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Polymer and Colloid Highlights

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Functional Materials from Cellulose Nanofibers

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Cellulose is the most abundant natural polymer on earth, present in a wide range of plants and animals. In line with environmental concerns, aiming at the replacement of oil-based polymers as well as inorganic fillers such as glass or carbon fibers in composite materials, cellulose nanofibers (Fig. 1, left) have been in the focus of worldwide research activities. The fibers combine attractive properties like biodegradability, renewability, high strength and stiffness at low density and thermal expansion and have been demonstrated as suitable component for a wide range of applications such as automotive, construction, textiles, cosmetics, medicine, or packaging.[1]

In this context, we acquired a strong expertise in the production, chemical modification and use of the nanofibers as building blocks in functional coatings, films and foams (also called sponges).[2] We demonstrated *e.g.* the high effectiveness of alkoxysilane modified porous nanocellulose materials for purification technologies. Thus, hydrophobic, flexible and ultralightweight (density of 17.3 mg/cm^3, porosity >99%) nanocellulose sponges have been synthesized using a novel and efficient silylation process in water and a subsequent freeze-drying. The sponges combine both hydrophobic and oleophilic properties and can collect a wide range of organic solvents and oils (*e.g.* dodecane spills from a water surface) with absorption capacities up to 100 times their own weight depending on the density of the liquids (Fig. 1, middle).[3]

More recently, cellulose nanofibers functionalized with carboxylate entities have been prepared from pulp residue with a 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) mediated oxidation reaction followed by a mechanical disintegration step. Due to the introduced negative charges on the nanofibers surfaces, metal ions (*e.g.* copper(II), nickel(II), chromium(III) and zinc(II)) could be easily removed from wastewater by electrostatic attraction. The oxidized bio-based nanofibers represent thus an inexpensive and efficient alternative to classical sorbents for heavy metal ions removal from contaminated water.[4]

On-going research also focuses on fully polymeric and biobased CO_2 sorbents composed of oxidized cellulose nanofibers and a high molar mass polyethylenimine (PEI) prepared by a freeze drying process (Fig. 1, right). The resulting high porosity foams (>97% porosity) show at atmospheric humidity conditions and optimum PEI content, a considerably high, fast and reversible CO_2 capture. Compared with CO_2 sorbents cited in existing literature on direct air capture, this performance can be considered remarkably high.[5]

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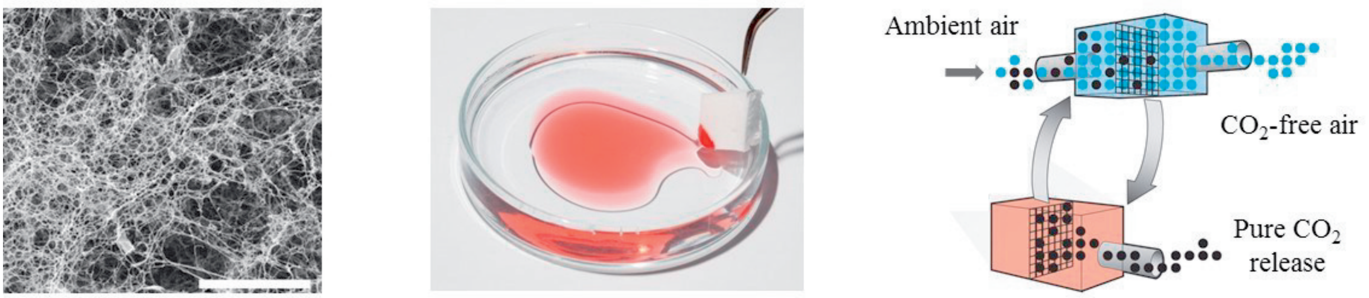

Fig. 1. (Left) Scanning electron microscopy image of cellulose nanofibers (scale bar is 10 microns). (Middle) Removal of dodecane (colored in red) spilled at water surface with a silylated nanocellulose sponge. (Right) CO_2 capture from ambient air with amine-functionalized cellulose sorbents (adapted from ref. [6]).

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