High Performance Bio-based Functional Coatings for Wood and Decorative Applications

Making bio-based compounds

Developing bio-based binders for wood coatings

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Wood coatings

For embellishing and/or protecting wooden surfaces

The current paints and coatings market is mainly populated by formulations that are optimised for the use of synthetic chemicals and fossil-based resins.

In 2019, Europe's bio-based production of paints and coatings was ~164 kt/yr, while fossil-based production was ~718 kt/yr

The most promising path towards the development bio-based coating formulations, lies in the replacement of binders, fillers & pigment with plant-based materials

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Binders

- Polymers that form continuous films on substrate surface
- Good adhesion to substrate
- Holds pigment particles distributed throughout coating
- Dispersed in solvent either in molecular form or colloidal dispersion

- **Alkyd resins** – condensation polymerisation of fatty acids and polyols (e.g., glycerol) with polybasic acids
- **Acrylic resins** – polymerisation of acrylic or methacrylic esters
- **Latex (PVA)** – Free radical vinyl polymerisation of monomeric vinyl acetate
- **Phenolic resins** – Reaction of phenol with aldehydes
- **Urethane resins (polyurethanes)**- polymerisation of isocyanates reacting with molecules containing hydroxyl (alcohol) groups
- **Epoxy**-crosslinking a resin containing short molecules in the presence of a hardener
- **Chlorinated rubber** – polymerisation of degraded natural rubber

UV curable and water-based binders

UV curable binder

Target application: Wood coatings

Requirements:

Liquid pre-polymer

- Liquid oligomer with acrylate moieties
- Acrylate moiety must not be sterically hindered, ideally with spacer between acrylate and polymer backbone for good accessibility

Low viscosity solution of resin in reactive diluent

- Solubility in reactive diluents, e.g. ethoxylated TMPTA, TPGDA
- Resin content not lower than 50%, preferred 70%

Water-based binder

Target application: Architectural paints

Requirements:

Water-insoluble polymer

- Hydrophobically modified polysaccharide backbone, dispersed in H2O

Low-viscous aqueous dispersion with high solids content

- Long-term (months) stability against sedimentation and microbial growth

Coalescence into water-resistant closed film

- No wash-out, no macroscopic changes upon prolonged contact with water

Film must be flexible

- Final film must not be tacky

Appealing optical properties

- Final film must be transparent, ideally with high gloss, no yellowing

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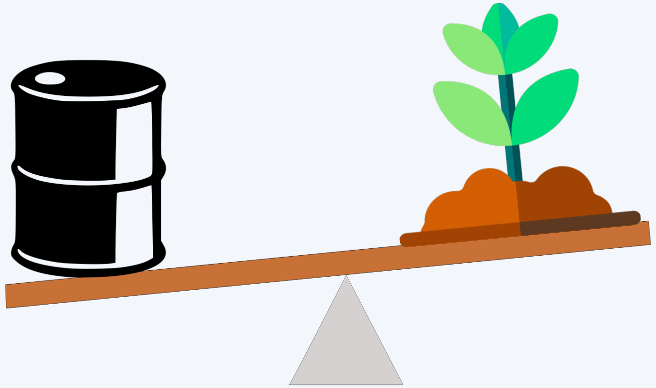
Bio-based binders

Bio-based product penetration in the paint industry has so far remained below 5 to 10% mostly due to sub-optimal technical performance and high cost

The use of polymers from renewable resources constitutes the base of the needed paradigm shift in the coatings industry as they constitute a non-toxic, non-depletable and biodegradable resource capable of competing with fossil fuel derived petrol-based products



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Base components explored in developing bio-based binders

- Alginate
- Xanthan
- Microbial lipids
- Free fatty acids

Alginate is made up of guluronic acid and mannuronic acid. The carboxyl groups and hydroxyl groups present in these sugar acids provide opportunities to tailor the polymer and to form composites with other polymers

Xanthan has backbone similar to cellulose and side chains beta-D-glucose, alpha-D-mannose and alpha-D-glucuronic acid. The hydroxyl groups and carboxyl groups on xanthan can be modified to change the physical properties of xanthan

Lipids and fatty acids provide beneficial hydrophobic properties when grafted on to polysaccharides

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Base components explored in developing bio-based binders

Xylan
Fatty acids
Cellobiose

The structure of xylan varies based on the source of xylan. Xylan from grasses is highly branched, while xylans from hardwood is relatively less branched and easy for tailoring and grafting using chemicals/enzymes. Xylans have reactive hydroxyl and carboxyl groups that can be taken advantage of for synthesis of new molecules.

