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ORIGINAL PAPER

Conversion of Oil Palm Kernel Shell Biomass to Activated Carbon for Supercapacitor Electrode Application

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Abstract

Electrochemical charge storage of physically and chemically activated carbon synthesized from oil palm kernel shell (PKS) in three different aqueous electrolytes (1 M H_2SO_4, 1 M Na_2SO_4 and 6 M KOH) are presented. Coin type CR2032 cells fabricated using the PKS ACs electrodes separated by fiber glass separator and electrolyte are used as devices for measurements. Achievable operating potential for these devices varied as H_2SO_4 (1.0 V) < KOH (1.2 V) < Na_2SO_4 (2.0 V). The highest energy density was obtained in Na_2SO_4 electrolyte (7.4 Wh kg^{-1}) at a power density of 300 W kg^{-1}. The device stability cycle at low current density (0.5 A g^{-1}) for 3500 times showed capacitance retention in range of 78–114% in all devices.

Keywords Renewable materials · Biomass · Electrochemical capacitors · Aqueous electrolyte · Energy storage · Symmetric supercapacitors

Introduction

Electrochemical charge storage at an electrical double layer formed at an electrode—electrolyte interface (electrochemical double layer capacitors, EDLC) is currently under extensive investigation owing to their high power capabilities than other existing electrical energy storage devices [1–3]. Carbons nanomaterials or nanostructures of all forms, viz. activated carbons (ACs), graphite, graphene, carbon nanotubes (CNTs), carbon nanofibers, carbon aerogels and carbon quantum dots, are the commercial choice for EDLCs because (i) their higher electrical conductivity (among other materials of large surface area) enable fast charging and discharging and high power density (P_D) thereby, (ii) long cycle stability, and (iii) cost practicality. Although graphene and CNTs offer much superior electrical conductivity and surface area than the other forms of carbon, ACs is currently used for commercialization of supercapacitors (SCs) due to their renewability and ease of processability and lower cost, tunable surface area to enable optimum electrode–electrolyte interface, tailorability of pore distribution by controlling the synthetic conditions, and acceptable electrical conductivity. Many non-edible agricultural and industrial byproducts derived ACs such as ginkgo shells [4], celtuce leaves [5], rice husk [6], argan seed shells [7], orange peels [8], palm kernel shell [9], beer less [10], citreae peel [11], sugarcane baggase [12], bamboo [13], conrncob [14] and camellia flower [15] have been screened for their usefulness as SCs electrodes.

Among the above, oil palm (*Elaeis guineensis*) is one of the largest commodity in world market and abundantly planted throughout the globe. Upon production of 2.5 kg of crude palm oil over 100 kg of non-edible biomass is produced; which was ~ 80 million tons in the year 2010 and estimated ~ 100 million tons in 2020 [16]. Palm oil plant and processing produces several waste such as fronds, trunks, mesocarp fiber (MF), palm kernel shells (PKS), empty fruit bunches (EFB), and palm oil mill effluent (POME). From this abundant byproducts, ~ 6–8% of it is in form of PKS [17]. The PKS are relatively cheap, non-edible and having continuous biomass supply for upscaling purpose, PKS is foreseen as suitable candidate as carbon precursors in producing ACs for SCs.

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