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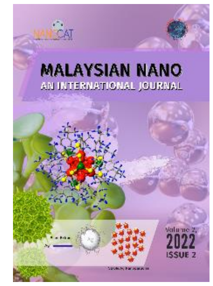

Research Article

Preparation and analysis of activated carbon from pomegranate peel for battery applications

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Abstract

Currently, natural nontoxic carbon in energy storage systems has attracted much attention because of its scalability, low cost, and microspore nature. Activated carbon has a network of interconnected micro-and mesopores. As a result, the carbon material has a large amount of porosity and specific surface area. The pomegranate peel and activation agent significantly affected the surface area and pore structure. Therefore, a pomegranate peel carbon (PPC) anode material was prepared using a hydrothermal method. The effective carbonization of the pomegranate peel was investigated using scanning electron microscopy. Electrochemical measurements were performed using cycle voltammetry. Powder X-ray diffraction (XRD) analysis was used to investigate the nature of the sample. Scanning electron microscopy (SEM) was used to characterize the morphology of the prepared activated carbon.

Keywords*:* Activated carbon; Hydrothermal; Anode material; XRD; SEM; CV

1. Introduction

Recycling agricultural residues have recently gained popularity because of environmental and energy concerns. The lignocellulosic waste is considered as a intriguing application for the production of activated carbon (ACs) [1-3]. These carbonaceous materials are prepared at high temperatures using oxidizing gases (steam, air, etc.) or chemicals (H_2, SO_4, KOH, etc.) since it have high surface area. While coal is the primary source, other carbonaceous materials such as wood and fruit stones are also used. The increased demands in the production of energy and the pollution in the environment due to fossil fuels made increase in the manufacturing cost from the past years. Consequently, widespread concern has been expressed regarding the progress in the clean energy environment [4]. Batteries and supercapacitors have remained as the major devices in the energy storage applications through renewable and sustainable energy sources such as solar, geothermal, and wind energy [5]. The green carbon electrode materials modified from biomass has gained much interest in the last few years [6]. Supercapacitors and batteries are used in electrical energy storage systems are preferred as it they have long life span with quality in power. Activated carbon has a porous structure with a large surface area of > 3000 m^2/g, as it is essential in manufacturing lithium-ion capacitor batteries to generate more lithium ions for charging and discharging process [7]. Their high porosity makes them ideal materials for use as adsorbents in industrial purification. They are also excellent materials for supporting catalytic reactions. Activated carbons have recently emerged as an appealing material for electric double-layer capacitors (EDCLs) [8, 9]. The interaction between the electrode and the electrolyte stores energy in the EDCL. Activated carbon acquired from pomegranate seeds is an ecologically material substituted to cover a large surface area. AC productions are classified into two processes: physical and chemical. Zinc chloride ($ZnCl_2$), phosphoric acid (H_3PO_4), and sulfuric acid (H_2SO_4) are the frequently used activating agents, although potassium compounds have also been suggested [10]. Raw materials and activation agents significantly influence the surface area and pore structure [11]. The carbon source and production process had a significant impact on the electrochemical performance of ACS in supercapacitors. The preferred porosity, electrical conductivity, and particle size can be attained by opting the appropriate carbon source and optimal conditions for the preparation of ACS as an electrode [12]. The earlier reports show the usage of numerous biomass sources as carbon for electrode materials, such as rice husks, peanut shells, and chicken eggshells [13]. Specific surface area and supply of pore size are important factors that influence the capacitive properties of carbon materials. Therefore, pomegranate seed is a raw material obtained from the agricultural biomass waste use in the generation of the activated carbon. Activation involves physical and chemical processes.