Cellobiose is a disaccharide derived from cellulose and its unique small molecule and abundance hydroxyl group makes it a suitable candidate for synthesis of molecules suitable for binder applications

Chitin/Chitosan

Chitin/Chitosan is a cationic polymer and can provide unique amine functionality to the synthesised molecules

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Bio-based binder development strategies

Alginate, xylan, and chitin explored for chemical and/or enzymatic modification to function as bio-based binders in waterborne coating formulations

Grafting of UV-cross-linkable double-bonds onto alginate, xanthan and lipids by mean of (bio)catalysis or microbial engineering will yield UV-curable binders for solvent-free UV-curable coating formulations

Additional properties like hardness and scratch resistance as well as fine-tuning of the hydrophilic/hydrophobic balance can be conferred through the introduction of novel nanomaterials

Examples of nanomaterials include microfibrillar cellulose (MFC) and polyhedral oligomeric silsesquioxane (POSS).

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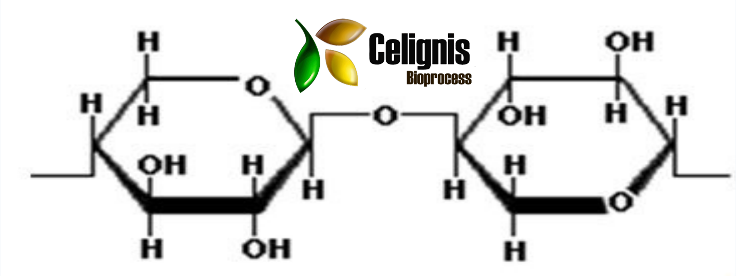
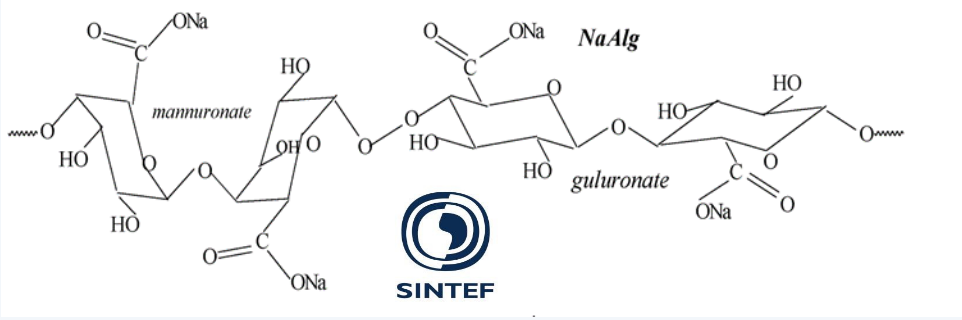
Polysaccharide modifications

Xylan



- Esterification of the OH groups with organic acids, short chain and long chain fatty acids
- Esterification of OH groups by acrylic acid derivatives

