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Lithium-ion storage in honeycomb-structured biomass-derived porous carbon

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ABSTRACT

Honeycomb-shaped porous carbon (HSPC) offers unique surface properties for rapid ion transport through the bulk and hence could deliver desirable electrochemical charge storage performance; however, their fabrication is through time and cost intensive sacrificial template methods. Herein, HSPC was synthesized from a carefully selected plant component (coconut rachis) containing a dense network of phloem and xylem. The synthesized activated carbon has relatively high carbon content (>80 %), desirable textural characteristics (specific surface area ~ 1290 $m^2 \cdot g^{-1}$ and pore diameter ~ 2.0 nm), and high edge-plane fraction (ratio between relative density of edge and basal plane ~0.26). The HSPC electrodes delivered specific capacitance up to ~126 $F \cdot g^{-1}$ at 100 $mA \cdot g^{-1}$ at a potential window of 2–4 V in the HSPC//$LiPF_6$//Li lithium metal capacitor configuration and retained ~98 % of its initial capacity after 1000 cycles with coulombic efficiency ~100 %. The performance of the device has been validated by electrochemical impedance spectroscopy before and after cycling. A post-mortem analysis confirmed structural and chemical stability of the device upon cycling.

1. Introduction

In response to the rapid rise in energy demands in a world of depleting natural reservoirs and life-threatening environmental concerns, alternative sources characterized by energy efficiency, eco-friendliness, and sustainability are actively investigated across the world [1]. Past decades witnessed the domination of electrochemical energy storages system (EES) as part of energy transition from life-threatening fossil fuels to eco-friendly renewables. Lithium-ion batteries (LIBs) and electrochemical capacitors (ECs) are the most popular EES devices available in the present-day market with differing performance indicators due to different charge storage mechanisms. Charge storage in LIB is through a faradic reaction enabled via Li^+ ions in the electrolyte to undergo a redox reaction with electrode materials such as TiO_2, NiO, MnO_2, Co_3O_4, etc. or intercalated (e.g., graphite, lithium titanite, lithium cobaltite, lithium iron phosphate, etc.) or alloyed (e.g., silicon, tin, aluminum, etc.) [2,3]. As a result, LIB offers higher specific energy (i.e., energy stored per unit weight of the electrode; which is commercially ~200–250 $Wh \cdot kg^{-1}$ [4,5] and up to ~700 $Wh \cdot kg^{-1}$ in research laboratories [6]), but with lower specific power (i.e., rate of energy storage per unit weight; 250–340 $W \cdot kg^{-1}$) due to low Li^+ ion diffusion coefficient of 10^{-10} to 10^{-13} $cm^2 \cdot s^{-1}$ for both layered cathode materials as well as the graphite anode [7]. On the other hand, the electrolyte ions in the ECs are adsorbed on the pores of the electrode, which is most commonly porous carbon, through formation of an electrochemical double layer (EDL) [8] or undergo a redox reaction limited to a few monolayers (many metal oxides in suitable electrolytes), known as pseudocapacitors [9,10]. The ECs offer higher specific power of >10 $kW \cdot kg^{-1}$ (i.e., shorter charging time) but only store much lower charges (specific energy ~5–80 $Wh \cdot kg^{-1}$) than that can be achieved via faradic reaction.

Carbons are sustainable and eco-friendly materials if bio-resourced,

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