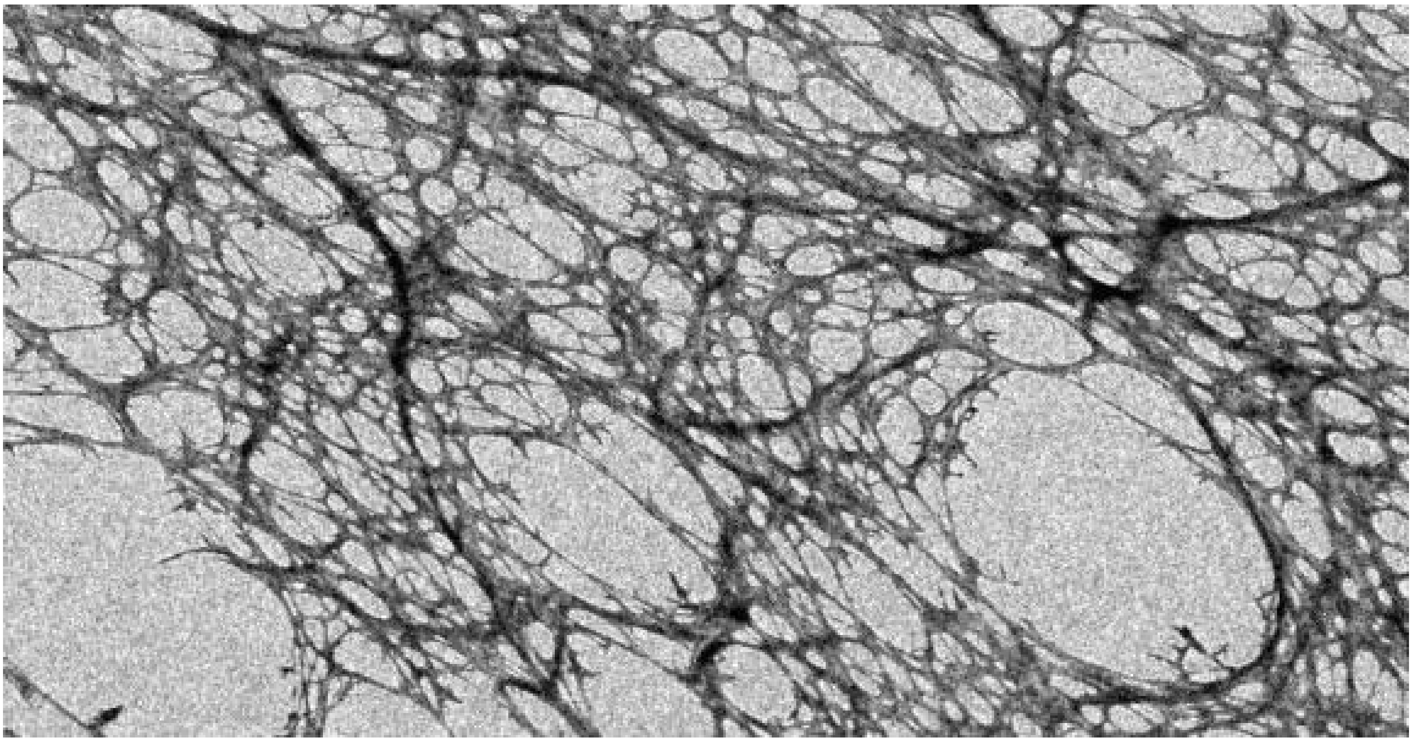

Production and functionalisation of nanocellulose

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Versatile bio-based material ready for industrial application

Depending on the type of nanocellulose produced the possibilities of this promising material are huge. So are its properties, which can be made very specific and tunable through functionalisation. The resulting materials can be used for a wide range of technological applications. We give you an overview of the different production and pre-treatment steps of nanocellulose.

In a previous blog we introduced nanocellulose as a versatile, environmentally-friendly material that shows great potential in a wide range of applications. This wide range of possibilities is linked with the fact that different types of nanocellulose material can be produced: fibrous, crystalline and bacterial, depending on the production method used. Additionally, the source material influences the dimensions of the nanocellulose and functionalisation can give the nanocellulose very specific and tunable properties. In this blog, a short overview is given of these different production and pre-treatment steps.