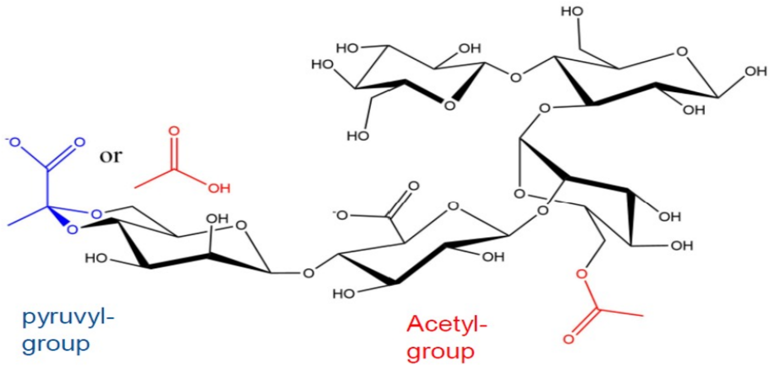
Alginate



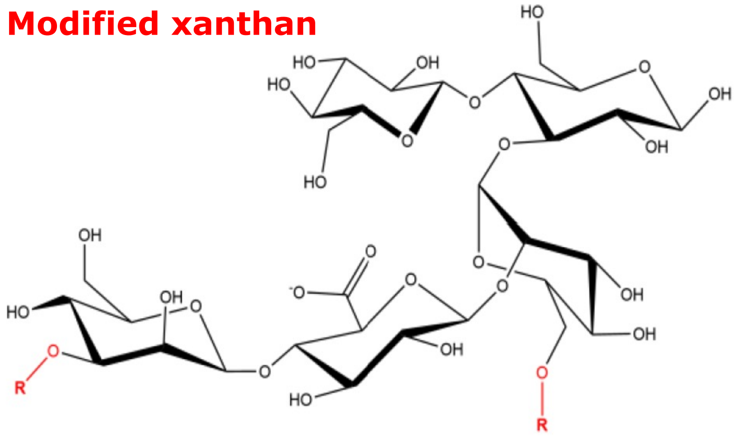
- Converting the COOH groups into methyl and ethyl esters (increasing hydrophobicity)
- Esterification of the OH groups with short chain and long chain fatty acids
- Esterification of OH groups by acrylic acid derivatives

Polysaccharide modifications

Natural xanthan



Modified xanthan



- Acetylation and pyruvylation of xanthan
- Chemical modification with unsaturated organic acids
- Biochemical modifications vivo synthesis of methacrylated xanthan

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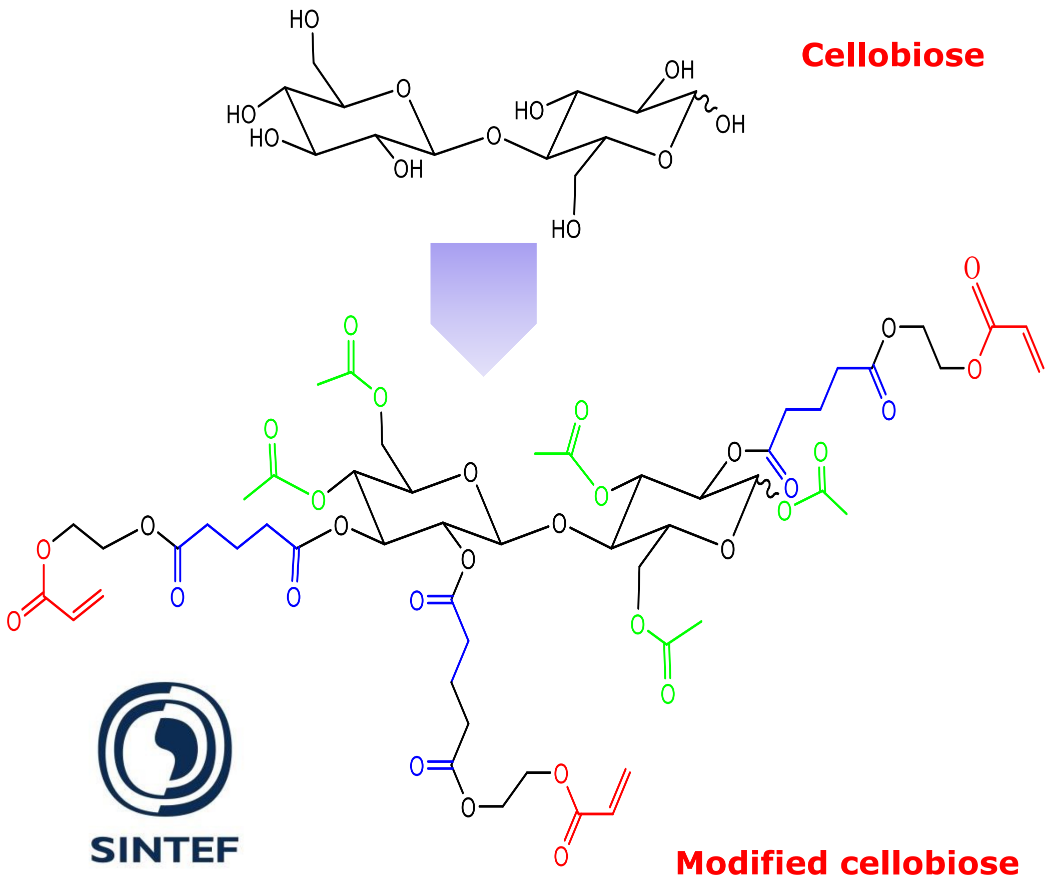
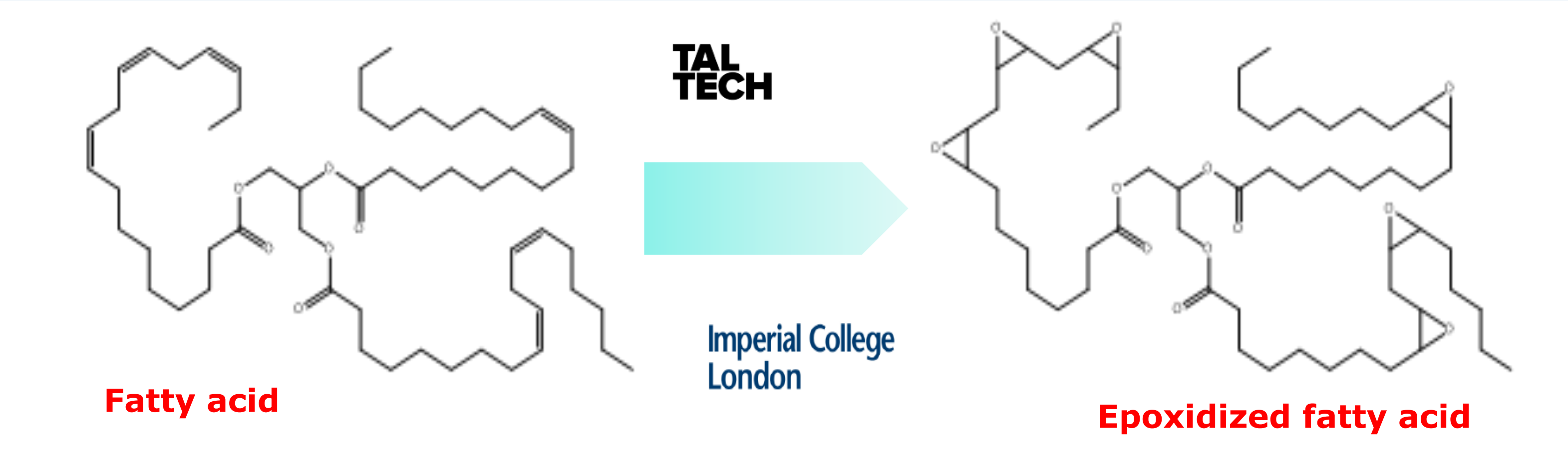
Cellobiose modifications



