Imperial College London

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2021_85: Nanocellulsoic materials from waste wood using low-cost ionic liquids

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Cellulose is the main constituent of lignocellulosic biomass (35-45%) and the most abundant natural polymer. Because of desirable properties such as high strength, high stiffness, low thermal expansion, biodegradability and tuneable surface chemistry, it is employed in a wide range of applications, most notably in the paper industry. At industrial level, around 70% of the cellulose pulp on the market is produced by chemical pulping processes, mainly Kraft or sulphite pulping, which are very polluting and energy intensive. They are also only commercially viable in huge plants which require large quantities of local wood supply.

We have developed a novel wood fractionation technology, called ionoSolv, that allows us to fractionate any type of lignocellulosic biomass, including commercial waste wood, which is a landfilled hazard due to the presence of toxic heavy metal and arsenic based preservatives. The technology employs low cost (<£1/kg) recyclable ionic liquids (ILs) to extract the majority of the hemicellulose and lignin (and the heavy metal toxins), leaving a cellulose pulp. It allows for independent valorisation of all 3 biopolymers contained in wood (cellulose, lignin and hemicellulose) and safe disposal of the toxic preservatives. IonoSolv is a zero-waste process consuming 65% less heat and 70% less electricity per tonne of pulp when compared to current state-of-the-art.

Nanocellulosic Materials (NCMs), cellulose fibers that have at least one dimension that measures less than 100 nm, such as Nano-Crystalline Cellulose (NCCs) and Cellulose Nano-Fibers (CNFs), is an emerging group of materials that utilise the added functionalities of cellulose when at a nanoscale. NCMs have high aspect ratio and a lower density and higher tensile strength than traditional reinforcement materials, while their Young's Modulus is comparable. The abundance of hydroxyl surface groups allows for surface modification of the nanocellulose particles which can impact their dispersibility and ability to form ordered alignments. These are important characteristics for applications such as fillers and reinforcements in composites, for films, hydrogels and emulsions, which can be used in applications such as for packaging, drug delivery, sensors and electronic devices.

We have recently proven that ionoSolv cellulose remains in fibre form and the fibre length is shortened, making it potentially an ideal raw material for NCM production.

This project will develop and optimize the production of NCMs using the ionoSolv process followed by total chlorine free bleaching (green oxidation) from waste feedstocks. You will characterize the bleached pulps and final NCMs and correlate the final properties with the starting feedstocks and process conditions, with the goal of optimizing particle size, crystallinity, chemical modifications and adding tailored surface groups. This will produce low-cost, sustainable NCMs, using fewer steps than current processes.