2. Experimental procedure

Pomegranate fruits were collected from the Dharmapuri District, Tamil Nadu, India. The pomegranate was peeled and cleaned with running and deionized water and dried for 20 days at the surrounding temperature. The final product of pomegranate seeds was then immersed in 100 ml of 9 mol concentrated sulfuric acid and maintained at an ambient temperature for 48 h. The supersaturated solution has then strained using filtering process and the black residual powder was separated and kept in an oven for 24 h at 80° C. It was then grained using a mortar. The final product of pomegranate seed carbon (PSC) was investigated by various characterization studies, including X-ray diffraction, cycle voltammetry, and scanning electron microscopy. A block diagram of the preparation of pomegranate seed carbon (PSC) is given in Figure 1.

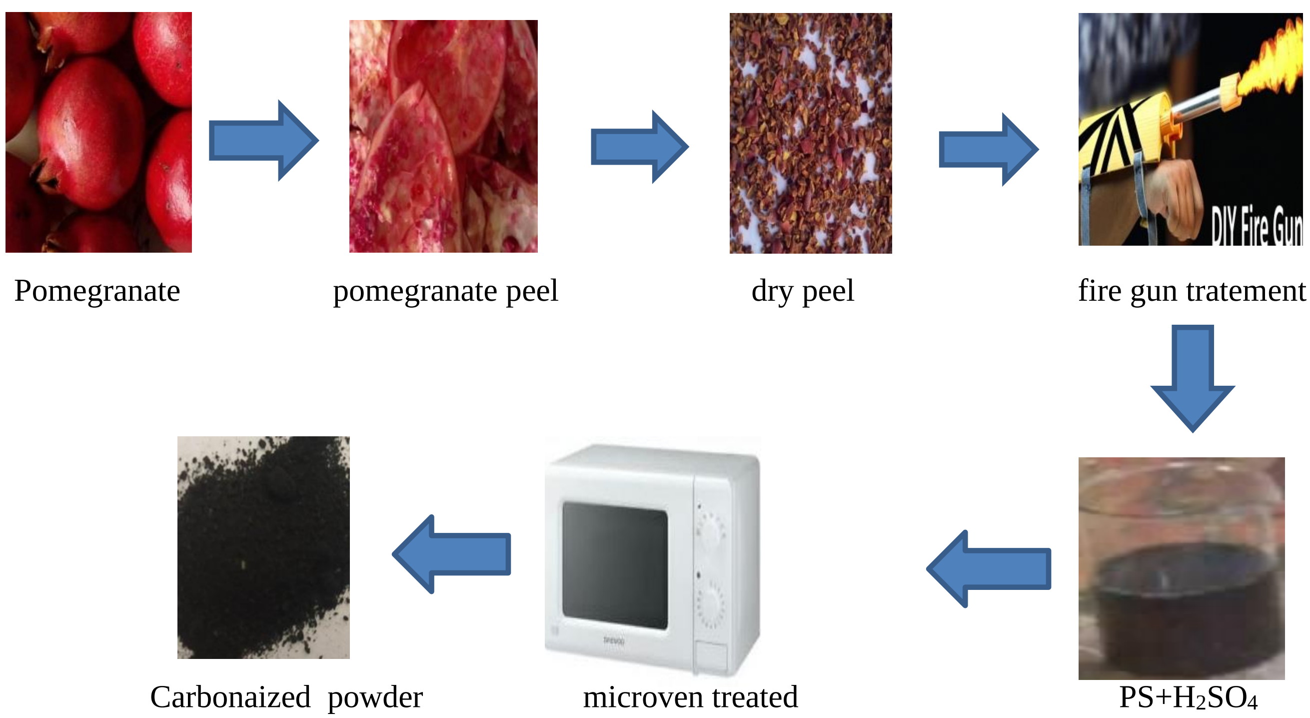

Figure 1: Method of preparation of carbon from pomegranate peel

3. Results and Discussions

3.1 Powder X-ray diffraction analysis

Powder X-ray diffraction studies of the prepared pomegranate seed carbon were performed using an Analytical X'pert Pro diffractometer in the 2θ range of 5–80° using Cu-Kα radiation wavelength of 1.5406 Å. The diffraction pattern of pomegranate peel carbon (PPC) analyzed in the form of powder is shown in Figure 2. The obtained powder XRD pattern clearly revealed that the PPC was amorphous.