Production methods

The production of nanocelluloses involves several steps with pretreatment, extraction and purification under a combination of mechanical, physical, chemical and biological conditions. The specific morphology of the resulting nanocellulose highly depends on the selection of specific sources and processing conditions. Starting from natural fibres and plants, different methods are employed to remove impurities such as lignin, hemicellulose, and pectin, while other sources may be selected to obtain more pure forms of nanocellulose with less intensive processing. The broad range of resources and toolbox of processing steps provides nanocellulose materials that can be assembled into functional structures and high-quality materials for technological applications (e.g., hydrogels, aerogels, macroscopic filaments, membranes, composites and coatings). The mechanical properties of resulting nanocelluloses may become comparable to traditional steel fibres, ranging from 10 to 130 GPa Young's modulus.

Acid Hydrolysis: In this method, cellulose is treated with acid to break down its fibres into nanoscale dimensions. Careful control of the reaction conditions is essential to achieve the desired size and morphology of the resulting nanocellulose.

Enzymatic Hydrolysis: Enzymes selectively break down cellulose into nanofibres or nanocrystals. This method is often milder than acid hydrolysis and can be more environmentally friendly.

Mechanical Methods: High-pressure homogenisation, microfluidisation or grinding can be employed to physically break down cellulose into nanosized particles with precise control over particle size. Although these methods are intrinsically energy-intensive, significant efforts and advances were recently made to make the processing more sustainable in combination with suitable pretreatment.

Nanocellulose type	Production	Crys tallinity	Morphology
Spherical cellulose nanoparticles (SCNPs)	Enzymatic or chemical pretreatment and hydrolysis (acidic and alkali treatment)	30–50 %	Spherical shape with diameter
Nanocrystalline cellulose (NCC)	Chemical pretreatment (Alkali pretreatment, acid hydrolysis, oxidizing agent, organosolv, and ionic liquids)	54–88 %	Crystalline needle-sh like cellulose particle crystallinity
Cellulose nanofibers (CNFs)	Mechanical disintegration (Homogenizing, cryocrushing, microfluidization, grinding, and high-intensity ultrasonication)	68.5 %	Nanofibrils with a di 10–100 nm, amorph crystalline sections
Bacterial Nanocellulose (BNC)	Biosynthesis (enzymatic pretreatment and bacterial synthesis)	75–80 %	Ribbon-like nanofibe diameter of 20–100
Cellulose Nanoyarns (CNY)	Wet, dry, and melt spinning, or electrospinning of soluble cellulose derivatives such as cellulose acetate (CA) and hydroxypropyl cellulose (HPC).	50–60 %	Highly aligned fibril- with a 100–1000 μm
Cellulose nanohybrids	Melt extrusion and casting techniques using hydro-soluble, emulsion, and non-hydro-soluble systems	N/A	Different shapes wit of length
Aerogels	Dissolution, gelation, and freeze-drying or supercritical drying. The Dissolution of cellulose followed by gelation and fabrication of the pore structure	N/A	A network structure fibers with 50–200 n foam-like structure w porosity

