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Three-dimensional flexible carbon electrode for symmetrical supercapacitors

Kai Wu [a], Jijiang Fu [a], Xuming Zhang [a,b,*], Xiang Peng [b], Biao Gao [a,*], Paul K. Chu [b]

[a] The State Key Laboratory of Refractories and Metallurgy, Wuhan University of Science and Technology, Wuhan 430081, China
[b] Department of Materials Science and Physics, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China

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ABSTRACT

Three-dimensional (3D) porous active carbon (AC) is fabricated by pyrolysis, pre-carbonization, and alkali activation of the biomass of pomelo peels (PP). The PP-derived AC has abundant micro/meso/macropores boosting a large specific surface area of 1665 $m^2\ g^{-1}$ and facilitating incorporation of the carbon nanotubes (CNTs) and reduced graphene oxide (rGO) into the materials. After mixing with CNTs and rGO, the hybrid carbon film with 80 wt% AC (AC/rGO/CNT) exhibits a large capacitance of 214 $F\ g^{-1}$ at 1 $A\ g^{-1}$, good rate capability, as well as excellent mechanical properties. The specific capacitance of the assembled symmetrical capacitor comprising the hybrid carbon film is 101.5 $F\ g^{-1}$ at 1 $A\ g^{-1}$ and in conjunction with the superior cycling stability, the high-performance flexible carbon-based supercapacitors (SCs) have large commercial potential.

1. Introduction

Carbon-based materials such as carbon nanotubes (CNTs), graphene (G), and active carbon (AC) have received tremendous attention as electrode materials in double electric layer capacitors (EDLCs) [1] on account of their environmental friendliness, conductivity, physical/chemical stability, and mechanical properties [2,3]. The capacitance of EDLCs which is derived from the accumulated electrostatic charges stored and released at the electrode/electrolyte interface depends mainly on the specific surface area, surface wettability, and ion diffusion resistance of electroactive materials [4]. Porous carbon has shown promise in elevating the energy and power densities of EDLCs. Recently, sustainable biomass has attracted attention concerning the fabrication of porous carbon due to the inherent microstructure, natural abundance, and low cost including water hyacinth, husk and rotten potatoes, and so on [5–7]. Moreover, the impurities and oxygen-containing functional groups in the product after carbonization and activation can enhance the capacitance [8,9] and there have been efforts to fabricate three-dimensional (3D) porous carbon from the biomass because of better permeability of the electrolyte and shorter diffusion paths [10]. A facile approach to produce flexible binder-free 3D carbon electrodes is of technological and commercial interest. However, most AC derived from waste biomass is powder or granular form showing limited electron conductivity after incorporation of additive or binder [11]. Furthermore, it is difficult to obtain well-dispersed 1D graphitic nanostructures on the surface of AC due to the complicated surface conditions with sp^2 and sp^3 bonds [12].

In this work, flexible 3D carbon electrode consisting of pomelo peels (PP) derived honeycomb-like AC, rGO and CNTs with an AC content of 80 wt% is fabricated. The PP-derived AC possesses abundant micro/meso/macropores, which enhances the capacitance and facilitates incorporation of CNTs, rGO and electrolyte into the structure to boost the structure integrity, flexibility as well as capacitance [13]. This hybrid carbon film (AC/rGO/CNT) delivers outstanding supercapacitive performance such as a capacitance as high as 214 $F\ g^{-1}$ at 1 $A\ g^{-1}$, good capacity retention, and cycling stability. A packaged symmetrical capacitor composed of the AC/rGO/CNT electrode shows a high capacitance of 101.5 $F\ g^{-1}$ at 1 $A\ g^{-1}$ which is better than that of carbon electrodes prepared by conventional methods.

2. Experimental details

The washed PP were pyrolyzed at 200 °C for 10 h in a hydrothermal treatment. The dry product was mixed with KOH with the mass ratio of 1:1, annealed at 450 °C for 1 h, and then heated to 750 °C for 2 h under N_2 at a rate of 5 °C min^{-1}. The AC was rinsed

* Corresponding authors.
E-mail addresses: xumzhang@wust.edu.cn (X. Zhang), gaobiao@wust.edu.cn (B. Gao).