The high-intensity peak at ~ 25 °(002) revealed the irregularities and disordered nature of the sample. The lower intensity peak at ~ 45 °indicates the formation of honeycomb-like structures in the PSC.

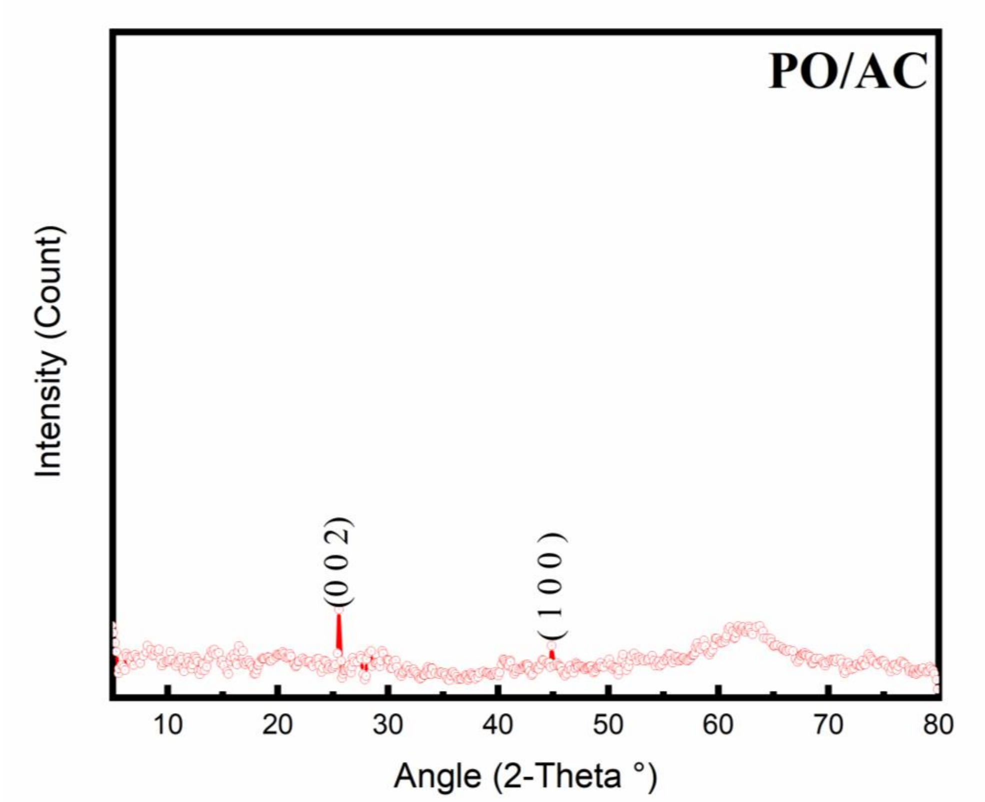

Figure 2: Powder XRD pattern of activated carbon

3.2 SEM analysis

Scanning electron microscopy (SEM) analysis was used to conduct morphological studies of the activated carbon. The morphological analysis of the pomegranate peel carbon (PPC) anode electrode material was carried out using VEGA3. Figure 4 shows the SEM images at different magnifications. The rough surface of the prepared AC was visible in the micrographs; which shows a uniform nanowhisker morphology. Thus, we concluded that pomegranate seed carbon is a vital anode material that has an important part to enhance the life of Li-ion battery.

