Dispersion of cellulose nanocrystals into thermoplastic polymers

Oct 2021 – sept 2024

Material Center of IMT Mines Alès (C2MA @ IMT Mines Alès) – Team: Polymers, Composites and Hybrids (PCH)

Context

Polymer matrix nanocomposites have been studied since the 1990s. They have improved mechanical, thermal, fire and electrical properties compared to polymeric materials, with a small amount of nanoparticles. However, their use at an industrial scale remains limited due to the toxicity of certain nanoparticles and their cost. However, the search for technologies that are more respectful of the environment and less costly in terms of energy is driving the development of lighter materials, endowed with exceptional mechanical properties and made from renewable resources.

Cellulose nanocrystals (CNCs) are nanoparticles derived mainly from lignocellulosic biomass (see Figure 1). Researchers and manufacturers are interested in these nanoparticles for paper, packaging, construction, opto-electronics, or even biomedical domains because they have remarkable physical and chemical properties. Cellulose nanocrystals (CNCs), obtained by mechanical treatment and acid hydrolysis of cellulose fibers, are often chemically modified to improve their dispersion and their interfacial adhesion with polymer matrices.

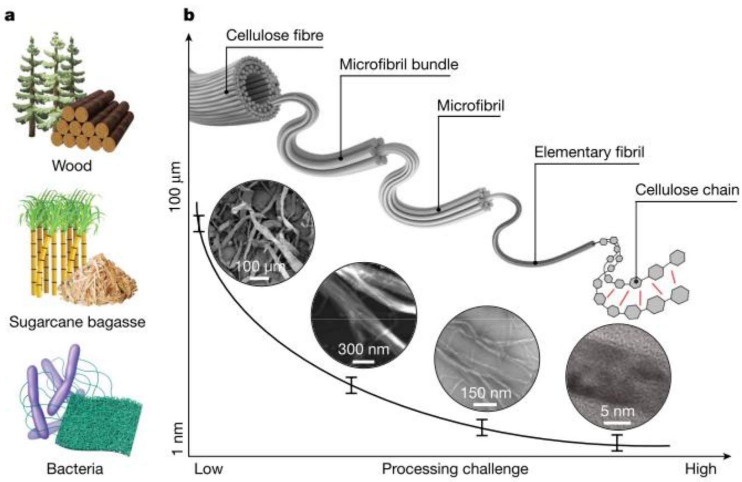

Figure 1 : a. *Several common resources of nanocelluloses;* ***b.*** *Schematic description from the hierarchical structure of cellulose fibers to cellulose. [1] (Li, T. al. Nature 590, 47–56, 2021)*

The laboratory and the objectives of the thesis

The Polymers, Composites and Hybrids (PCH)[1] team of the Materials Center of IMT Mines Alès (C2MA) aims to develop multifunctional polymer and composite materials with low environmental impact. The research work of the PCH team focuses on the development and characterization of eco-materials mainly derived from renewable resources or recycled materials in an approach aimed at relating the structure of materials, transformation processes, functional properties (mechanical, thermal, reaction

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to fire, absorption, etc.) and their development during the product's life cycle. The fields of application of the studied materials are multiple: building, transport, energy, health, environment, fashion ...

The objective of the proposed thesis is to study the dispersion of CNCs in thermoplastic polymer matrices while ensuring the use of clean processes and limiting the preparation steps. Previous work has been done in the PCH team, in collaboration with other partners. In particular, it has been shown, in partnership with the Ecole Polytechnique de Montréal, that a solvent-casting step made it possible to disperse commercial CNCs in a polymer blend based on PLA / PBAT. In addition, it is possible to vary the location of these CNCs in the blend and thus the morphology of the nanocomposite [2]. Other work, in partnership with LGP2 (INP Grenoble) and INRAe (Nantes), on biobased composites with a hierarchical structure has shown the interest of locating nanocelluloses at the matrix / fiber reinforcement interfaces to improve the mechanical performance of composites [3,4]. Nevertheless, the dispersion of CNCs in thermoplastic matrices remains a scientific and technological challenge [5]. Thus, the thesis proposed here aims to study the operating conditions and parameters which would make it possible to dispense with the solvent-casting step and to disperse the CNCs in thermoplastic polymer matrices by a melt-processing. Different types of CNCs will be used (commercial grades or synthesized in the laboratory). These CNCs will be melt blended in polymer matrices (different extrusion and injection / 3D printing routes), and nanocomposites characterized in terms of rheological behavior and microstructure to assess the state of dispersion of the CNCs. The thermomechanical behavior of the developed nanocomposites will be studied.

The candidate

This thesis is aimed at graduated students of engineering schools and Master of Science.
The candidate should have solid knowledge in the physico-chemistry of polymers, ideally with a first experience in the field of polysaccharides and more particularly nanocelluloses, through a master's internship. Knowledge of plastics processing is also required. Knowledge of rheology would be considered. The candidate must speak and write in English. Ideally, he / she should have obtained a score of 800 on the TOEIC (or any other test that measures written and oral comprehension skills in English).

The phD agreement

The thesis contract is a doctoral contract of the Balard Chemical Sciences doctoral school. This is a full-time contract, starting October 1, 2021 and lasting for 3 years. During his.her contract, the doctoral student will have to follow training modules. He.she will also participate in the supervision of engineering students at IMT Mines Alès.

Salary: ~€ 1,750 « brut »

Supervisors

The supervisors are Aurélie Taguet (supervisor) et Nicolas Le Moigne (co-supervisor).

Collaboration with the Ecole Polytechnique de Montréal is envisaged with a possible stay for the doctoral student in the team of Prof. Pierre Carreau and Marie-Claude Heuzey.

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How to apply ?

The application, including a detailed Resume, a covering letter, a transcript of records (Master marks/grades), and support letters have to be sent to, both :

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References

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