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Scalable synthesis of graphitized carbon powder from *Prosopis* juliflora and its supercapacitve performance

G. Sivagaami Sundari [a], K. Thileep Kumar [a], E. Senthil Kumar [a], A.M. Shanmugaraj [b], R. Kalaivani [a], S. Raghu [b]

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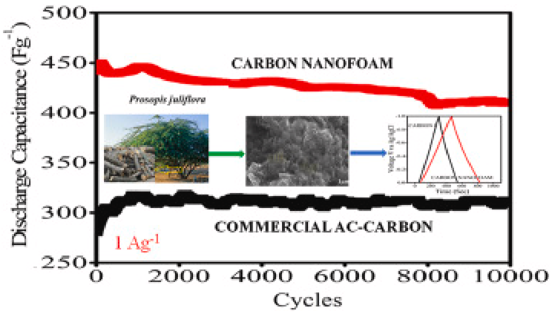
Abstract

Herein, we report a scalable synthesis of 3D porous graphitized carbon power (GC) using the one-step carbonization and activation of *Prosopis* juliflora for symmetric supercapacitor applications. Electron-microscopy (SEM and TEM) showed the optimized GC forms a 3D-foam cluster morphology with a maximum surface area of ~1183 m^2g^{-1}, which induces rapid charge transfer reactions. The GC exhibit a prominent Raman 2D peak at ~2670 cm^{-1}. The electrochemical performance of the GC has been compared with commercially available carbon for the first-time. The GC showed an exceptional half-cell specific capacitance of ~415 Fg^{-1} at 1 Ag^{-1} and the commercial carbon sample delivered ~270 Fg^{-1} at 1 Ag^{-1}, which is very high compared to other reported porous carbon materials obtained from biomass. The GC delivered ~50% higher power and >90% capacitance retention when compared to the commercial carbon sample with an energy density of ~47 $Whkg^{-1}$ and power density of ~49 $kWkg^{-1}$. Thus, the GC electrode material is a green, sustainable, and alternative electrode for use in high energy supercapacitor applications.

Graphical abstract



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Introduction

The growing demand for energy storage and delivery worldwide has been challenging over the past few decades. Supercapacitors (SCs) are clean energy storage devices with high power density, rapid charge-discharge rate, low maintenance and high-long term stability. Electrical-double layer capacitors (EDLC) and pseudo-capacitors are two classes of SCs based on their energy storage mechanism. Carbon-based materials such as graphene, activated porous carbon and carbon nanotubes contribute to the EDLC process due to their large-specific surface area, high electrical conductivity, thermal stability, etc [1]. Carbon-based electrode materials exhibit high electrical and thermal conductivity, high surface area, excellent long-term stability, etc which makes them very useful for SCs applications [2].

Biomass-derived carbon-based materials, such as carbon flakes [3], mesoporous carbon [4], fibers [5], carbon nanosheets [6], sponge aerogels [7] and activated carbon [8], have gained a lot of attention as electrode materials used for the supercapacitor applications. Biomass-based precursors are inexpensive, highly abundant, renewable and environmentally friendly. Biomass-derived carbon materials are prepared using various physical and chemical activation methods [9]. Physical activation methods give very low yields and use exhaust gases or water steam employing gasification [10]. These techniques involve high energy, pressure and temperature, the emission of toxic gases and longer reaction times. Therefore, developing a facile synthesis route to prepare activated carbon is of great significant in the area of affordable and sustainable synthesis.

For example, Ding et al. have prepared activated carbon using in-situ nitrogen doping of bean pulp via a one-step carbonization and activation process. The resulting carbon material delivered 106 Fg^{-1} at 0.25 Ag^{-1} and 93% capacitance retention over 20,000 cycles with a 6M KOH electrolyte [11]. Yakaboylu et al. have prepared carbon from a lignocellulosic biomass precursor and achieved ~188 Fg^{-1} and 91.1% cyclic stability [12].

In this work, *Prosopis* juliflora (PJ) was chosen as a biomass source for high performance supercapacitor applications. PJ is a phenolic-based precursor, which has a good heat of combustion, higher rigidity and hardness, which is present in the Gulf Coast, Caribbean Islands, Mexico, Venezuela, dry zones of the United States, Central America, West Indies, Peru, Argentina, Iran, India and Hawaii [13]. PJ yields 12.5 ton of wood every three years from 1 ha of plantation and has attractive properties like zero emissions, fixed price and good availability, which makes its biomass recognized by international standards. Due to the abundant raw material available, the preparation of GC can be performed on a large scale at low cost [14].

Herein, we report a scalable synthesis of 3D porous graphitized carbon powder (GC) using the one-step carbonization and activation of *Prosopis* juliflora used for high-performance symmetric supercapacitor applications. The obtained GC has a maximum half-cell specific capacitance of ~415 Fg^{-1} at 1 Ag^{-1} and energy density of ~47 $Whkg^{-1}$ at a power of ~49 $kWkg^{-1}$. To the best of our knowledge, this is the first report on GC prepared from PJ via a one-step carbonization and activation process used for high-performance supercapacitor applications and its comparison with commercially available activated carbon.

Section snippets

Materials and reagents

PJ wood waste, porous carbon (2000–2500 m^2g^{-1}) and conducting carbon (Super Conductive Carbon Black SUP-C65) were purchased from Xiamen TOB New Energy Technology Co Ltd, China. Potassium hydroxide (KOH), methanol, xylene and sodium lauryl sulfate were purchased from SD Fine Chemicals, India Limited. Polytetrafluoroethylene (PTFE, Teflon®) (60%) was purchased from Sigma Aldrich, India. All chemicals were of analytical grade and used without any further purification. All aqueous solutions were…

Physiochemical morphological study

The surface morphology of the GC sample was analyzed using SEM, which is depicted at low and high magnifications in Fig. 1(a–b). The prominent 3D nanofoam morphology was clearly visible. The low magnification SEM image shows a 3D graphitized foam structured morphology and the high magnification SEM image shows a hanging fruit cluster morphology. The diffraction pattern (SAED) is shown in Fig. 1(c), which clearly depicts the (101) and (002) planes. The 3D carbon nanofoam clusters were also…

Conclusions

The GC obtained from PJ wood waste has been synthesized using a one-step carbonization and activation technique and used for supercapacitor applications. The as-prepared GC electrode material delivered an excellent half-cell specific capacitance of ~415 Fg^{-1}. The data and analysis have revealed that the GC prepared from PJ wood waste has great potential for application in ultracapacitor energy storage devices. The maximum energy density was ~47.60 $Whkg^{-1}$ at a current density of 1 Ag^{-1} and the…

Author statement

Sivagaami Sundari G: Data curation; Formal Analysis; Investigation; Methodology; Validation; Visualization; Writing-original draft.

Thileep Kumar: Formal analysis; Methodology; Software.

Senthil Kumar E: Formal analysis; Methodology.

Shanmugaraj A M: Resources; Supervision; Writing-review & editing.

Kalaivani R: Supervision; Project Administration; Funding Acquisition.

Raghu S: Conceptualization; Methodology; Investigation; Data Curation; Supervision; Project Administration; Funding Acquisition.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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