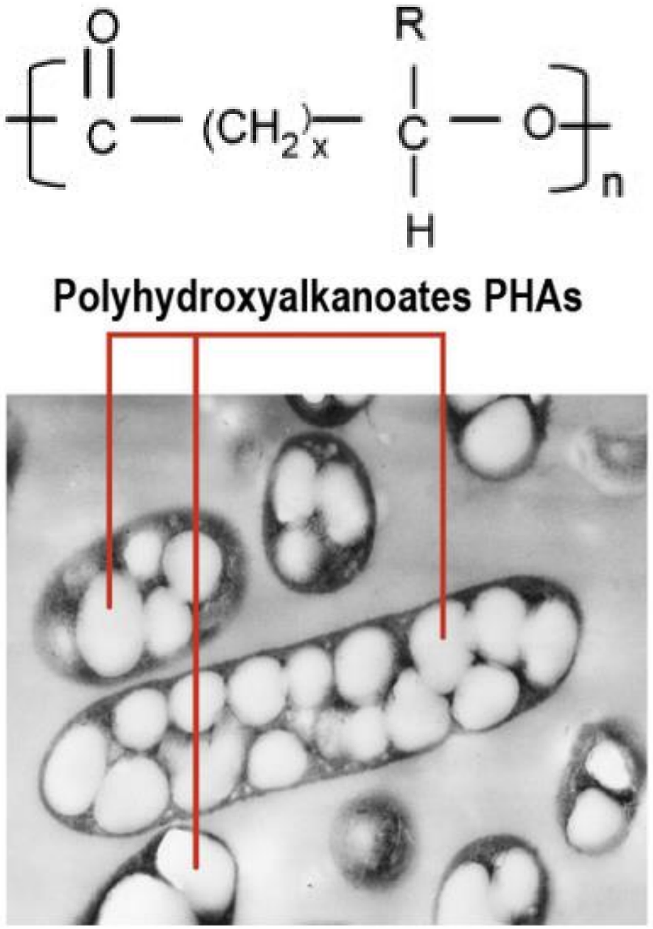
Source: Fachhochschule Hannover

Environmental impact of plastics

- In food packaging…
  - energy demand would **double,**
  - greenhousegas emissions would **triple** and
  - weight of packaging materials would **quadruple,**
- …If food is not packed in plastics.
- In USA food production one kilocalorie of food requires ten kilocalories of fossil fuels
  - → If reduction of plastic increses wastage, the environmental damage is ten times larger than the benefit.
- The environmental impact of one ham slice is bigger than the environmental impact of the whole package.
- Less food waste means less packages. → It is more crusial to pack properly rather than ”green”.

Biodegradable bio-based polymers for packaging applications

- **Research group has been studying bio-based materials over 20 years (PLA, PHA, starch, etc.)**
- **Polyhydroxyalkanoate (PHA)** is a linear polyester naturally occurring as a result of bacterial fermentation of sugar.
- There are over 150 different PHA monomers→ many different material properties.
- **PHB (polyhydroxybutyrates)** are the most studied PHA groups. They are intracellular biopolymers formed by bacteria as carbon and energy storage.
- PHB is a homopolymer, PHBV is a copolymer with varying content of Hydroxy Valerate (HV).
- PHA can be derived e.g. from sugar beets.



