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Original Research Paper

Superior capacitive behavior of porous activated carbon tubes derived from biomass waste-cotonier strobili fibers

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ABSTRACT

As supercapacitor electrode materials, the sustainable biomass-derived activated carbons have attracted a great deal of attentions due to their low-cost, abundant, and unwanted natural wastes. In this work, a facile KOH activation method is adopted to prepare activated carbon tubes from the biomass waste-cotonier strobili fibers for the first time. The resultant PTAC-*x* materials possess highly accessible surface areas and abundant micro-mesopores, which benefit large ion storage and high-rate ion transfer. The optimized material denoted as PTAC-6 demonstrates a high specific capacity (346.1 F g^{-1} at 1 A g^{-1}) and a superior rate performance (214.5 F g^{-1} at 50 A g^{-1}) in the three-electrode supercapacitors. In addition, the symmetric supercapacitor exhibits excellent cycling stability with a capacitance retention of 84.21% and a columbic efficiency of nearly 100% after 10,000 cycles. Furthermore, the PTAC-6-based symmetric supercapacitor gives a remarkable specific energy of 33.04 Wh kg^{-1} at 160 W kg^{-1}. Meanwhile, our proposed porous activated carbon tubes provide a green and low-cost electrode material for high-performance supercapacitors.

1. Introduction

The human being is facing serious energy crisis, and the clean, efficient, sustainable and cheap energy-storage device is thus urgent. As one of the most promising energy storage devices, supercapacitor has received extensive attention due to their high power density, fast charge and discharge rates, and long-term cycling stability, etc. [1–8]. Compared with the pseudo-capacitors based on quick and reversible Faradaic redox reaction on the surface and bulk structure of metal oxides, the electrical double layer capacitors (EDLCs) dependent on the electrostatic interaction between the ions on surface area of the electrode materials and electrolytes, are a more commonly mode for energy storage. However, the intrinsic low energy density limits the practical application in energy-efficient industrial equipment [9,10].

Activated carbon (AC) is a common electrode material for many electrochemical storage systems owing to its high surface area, abundant porosity, efficient electrical & thermal conductivity, high stability, availability, and cost-effective [11]. At present, the main raw materials for ACs are classified into three types: (1) Organic polymer including phenolic resin, polysaccharide, etc.; (2) Plants, such as fruit shells, wood chips, ramie; and (3) Derivatives of coal and its mixtures. Biomass outperforms the other materials due to their cost-effective, environmentally friendly as well as readily available in high quality and quantity properties. Notably, the basic components of plant biomass (cellulose, hemicellulose, lignin, plant protein, plant lipids, etc.) offer a basic skeleton structure and abundant functional groups for the carbons [12]. Especially, the biomass consisting of 3D interconnected network with open pores facilitates the fast ionic and electronic diffusion and transmission. As a result, the biomass has a potential as superior electrode materials for supercapacitors.

Till now, various biomasses such as camellia oleifera shell [13], cotton, cotton-flax, and flax fabrics [14], ginkgo leaves [15], elm samara [16], bagasse [17], poplar catkins [18], corncob [19], and rice husk ash [20] have been used to prepare AC electrode materials for supercapacitors. Cotonier strobili are the fruits of cotonier (also called as plane tree). As shown in Fig. 1, they are formed by small nuts surrounded by cotonier strobili fibers. One cotonier strobili has 600–1400 small nuts and one small nut have roughly 3000 cotonier strobili fibers. When cotonier strobili are matured, the lightweight fibers fly around, leading to the serious environ-

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mental pollution, and harm people's health through a variety of pathways including skin irritation, or respiratory tract, etc. Although cotonier strobili fibers containing abundant cellulose have low economic value, the cotonier strobili fibers with hollow structure can be converted into ACs with interconnected networks as well as relatively high electrical conductivity. The converted ACs from cotonier strobili fibers are expected to possess superior electrochemical properties.

