A Promising Polymer Blend Electrolytes Based on Chitosan: Methyl Cellulose for EDLC Application with High Specific Capacitance and Energy Density

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Abstract: In the present work, promising proton conducting solid polymer blend electrolytes (SPBEs) composed of chitosan (CS) and methylcellulose (MC) were prepared for electrochemical double-layer capacitor (EDLC) application with a high specific capacitance and energy density. The change in intensity and the broad nature of the XRD pattern of doped samples compared to pure CS:MC system evidenced the amorphous character of the electrolyte samples. The morphology of the samples in FESEM images supported the amorphous behavior of the solid electrolyte films. The results of impedance and Bode plot indicate that the bulk resistance decreased with increasing salt concentration. The highest DC conductivity was found to be $2.81 \times 10^{-3} \text{ S/cm}$. The electrical equivalent circuit (EEC) model was conducted for selected samples to explain the complete picture of the electrical properties. The performance of EDLC cells was examined at room temperature by electrochemical techniques, such as impedance spectroscopy, cyclic voltammetry (CV) and constant current charge–discharge techniques. It was found that the studied samples exhibit a very good performance as electrolyte for EDLC applications. Ions were found to be the dominant charge carriers in the polymer electrolyte. The ion transference number ($t_{\text{ion}}$) was found to be 0.84 while 0.16 for electron transference number ($t_{\text{el}}$). Through investigation of linear sweep voltammetry (LSV), the CS:MC:NH$_4$SCN system was found to be electrochemically stable up to 1.8 V. The CV plot revealed no redox peak, indicating the occurrence of charge double-layer at the surface of activated carbon electrodes. Specific capacitance ($C_{\text{spe}}$) for the fabricated EDLC was calculated using CV plot and charge–discharge analyses. It was found to be 66.3 F g$^{-1}$ and 69.9 F g$^{-1}$ (at the first cycle), respectively. Equivalent series resistance ($R_{\text{ser}}$) of the EDLC was also identified, ranging from 50.0 to 150.0 $\Omega$. Finally, energy density ($E_d$) was stabilized to an average of 8.63 Wh kg$^{-1}$ from the 10th cycle to the 100th cycle. The first cycle obtained power density ($P_d$) of 1666.6 W kg$^{-1}$ and then it dropped to 747.0 W kg$^{-1}$ at the 50th cycle and continued to drop to 555.5 W kg$^{-1}$ as the EDLC completed 100 cycles.

Keywords: Biopolymer blend electrolyte; XRD analysis; Morphology study; Impedance spectroscopy; TNM and LSV; cyclic voltammetry; EDLC fabrication; Specific capacitance; energy density

1. Introduction

Typically, two types of host polymers are used in the preparation of solid polymer blend electrolytes (SPBEs) for energy storage devices: natural and synthetic polymers [1]. Most synthetic polymers,