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High Performance Lithium Ion Capacitors from Biomass Waste-Derived Activated Carbon

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Abstract : The ever-increasing energy demand has made research to develop high performance energy storage systems that are able to fulfill energy needs. Supercapacitors have potential applications as portable energy storage devices. In recent years, there have been huge research interests to enhance the performances of supercapacitors via exploiting novel promising carbon precursors, tailoring textural properties of carbons, exploiting various electrolytes and device types. 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 BET surface area of 1,901 m^2 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 high surface area OP-AC accommodates more ions in the electrodes and its well-developed porous structure facilitates fast diffusion of ions which subsequently enhance electrochemical performance. 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 hybrid capacitors. The lithium ion capacitor (LIC) fabricated using OP-AC with pre-lithiated graphite delivered 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 8.0 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 analysis, 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. The presence of functional groups is also corroborated from the FTIR spectroscopy. Characterization studies revealed the synthesized carbon to be promising electrode material towards the application for energy storage devices. Overall, the intriguing properties of OP-AC make it a new alternative promising electrode material for the development of high energy lithium ion capacitors from abundant, low-cost, renewable biomass waste. The authors gratefully acknowledge Agency for Science, Technology and Research (A*STAR)/ Singapore International Graduate Award (SINGA) and Nanyang Technological University (NTU), Singapore for funding support.

Keywords : energy storage, lithium-ion capacitors, orange peels, porous activated carbon
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