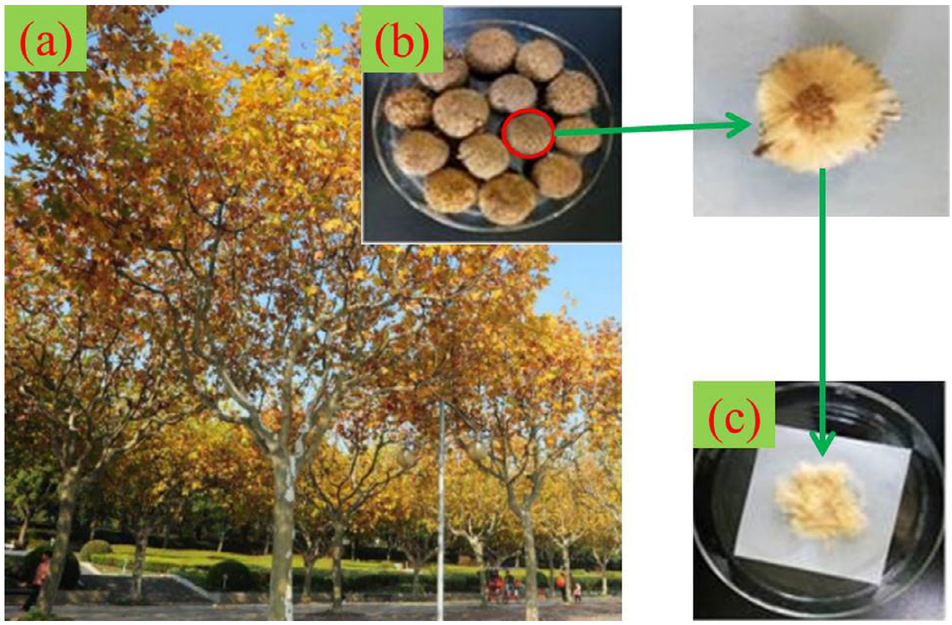

Fig. 1. Photos of cotonier (a), cotonier strobile (b) and cotonier strobile fibers (c).

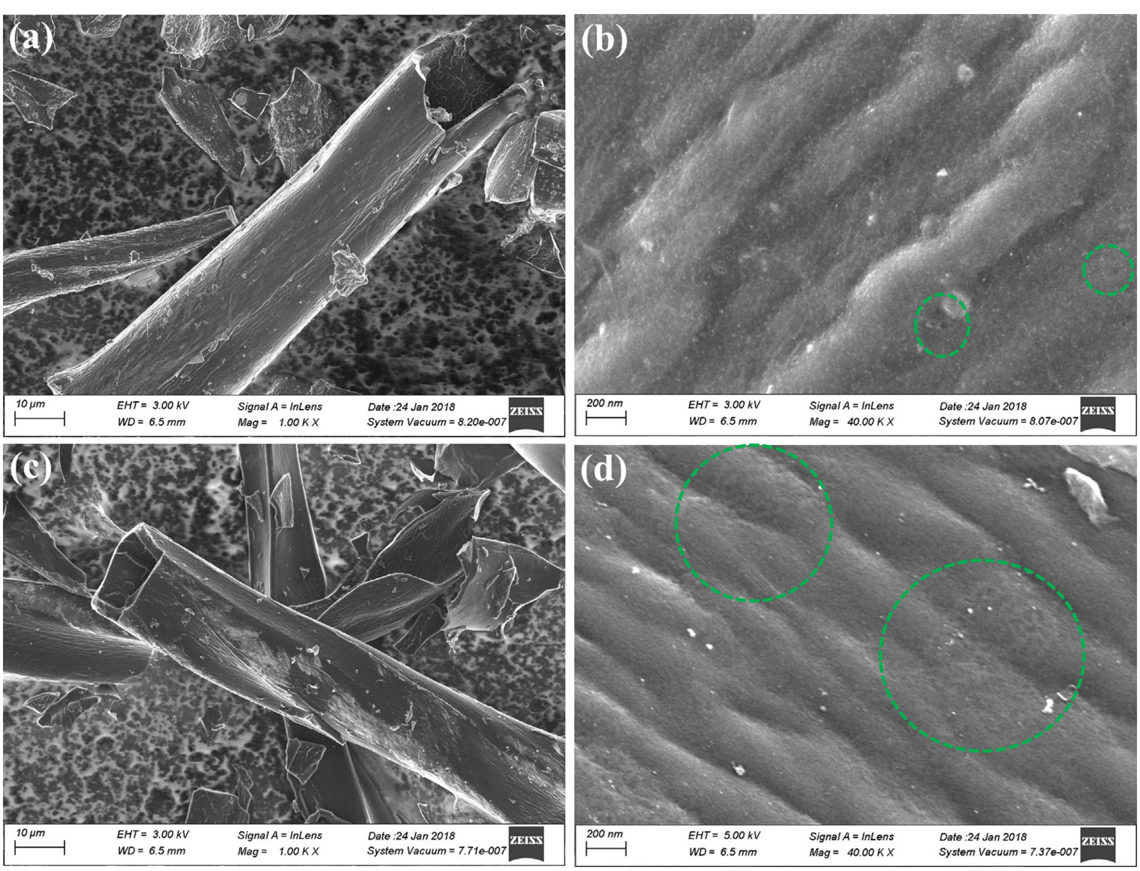

Fig. 2. SEM images PTC (a, b) and PTAC-6 (c, d).