**Supplementary Information**

Plant-based Cellulose Nanopapers with Applications for Packaging, Protective Films and Energy Device

**Table S1:** Summary of the main characteristics and results of the works reviewed for the section Nanopapers for packaging applications.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Type of nanocellulose | Processing method | Modification | Application/ Characteristic Properties | Reference |
| CNF/CNC (blends) | Continuous Casting | TEMPO | Transparent, flexible and gloss films. | [27,29] |
| CNF | Roll-to-roll | TEMPO | Multilayer film food packaging. | [28] |
| CNF | - | Chitosan | Transparent nanopapers and reduce the humidity effect | [33] |
| CNF/CNC | Vacuum filtered | Cationic-CNC | Improved mechanical properties even in the wet state | [34] |
| CNF | Hot pressing | Glycerol | Reduction of water sorption | [35] |
| CNF | - | TEMPO and Multivalent cations | Low oxygen permeability | [36] |
| CNF | - | Lignin | Films waterproof, antioxidant and antimicrobial activities and UV-shield agent. | [39,40] |
| CNF | Filtration method and auto-fibrillation | TEMPO | Packaging transparent paper | [42] |
| CNF | Coating on PET | TEMPO and cellouronic acid | Antifog properties and good performance as oxygen barrier. | [45] |
| CNF | Coating for Kraft paper | Nanoclay | Improved barrier properties due to the porosity reduction | [46] |
| CNF | Spray and corona discharge on commercial paper substrate. | Nanoclay | Reduction of the oxygen permeation and of the water vapor transmission. | [49] |
| CNF | Filtration/High pressure compression | TEMPO | Food quality sensors. | [50] |
| CNF | Polyethyleneimine grafted to CNF via a Schiff base. | Oregano essential oil. | pH indicator and had also antibacterial properties. | [51,52] |

**Table S2:** Summary of the main characteristics and results of the works reviewed for the sectionNanopapers/Nanocellulose films for conductive materials and electronic devices.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of nanocellulose** | **Prepared in combination or compounded with** | **Method of preparation** | **Application/**  **Characteristic Properties** | **Ref.** |
| CNF | PANI:poly(sodium 4-styrene sulfonate) | vacuum filtration | high specific capacitance | [69] |
| CNF | CNF/PEDOT:PSS/  Ti3C2Tx |  | improved mech. prop.  electromagnetic shielding | [70] |
| CNF | polythiophene | in situ polymerization of polythiophene | high conductivity | [71] |
| CNF | PANI | in situ polymerization of PANI | electromagnetic shielding  conductivity | [72,73] |
| nanocellulose | graphene (Gr), metal cations | exfoliation of Gr | improved mech. prop., electrical conductivity, electromagnetic shielding | [74] |
| CNC | SWCNT | layer by layer  immersion/rinsing/  drying | improved electrical conductivity | [75] |
| CNF | Ag nanowires, CNT | filtration | transparency, flexibility, improved conductivity | [76] |
| CNF | Ag nanowires | "crosslinked" (consolidated) with hydroxypropylmethyl cellulose | improved conductivity | [77] |
| CNF | Ag, CNT | printing | improved conductivity | [78] |
| CNF | Ag inks | crosslinked with glutaraldehyde,  ink printed | dimensional stability,  conductivity | [37] |
| CNF | hydrophobized cellulose nanomaterialas | coatings of CNF films with hydrophobized cellulose | reduced sensitivity to water | [79] |
| CNF | phosphorylated CNF | complexation with chitosan | thermal stability, self-extinguishing, stabilization in humid environments | [38] |
| CNF | Ag nanowires | from hemp &bamboo pulps | transparency, constant sheet resistance during 1000-bending cycles | [77] |
| CNF | Ag printing | low carboxylate content | low coloring after heating | [82] |
| TEMPO-microfibers | Gr deposition | partial dissolution in ionic liquids | transparency, flexibility, touch screen response | [65] |
| CNF | Ag nanowires | layer by layer with  chitin | improved stability UV/O3 | [83] |
| CNF & microfibers |  | coating on silicon wafers | improved absorption light energy;  solar cells, OLED backing | [85] |
| CNF |  | coating for GaAs solar cells | reduced reflection, higher PCE; solar cells | [41] |
| CNF | Ag nanowires | casting of nanopaper onto deposited nanowires | high transmittance, high PCE, low sheet resistance (~constant for 20 folding cycles) | [63] |
| TEMPO-CNF |  | perovskite solar cells | higher haze, PCE, transmittance | [86] |
| CNC & carboxymethylated CNF | composites made with added MTM | solar cells | higher transmittance w/o MTM;  UV protection and swell resistance with MTM | [87] |
| CNC |  |  | PCE, recyclability; solar cells | [6] |
| TEMPO-microfibers | with fines | coating of solar cells | high transparency and haze, high PCE | [81] |
| TEMPO-CNF | amine crosslinked |  | tribological effect; lighting LED stepping active board | [88] |
| CNF | graphite |  | conductive when rolled around hoses; electrodes | [89] |
| CNF | dispersed in water /isopropyl alcohol |  | tuned porosity by solvents selection, high ionic conductivity; separator in batteries | [90] |
| CNF | layers:  CNF-graphite-SuperP carbon/  CNF-SiO2/ CNF-LiFePO4-SuperP carbon/ | vauum filtering succesive layers | good strength at break when soaked in electrolytes | [91] |
| CNF | CNF /PANI/PEDOT:PSS or rGO | layer by layer deposition | transparency, flexibility; supercapacitors | [95] |
| CNF | silicon membrane | patterning & etching of silicon | microwave range; transistor | [96] |
| CNF | CNT | substrate coated with CNT | good bonding; transistors | [15] |
| CNF | as substrate and dielectric layer | spin coating | similar performance to plastic substrates; transistors | [97] |
| CNF | as substrate and dielectric layer | semiconductor oxides sputtering | on/off modulation better than regular paper substrates | [98] |
| TEMPO microfibers | mixture of microfibers and CNF | hybrid nanopapers | transparency, tuned haze; transistor | [99] |
| CNC or CNF |  | films | better performance of CNC in piezoelectric films | [101] |
| CNF | cationic modified doped with Li salts |  | piezoelectric soft actuators | [104] |
| CNF | composites with Ti3C2 | vacuum filtration | sensitivity to humidity and correlation with voltage | [106] |