- Acetylation of cellobiose
- Esterification of OH groups with acrylic groups
- Modification to introduce spacer groups to facilitate crosslinking

Lipids and fatty acids modifications



- Epoxidation and acrylation of lipids
- Reaction with anhydrides and carboxylic acids
- Converting the lipid epoxide to alcohol followed by esterification
- Reaction with other base polymers

Outcomes of the bio-based binder trials

Progression of binder development

Funzionano
TAL TECH
SINTEF
Imperial College London
Technical University of Munich TUM
Celignis Bioprocess

Binder development
Preliminary testing

EVONIK Leading Beyond Chemistry

Film forming ability
Curability
Hydrophobicity
Mechanical strength (Pendulum hardness)
Film uniformity and clarity
Structural analysis (NMR, GPC, etc.)

remmers
ORGANİK KİMYA

Formulation and application testing

Flow of feedback for binder improvement

Alginate
Poss
MFC

Microbial lipids
Cellobiose
Xylan

Way forward

PERFECOAT consortium seeks to established a modular and flexible technology platform for the production of innovative bio-based binders from a range of biopolymers and functionalised materials

Efficient biotechnological processes based on sustainable feedstock are thereby at the core of our approach and developments

The coating functionalities obtained through the materials developed in the PERFECOAT project will be wood protection, self-cleaning, waterproofing in addition to inherent properties that will provide the necessary integrity of the coatings for the targeted applications

The targeted bio-based binder concentration in our new formulated coatings will be in the range of 25-50 wt% and thus alone fulfil the bio-based content required by the call for proposals

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Thank you very much for your attention!

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