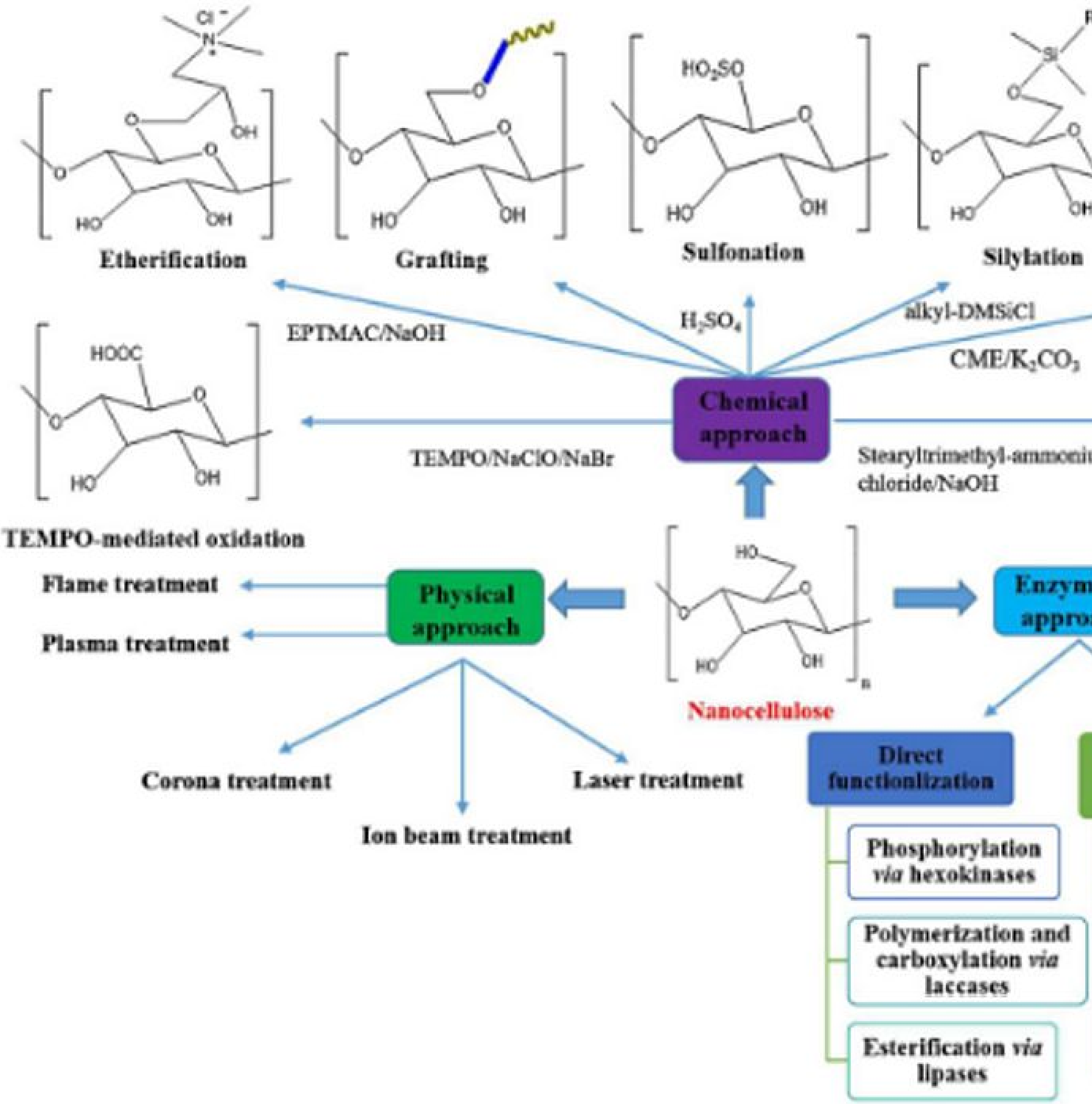
Types of nanocellulose, the production method and resulting morphologies and dimensions

Following nanocellulose production, purification steps such as washing and filtration are performed to eliminate any remaining impurities and achieve a clean and refined nanocellulose product for further modification.

Functionalisation of nanocellulose

In combination with their intrinsic properties such as high specific surface area, light weight, amphiphilic properties, water holding capacity, chemical reactivity, biodegradability, high mechanical strength, environmental friendliness and non-toxicity, functionalisation is a key step in enhancing the properties of nanocellulose for specific applications. It involves modifying the surface of the nanocellulose structure or introducing functional groups to reach desired characteristics and functionalities. The most commonly used routes are chemical, physical or enzymatic. Each of these routes consist of different possible techniques creating a wide variety of possibilities and surface functionalities.

Through the surface modification of nanocellulose, the hydrophobic properties and compatibility within composite matrixes may be enhanced, or additional features are introduced, such as antimicrobial activity, biocompatibility, thermal stability and flame retardance, selective absorption capacity, barrier properties or electrical conductivity.



Schematic representation of the most commonly used surface modification routes of nanocellulose

Want to know more?

As we believe this material can become a game changer in future applications, we want to introduce you to this material during a **seminar** with experts in the field, from Belgium and abroad. Don't miss this opportunity to delve into the world of nanocellulose and explore how it can enhance your company's sustainability, innovation and competitiveness: check our agenda regularly or contact us, we'll be happy to keep you up to date!

Sources

Table: P. Samyn et al., “Nanocelluloses as sustainable membrane materials for separation and filtration technologies: Principles, opportunities, and challenges” Carbohydrate Polymers 317 (2023) 121057.

Figure: Trache Djalal, Tarchoun Ahmed Fouzi, Derradji Mehdi, Hamidon Tuan Sherwyn, Masruchin Nanang, Brosse Nicolas, Hussin M. Hazwan, Nanocellulose: From Fundamentals to Advanced Applications, Frontiers in Chemistry, Vol. 8, 2020

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