Applied Surface Science 613 (2023) 156069

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Full length article

Pseudocapacitive performance of phenothiazine functionalized graphene aerogel

Soon Poh Lee [a,b], Gomaa A.M. Ali [c], Mohammed A. Assiri [d,e], Kien Voon Kong [f], Ellie Yi Lih Teo [g], Kwok Feng Chong [a,b,*]

[a] Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang, Gambang, 26300 Kuantan, Malaysia
[b] Center for Advanced Intelligent Materials, Universiti Malaysia Pahang, 26300 Kuantan, Pahang, Malaysia
[c] Chemistry Department, Faculty of Science, Al–Azhar University, Assiut 71524, Egypt
[d] Research Center for Advanced Materials Science (RCAMS), King Khalid University, P.O. Box 80203, Abha 61413, Saudi Arabia
[e] Department of Chemistry, Faculty of Science, King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia
[f] Department of Chemistry, National Taiwan University, Taipei 10617, Taiwan
[g] Department of Science & Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia, Bintulu Campus, Sarawak, Malaysia

ARTICLE INFO

Keywords:
Graphene aerogel
Phenothiazine
Functionalization
Pseudocapacitive
Supercapacitor

ABSTRACT

This study utilizes light adsorbing molecule, phenothiazine (PTZ) to reduce graphene oxide (GO) and functionalize into PTZ-rGO aerogel (PTZ-rGO). The UV excited PTZ reduces GO via electron transfer while PTZ is simultaneously oxidized and functionalized onto rGO to produce PTZ-rGO aerogel. The optimum incorporation of PTZ on rGO sheets renders good electrochemical active surface area of 495.71 m^2 g^{-1} and enhances the diffusion behavior up to 41.92%. This pseudocapacitive effect and the excellent surface property provide promising charge storage results of 235.5 F g^{-1} at 0.5 A g^{-1}. Furthermore, the stable charge-discharge cycles with 92% capacitance retention after 10,000 cycles render it an excellent electrode material for supercapacitor fabrication.

1. Introduction

The advancement of charge storage systems ranging from conventional Li-ion batteries to supercapacitors have created an exponential leap for this technological era. Generally, batteries are well known for their high energy density, while capacitors excel in their power density [1–4]. Hence, by leveraging the advantages of both types of charge storage devices, supercapacitors are invented to hold a greater charge capacity like batteries without sacrificing the fast-charging properties of capacitors [5]. The current trend in supercapacitor electrode materials focuses on the pseudocapacitive materials, which possess stable charge-discharge cycles (adopted from electric double layer capacitor, EDLC) [6,7] and higher charge storage performance (adopted from battery) [8]. Due to the excellent EDLC performance in graphene-based electrode materials, modification of graphene has been made to achieve pseudocapacitive behavior by introducing hetero compounds via functionalization or doping [9,10].

Doping of nitrogen and sulphur on reduced graphene oxide (rGO) has become one of the famous approaches for improving the charge storage performance in supercapacitors. The electron-rich nitrogen and sulphur are widely used as the dopant due to their contribution in enhancing electrical conductivity and eventually assist in charge transfer as the supercapacitors electrode materials [11,12]. This enhancement had been shown by Cao et al. with the N/S co-doping can reduce the charge transfer resistance from 2.4 Ω (rGO) to 0.52 Ω (N/S co-doped rGO) [13]. However, this doping technique is challenging as it operates under high temperature such as carbonization at 800 °C [14] or the requirement of costly instruments (inductively coupled plasma [15], and chemical vapor deposition [16,17] approaches), which is not feasible for all laboratories. Hence, the functionalization approach is more preferred due to its comparative performance as of doping technique with a more feasible experimental procedure. The facile one-pot hydrothermal method is widely used to functionalize rGO with N/S precursor, as shown by Liu et al., which uses 5-mercapto-3-phenyl-1,3,4-thiadiazole-2

Abbreviations: PTZ, Phenothiazine; rGO, Reduced graphene oxide; DMSO, Dimethyl sulfoxide; EDLC, Electric double layer capacitor; XPS, X-ray photoelectron spectroscopy; XRD, X-ray diffraction; CV, Cyclic voltammetry; GCD, Galvanostatic charge-discharge; EIS, Electrochemical impedence spectroscopy.

* Corresponding author at: Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang, Gambang, 26300 Kuantan, Malaysia.
E-mail address: ckfeng@ump.edu.my (K.F. Chong).

https://doi.org/10.1016/j.apsusc.2022.156069
Received 16 October 2022; Received in revised form 6 December 2022; Accepted 10 December 2022
Available online 16 December 2022