Ref: www.bio-on.it

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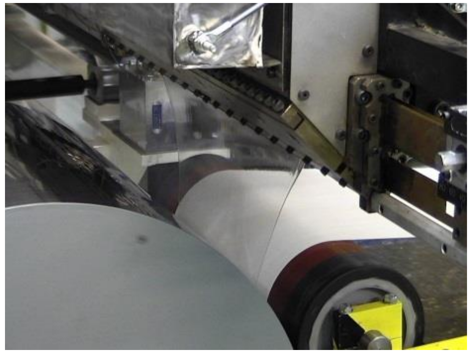
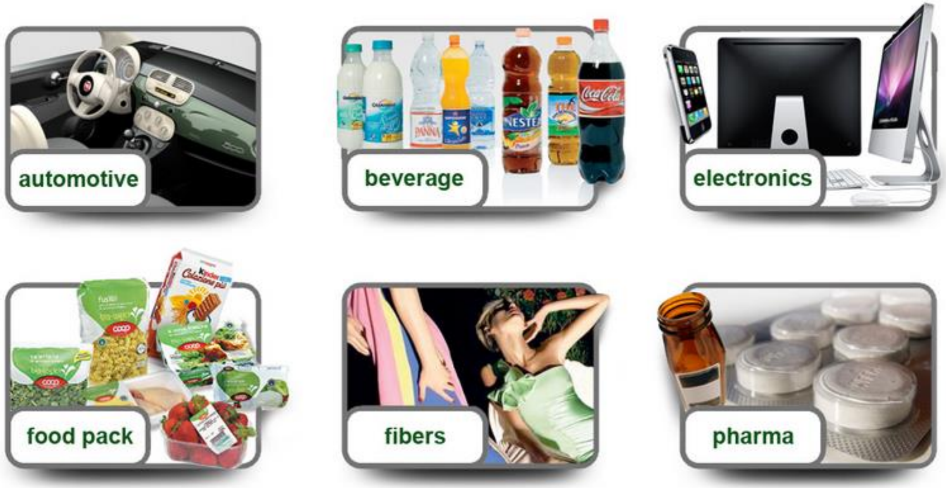
BioBarr H2020 project develops new **bio**-based food packaging materials with enhanced **barr**ier properties

Bio-on produces the polymer



TAU conducts casting into films



- MINERV-PHA™ is based on renewable raw materials, *i.e.* produced from side streams of sugar production (sugar co-products).
- Polymer is biodegradable. (Vincotte, TÜV)
- 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,

Bio Barr
http://www.biobarr.eu/
GA. No. 745586

Challenges with biopolymers

- Biopolymers can be moisture sensitive, which restricts their use in certain applications especially in food packaging.
- Generally, the mechanical and barrier properties are not yet at the same level compared to traditional petroleum based polymers.
- Processability and runnability of biopolymers is often limited and the ”processing window” can be very narrow.

→ Converting into packaging solutions, where the requirements are very high, is challenging.

- Different definitions of biodegradability (compostability) → actual biodegradability with changing conditions?
- Terms and definitions from consumer’s perspective (e.g. biobased vs. biodegradable, the amount of biobased content etc.)

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Eucaliva H2020 project develops bio-based products from Eucalyptus

- Target to valorise current waste, known as black liquors from the kraft process of a Eucalyptus, separating useful components such us **lignin and polyurethanes**
- Lignin is the second most abundant natural polymer
- **Target** to develop and set-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**, mainly for functional applications.

- **New applications** will be reached: multifunctional film-like conductive, piezo-resistive and piezoelectric materials, smart fabrics and functional fibres, as well as applications based on fibrous mats, non-woven fabrics and their carbonized derivatives.

http://eucaliva.eu/
GA No. 745789

EUCALIVA

Nanocellulose

- Group of materials, which do not have one standardized definition.
- Includes e.g.
  - Cellulose nanocrystals (CNC)
  - Cellulose nanofibrils (CNF)
  - Cellulose filaments (CF)
  - **Microfibrillated cellulose (MFC)**
  - Bacterial cellulose (BC)
- Not necessarily nanoscale (e.g. MFC) or not even cellulose due to chemical modification (e.g. CNC).
- Extraction by **mechanical**, chemical, or enzymatic treatment.
- Growing from bacteria.

