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Enhanced Electrochemical Performance of Tin Oxide-Doped Coconut Shell Charcoal-Derived Activated Carbon for Energy Storage Applications

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The growing demand for efficient and sustainable energy storage systems has driven interest in biomass-derived carbon materials. Coconut shell charcoal, an abundant and low-cost precursor, shows great potential for producing activated carbon electrodes for supercapacitor applications. However, few studies have explored the impact of metal oxide doping on the electrochemical performance of such biomass-derived carbons. This study investigates the effect of tin oxide (SnO_2) doping on the electrochemical performance of coconut shell charcoal-derived activated carbon for electric double-layer supercapacitors (EDLCs). Activated carbon was synthesised from coconut shell charcoal and doped with varying concentrations of SnO_2 powder (2%, 4%, 6%, 8%, and 10% w/w). A binder solution containing 0.05 g of polyvinylpyrrolidone (PVP) in isopropanol was prepared and mixed with the activated carbon. The resulting slurry was spray-coated onto titanium substrates preheated to 150 °C, followed by sintering at 200 °C for 20 minutes. Supercapacitor cells were assembled using 2.5 M H_2SO_4 as the electrolyte and filter paper as the separator. Electrochemical performance was evaluated through cyclic voltammetry, and the specific capacitance and energy density were calculated. Among all samples, the electrode doped with 4% SnO_2 exhibited the highest performance, achieving a specific capacitance of 74.33 F g^{-1} and an energy density of 10.32 Wh kg^{-1}. In contrast, the undoped activated carbon electrode showed significantly lower values, with a specific capacitance of 40.47 F g^{-1} and an energy density of 5.62 Wh kg^{-1}. These findings confirm that SnO_2 doping substantially enhances the electrochemical properties of biomass-derived activated carbon. This study highlights the potential of integrating metal oxide dopants into waste biomass carbon frameworks to develop high-performance, sustainable electrode materials for next-generation energy storage devices.

Keywords: Biomass-derived activated carbon, coconut shell charcoal, tin oxide (SnO_2) doping, electric double-layer capacitor (EDLC), supercapacitor electrode materials.