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2022_08_ChemEng_Hallett: Upcycling of waste cellulose to nanocomposites using ionic liquids

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Currently, there is a need to develop new high-performance materials that can be obtained from waste and renewable sources with low carbon emissions to reduce the environmental impact of our industries and our dependence on fossil fuels and to achieve sustainable growth.

Waste cellulose, which can be found in waste paper, construction wood and agricultural and forestry residues, is the most abundant natural biopolymer and the most promising feedstock candidate to achieve this goal. Thanks to its ideal properties such as high strength, high stiffness, low thermal expansion, biodegradability, conductivity and tuneable surface, it is employed in a wide range of industries such as paper, textiles and high-performance packaging and films. Furthermore, due to its multi-dimensional structure, it is possible to transform cellulose in terms of morphology and fibril size, allowing for further improvement on the physico-chemical properties of parent cellulose. Cellulose is also readily biodegradable, and higher-strength cellulosic materials are of interest as biodegradable packaging.

Nanocellulosic materials or nanocrystalline cellulose (NCC) are formed from cellulose with one dimension under 100nm.3 NCCs have high aspect ratio, lower density, higher tensile strength and similar Young’s Modulus when compared to traditional reinforcement materials (Moon et al., JOM, 2016, 68(9), 2383-2394). These are important characteristics in the production of fillers, composites, films, hydrogels and emulsions for applications in packaging, drug delivery, sensors and electronic devices, emerging industries that utilise the added functionalities of cellulose when at a nanoscale. The most widespread current methods to obtain cellulosic pulps at industrial scale are kraft pulping and bleaching, but these are highly polluting and need to be replaced by more environmentally friendly alternatives.

In this project, NCCs will be produced from waste wood using an environmentally friendly process developed at imperial, the Ionosolv process, followed by chlorine-free bleaching based on hydrogen peroxide. The Ionosolv process allows the separation of the 3 main components of lignocellulosic biomass -cellulose, lignin and hemicellulose- employing low cost ionic liquids. This yields a cellulose-rich pulp from a wide variety of feedstocks, including dedicated energy crops that don’t compete with food production, agricultural residues and waste wood (Abouelelea et al, ACS Sustainable Chemistry & Engineering 2020 (8), 14441). This method will allow us to obtain NCCs in a more straightforward way, using fewer steps than the current processes. This will allow us to convert a low value material into specialised products with markets in the aerospace, medical and computer industries. As a final step in the project, the obtained nanocrystalline cellulose could be tested in sustainable, biodegradable composites or (if fibrous) pressed into films for use as biodegradable packaging material.