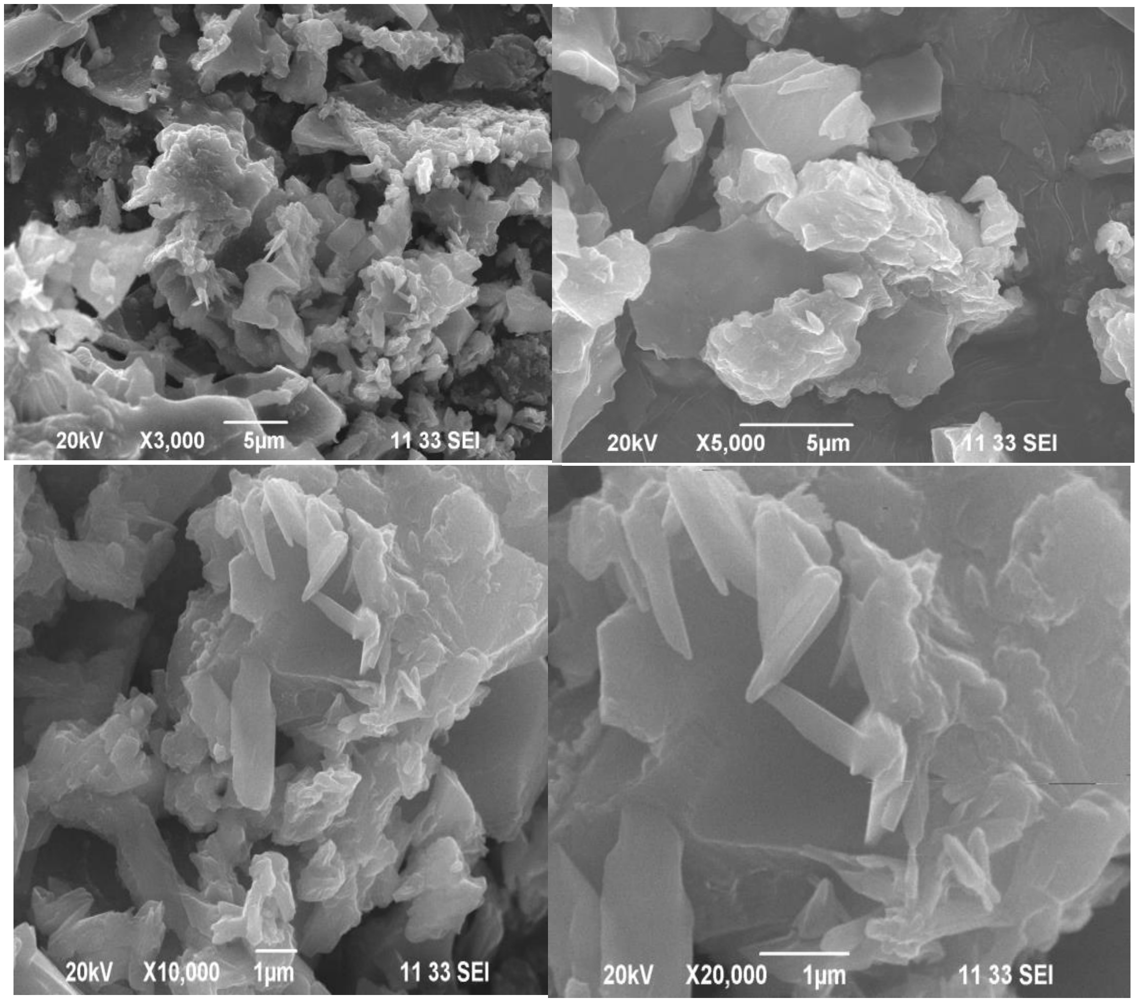

Figure 3: SEM images of activated pomegranate peel carbon

3.3 Cyclic Voltammetry analysis

Cyclic voltammetry has been used in discerning the mechanism and kinetic rates, with the thermodynamic parameters. The electrochemical characteristics of PPC (anode) in lithium-ion batteries were investigated by cycle voltammeter in the potential range -0.05 – 0.65 V observed in the scanning rate of $0.1mVs^{-1}$. In this study, the efficiency of the pomegranate peel carbon (PPC) anode was analyzed using a manganese (cathode) electrode and lithium hexafluorophosphate electrolyte. The cyclic voltammetry curve of PPC is shown in Fig.4. The cathodic broad peak obtained below ~ 0.48 V is because of the lithium intercalation attained by the solid electrolyte interphase. The analysis of the cyclic voltammetric-prepared PPC indicated that it was a more valuable anode material for battery applications.

