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Tuning the surface charge of rice straw-derived cellulose nanofibril membrane separator for electrochemical performance enhancement of supercapacitors

Abstract

The electrochemical performance of supercapacitors has often overlooked the effect of surface charge on cellulose-based separators. Cellulose nanofibrils (CNFs) produced by 2,2,6,6-tetramethylpipridine-1-oxyl (TEMPO) oxidation possess a high anionic surface charge due to the presence of carboxylate groups, which could affect the transport of electrolyte ions. In this work, the surface of CNFs is modified with a cationic polyelectrolyte, namely polydiallydimethylammonium chloride (PDADMAC), to yield a nearly-zero surface charge CNF membrane derived from rice straw. The surface modification of CNFs using 20 wt% PDADMAC results in CNF-M2, with a surface charge of +5.3 mV, notable porosity (64 %), excellent electrolyte uptake (225 %), and improved ionic conductivity (5.0 mS cm^{-1}). A symmetric supercapacitor assembled with CNF-M2 as a separator, exhibits enhanced specific capacitance (185.3 F g^{-1} at 0.1 A g^{-1}), energy density (37.1 Wh kg^{-1} at a power density of 0.24 kW kg^{-1}), and is able to maintain 100 % capacitance retention over 10,000 cycles in 1.0 M Na_2SO_4 aqueous electrolyte solution. This surface modification leads to 1.2–1.4 times increase in energy and power densities compared to the unmodified CNF membrane. Thus, the nearly-zero surface charge of the modified CNF membrane holds promise as a separator that elevates the performance of supercapacitors.

Keywords

Cellulose nanofibrils (CNFs); Electrochemical performance; Polyelectrolyte; Separator; Supercapacitor