- Mechanical properties
  - High aspect and strength to weight ratio
- Physical properties
  - Piezoelectric and optical properties
- Chemical properties
  - **Oxygen barrier properties**
- Rheological properties
  - Thixotropy
- Environmental properties
  - Abundant and renewable

Challenges with nanocellulose

- Costs
- Application
  - Upscaling is difficult
- Solid content
  - Increasing may cause clogging and hinder dispersion
- Drying
  - High capacity is necessary and skin formation is possible
- Performance in converting
  - Folding, heat sealing etc.
- Agglomeration and redispersion
  - Strong hydrogen bonding of the fibers when dried
  - Redispersion can be difficult if not impossible
- Energy consumption caused by drying and redispersion vs. transportation of “water”
- Hydrophilicity
  - Absorbs moisture from air
  - Mechanical and barrier properties decrease
- Regulatory

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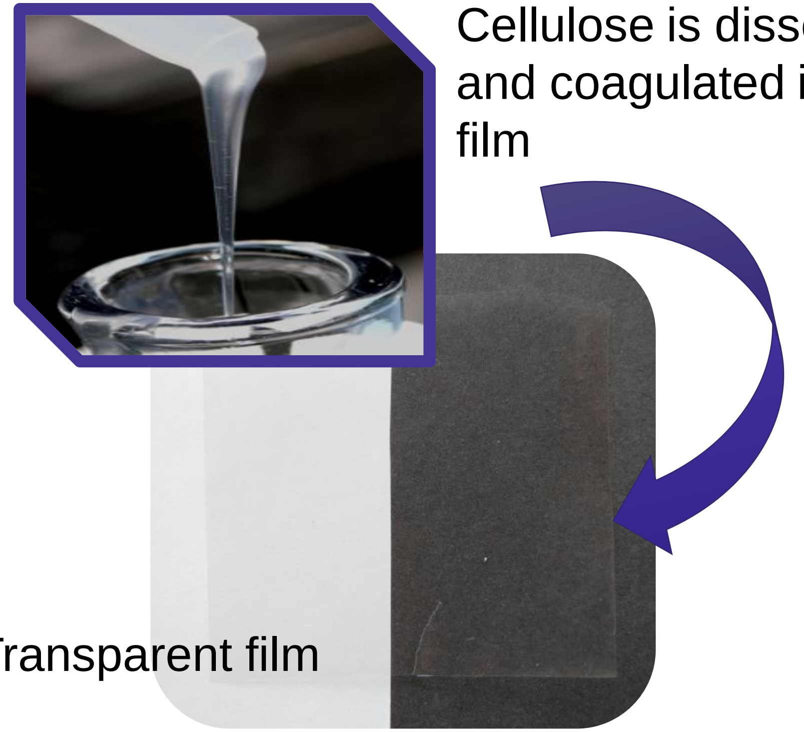
From wood to films

”Biocelsol” film

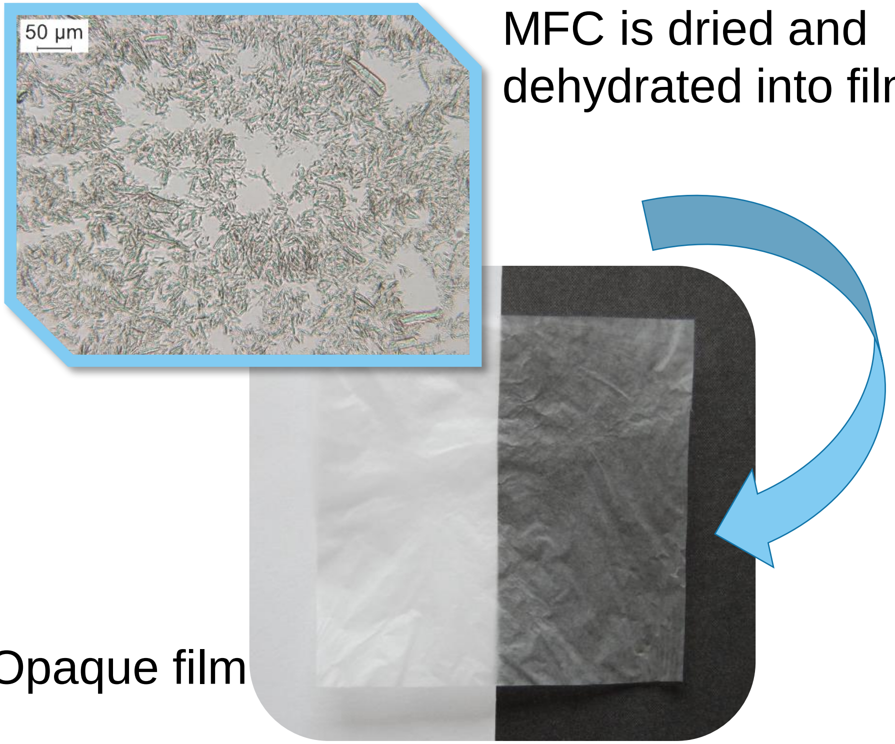
Cellulose is dissolved and coagulated into film



