Performance Comparison of Activated Carbons from Various Biomass Precursors for Supercapacitor Electrode Applications

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Abstract

Agricultural waste-derived carbon materials have attracted increasing interest as sustainable electrode materials for energy storage. This study developed and compared activated carbons derived from spent coffee grounds, spent tea leaves, and a coffee–tea mixture for supercapacitor applications, using commercial activated carbon (YP50F) as a reference. The biomass precursors were carbonized and chemically activated with KOH 1:1 mass ratio at 700 degrees Celsius. The resulting materials were characterized by SEM, BET, XRD, and Raman spectroscopy, while their electrochemical performance was evaluated using galvanostatic charge–discharge (GCD) and electrochemical impedance spectroscopy (EIS). All synthesized carbons exhibited predominantly amorphous structures and well-developed porosity. Among the biomass-derived samples, tea-waste activated carbon (T-K1-700) showed the highest specific surface area of 1,170 square meters per gram and specific capacitance ranging from 150–160 farads per gram, outperforming YP50F of 75–80 farads per gram under identical conditions. T-K1-700 also demonstrated typical electric double-layer capacitance behavior and maintained stable charge–discharge performance. However, all synthesized materials exhibited increased charge-transfer resistance after cycling, whereas YP50F showed better electrochemical stability. These results indicate that KOH-activated tea-waste carbon is a promising, sustainable electrode material for supercapacitors and highlights the potential of agricultural waste valorization for environmentally friendly energy storage applications.

Keywords: activated carbon, tea waste, coffee waste, supercapacitors, energy storage