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Fabrication of High Energy Hybrid Capacitors from Biomass Waste-Derived Activated Carbon

Authors : Makhan Maharjan, Mani Ulaganathan, Vanchiappan Aravindan, Srinivasan Madhavi, Jing-Yuan Wang, Tuti Mariana Lim

Abstract : There is great interest to exploit sustainable, low-cost, renewable resources as carbon precursors for energy storage applications. Research on development of energy storage devices has been growing rapidly due to mismatch in power supply and demand from renewable energy sources This paper reported the synthesis of porous activated carbon from biomass waste and evaluated its performance in supercapicators. In this work, we employed orange peel (waste material) as the starting material and synthesized activated carbon by pyrolysis of KOH impregnated orange peel char at 800 °C in argon atmosphere. The resultant orange peel-derived activated carbon (OP-AC) exhibited a high BET surface area of 1,901 m2 g-1, which is the highest surface area so far reported for the orange peel. The pore size distribution (PSD) curve exhibits the pores centered at 11.26 Å pore width, suggesting dominant microporosity. The OP-AC was studied as positive electrode in combination with different negative electrode materials, such as pre-lithiated graphite (LiC6) and Li4Ti5O12 for making different hybrid capacitors. The lithium ion capacitor (LIC) fabricated using OP-AC with pre-lithiated graphite delivered a high energy density of ~106 Wh kg–1. The energy density for OP-AC||Li4Ti5O12 capacitor was ~35 Wh kg–1. For comparison purpose, configuration of OP-AC||OP-AC capacitors were studied in both aqueous (1M H2SO4) and organic (1M LiPF6 in EC-DMC) electrolytes, which delivered the energy density of 6.6 Wh kg-1 and 16.3 Wh kg-1, respectively. The cycling retentions obtained at current density of 1 A g–1 were ~85.8, ~87.0 ~82.2 and ~58.8% after 2500 cycles for OP-AC||OP-AC (aqueous), OP-AC||OP-AC (organic), OP-AC||Li4Ti5O12 and OP-AC||LiC6 configurations, respectively. In addition, characterization studies were performed by elemental and proximate composition, thermogravimetry, field emission-scanning electron microscopy, Raman spectra, X-ray diffraction (XRD) pattern, Fourier transform-infrared, X-ray photoelectron spectroscopy (XPS) and N2 sorption isotherms. The morphological features from FE-SEM exhibited well-developed porous structures. Two typical broad peaks observed in the XRD framework of the synthesized carbon implies amorphous graphitic structure. The ratio of 0.86 for ID/IG in Raman spectra infers high degree of graphitization in the sample. The band spectra of C 1s in XPS display the well resolved peaks related to carbon atoms in various chemical environments; for instances, the characteristics binding energies appeared at ~283.83, ~284.83, ~286.13, ~288.56, and ~290.70 eV which correspond to sp2 -graphitic C, sp3 -graphitic C, C-O, C=O and π-π*, respectively. Characterization studies revealed the synthesized carbon to be promising electrode material towards the application for energy storage devices. The findings opened up the possibility of developing high energy LICs from abundant, low-cost, renewable biomass waste.

Keywords : lithium-ion capacitors, orange peel, pre-lithiated graphite, supercapacitors
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