Transparent film

MFC film

MFC is dried and dehydrated into film



Opaque film

Cellulose as raw material:
- Abundant
- Renewable raw material
- Biodegradable

Cellulose films are:
- Biodegradable
- Non toxic
- Barrier to oxygen

Applications
- Packaging etc.

Ref. Lahti, J. et al,
Papermakers conf., Bled 2016

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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: Johanna Lahti and Taina Kamppuri, Tampere University

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

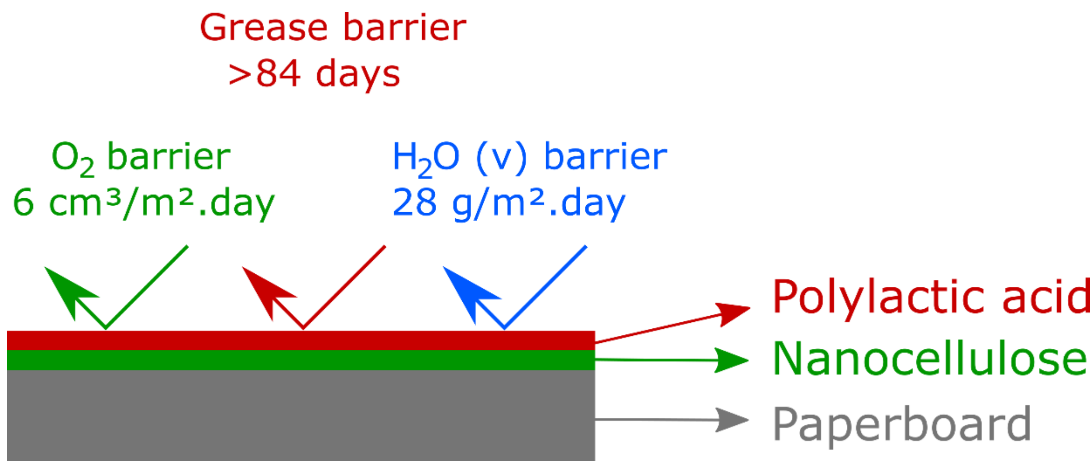
b) Syverud and Stenius (2009) Strength and barrier properties of MFC films. Cellulose 16:75-85. DOI 10.1007/s10570-008-9244-2

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

Multilayer structures

- Coextrusion technology provides multilayer structures
- Nanocellulose/MFC provides improved O_2-barrier properties
- On the other hand, NC/MFC layers can be protected with extrusion coating – PLA provides WV-barrier

→ **Bio-based multilayer packaging structure**



Ref. Lahti, J. et al, Tappi Place 2019; Koppolu R. et al., ACS Appl Mater Interfaces (2019)

Thank You!

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Further information:

- FP7: PlasmaNice http://www.tut.fi/plasmanice/
- FP7: NANOMend http://nanomend.eu/
- COST Action ActInPak: http://www.actinpak.eu/
- New wood initiative: http://www.uusipuu.fi/en/newtree
- H2020 BioBarr: http://www.biobarr.eu/
- H2020 Eucaliva: http://eucaliva.eu/
- BioÄly (”Bio-based intelligent solutions”, ERDF project: http://www.bioaly.fi/