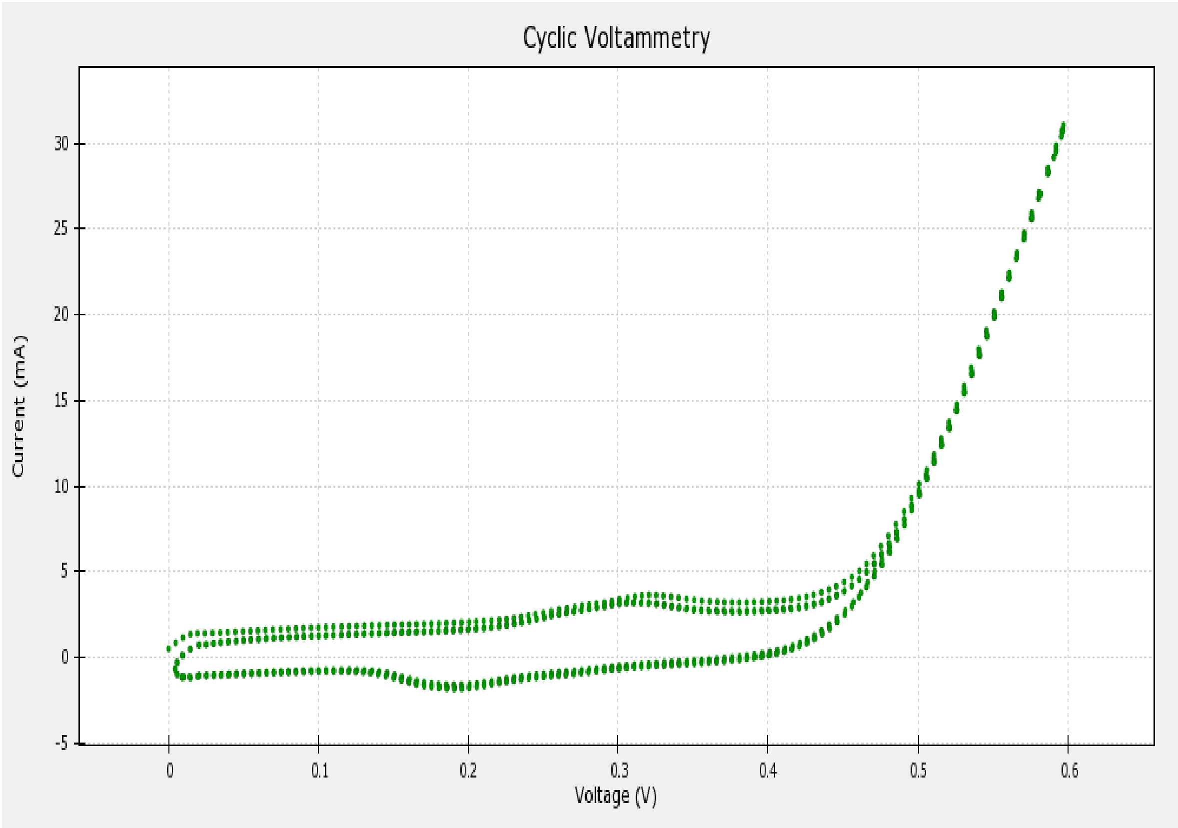

Figure 4: Voltage Vs Current curve of activated pomegranate peel carbon

4. Conclusion

In summary, the activated carbon was successfully produced from pomegranate seeds using the hydrothermal method at 80 °C. The obtained SEM images of the PSC anode electrode show uniform nanowhisker morphology. The cathodic broad peak examined below ~ 0.48 V is due to the lithium intercalation attained by solid electrolyte interphase. The lower intensity peak at ~ 45° indicates that the availability of honeycomb-like structure formation in PPC. The observed results clearly indicate that the prepared PPC material is a suitable anode material for lithium-ion batteries.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgement