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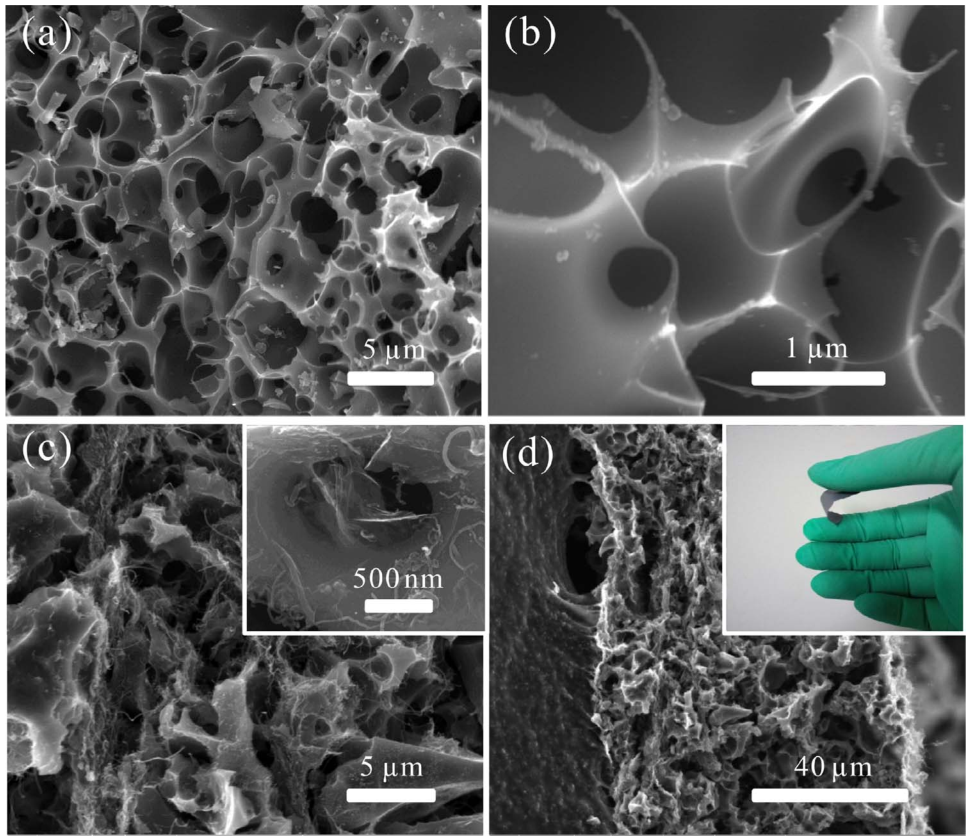

Fig. 1. (a, b) Low- and high-magnification FE-SEM images of the PP derived AC and (c, d) High-magnification and cross-sectional FE-SEM images of the hybrid carbon film (AC/rGO/ CNT).

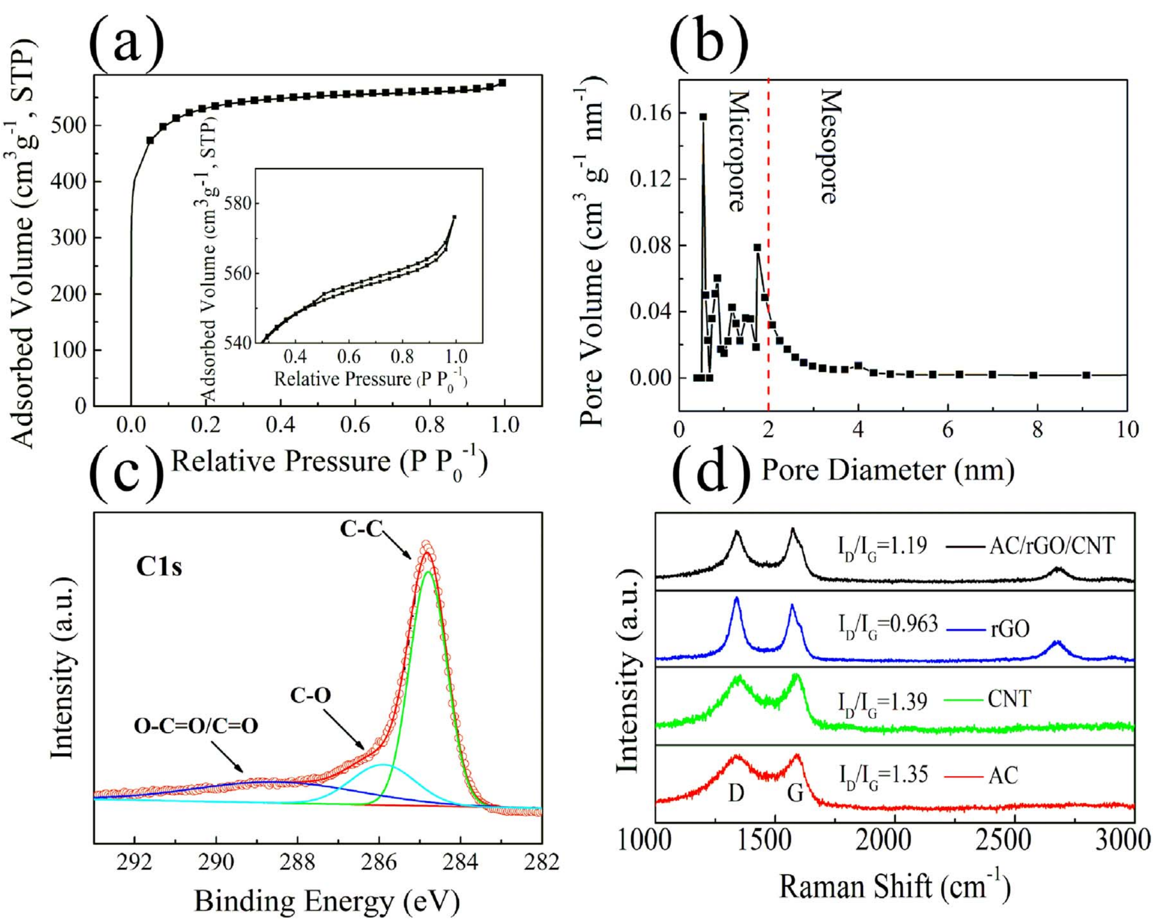

Fig. 2. (a, b) N_2 sorption isotherms and pore size distribution of the PP derived AC, (c) High-resolution C1s spectrum of the PP derived AC, and (d) Raman scattering spectra of AC, CNT, rGO, and AC/rGO/CNT.