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References

1. M.D.D. de Leon-Garza, E. Soto-Regalado, M. Loredo-Cancino, F.D. Cerino-Cordova, R.B. Garcia-Reyes, N.E. Davila-Guzman, J.A. Loredo-Medrano. Phenol adsorption onto coffee waste - granular activated carbon: kinetics and equilibrium studies in aqueous solutions. *Desalin. Water Treat*. 2017: 90; 231- 240.
2. F.M. Kasperiski, E.C. Lima, C.S. Umpierres, G.S. dos Reis, P.S. Thue, D.R. Lima, S.L.P. Dias, C. Saucier, J.B. da Costa. Production of porous activated carbons from Caesalpinia ferrea seed pod wastes: Highly efficient removal of captopril from aqueous solutions. *J. Clean Prod*. 2018: 197; 919-929.
3. N.G. Rincon-Silva, J.C. Moreno-Pirajan, L. Giraldo. Removal of phenol, p-nitrophenol and p-chlorophenol from activated carbon chemically with sulfuric acid from lignocellulosic waste material: Effect of the concentration of activating agent. *Afinidad*. 2017: 74; 112-123.
4. A.M. Abioye, F.N. Ani. Recent development in the production of activated carbon electrodes from agricultural waste biomass for supercapacitors: a review. *Renew. Sustain. Energy Rev*. 2015: 52; 1282-1293
5. A. Kalair, N. Abas, M.S. Saleem, A.R. Kalair, N. Khan. Role of energy storage systems in energy transition from fossil fuels to renewables. *Energy Storage*. 2021: 3; 135.
6. Z. Li, D. Guo, Y. Liu, H. Wang, L. Wang. Recent advances and challenges in biomass-derived porous carbon nanomaterials for supercapacitors. *Chemical Engineering Journal*. 2020: 397; 125418.
7. S. Li, S. X.Tan, H. Li, et al. Investigation on pore structure regulation of activated carbon derived from sargassum and its application in supercapacitor. *Sci Rep*. 2022: 12; 10106.
8. Y.H. Cao, K.L. Wang, X.M. Wang, Z.R. Gu, Q.H. Fan, W. Gibbons, J.D. Hoefelmeyer, P.R. Kharel, M. Shrestha. Hierarchical porous activated carbon for supercapacitor derived from corn stalk core by potassium hydroxide activation. *Electrochim Acta*. 2016: 212; 839-847.
9. E.Y.L. Teo, L. Muniandy, E.P. Ng, F. Adam, A.R. Mohamed, R. Jose, K.F. Chong. High surface area activated carbon from rice husk as a high-performance supercapacitor electrode. *Electrochim Acta*. 2016: 192; 110-119.
10. W.T Tsai, T.J. Jiang. Mesoporous activated carbon produced from coconut shell using a single-step physical activation process. *Biomass Conv. Bioref*. 2018: 8; 711–718.
11. A. Yürüm. "Sunflower Stalk Based Activated Carbon for Supercapacitors". *Hacettepe Journal of Biology and Chemistry*. 2019: 47; 235-247.

12. Z. Zhai, L. Zhang, T. Du, B. Ren, Y. Xu, S. Wang, J. Miao, Z. Liu. A review of carbon materials for supercapacitors. *Materials & Design*. 2022: 221; 111017.
13. V. Balasubramanian, T. Daniel, J. Henry, et al. Electrochemical performances of activated carbon prepared using eggshell waste. *SN Appl. Sci.* 2020: 2;127.
14. Phiri, Josphat et al. Highly Porous Willow Wood-Derived Activated Carbon for High-Performance SupercapacitorElectrodes. *ACS Omega*. 2019: 4;19; 18108-18117.