Synthetic Metals 227 (2017) 61–70

Contents lists available at ScienceDirect

Synthetic Metals

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

Biodegradable polymer-modified graphene/polyaniline electrodes for supercapacitors

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ARTICLE INFO

Article history:
Received 27 December 2016
Received in revised form 2 March 2017
Accepted 10 March 2017
Available online 26 March 2017

Keywords:
Graphene
Polyaniline
Chitosan
Supercapacitor
Hybrid capacitor

ABSTRACT

A promising supercapacitor material based on chitosan-modified graphene/polyaniline (CS-G/PANI) composite has been successfully synthesized by in situ polymerization. In this work, we established an environmentally friendly approach to the synthesis of well-dispersed graphene based on the biodegradable polymer chitosan (CS) using graphene oxide (GO) as a precursor. The merit of this approach is that CS acts as a stabilizing agent for GO after reduction. The resulting material was shown to exhibit good dispersion in water, and hence, this CS-G facilitates the adsorption of aniline monomers by increasing the exposure of aniline nuclei growth sites. Under the same polyaniline (PANI) concentration, chitosan modified graphene/PANI (CS-G/PANI) nanocomposites showed higher PANI adsorption than graphene/PANI (G/PANI). The CS-G/PANI nanocomposite achieved a greater which is the highest value reported to date for starch-modified graphene subjected to in situ polymerization. The modified CS-G/PANI electrode shows a potential alternative path to achieve high capacitance by preventing graphene aggregation in a simple and cost effective method, which consequently leads to a new avenue for fabricating excellent electrochemical devices.

1. Introduction

Since the end of the last century, decreasing energy sources and increasing pollution have inspired the development of environmentally friendly technologies. The need for supercapacitors utilizing eco-friendly techniques has escalated in these recent years, given the growing demand for portable systems and hybrid electric vehicles, which require high power in short-term pulses [1,2]. Supercapacitors have been reported to be efficient energy-storage devices compared to conventional batteries because of their excellent storage and effective release of electrical energy. Some of these devices' distinctive electrochemical properties are rapid charging time, high power density, increased cyclic stability, high cost effectiveness and high safety level [3–5].

Supercapacitors can be classified into two types based on the mechanism by which they generate and release electrical charge: electric double-layer capacitors (EDLCs) and reversible faradaic pseudocapacitors (PCs). At the electrode/electrolyte interface, the former release capacitance from non-faradic charge separation via the electrical double layer, which is a very fast and stable process; therefore, these devices have long-term cycling stability and high rate capability but low capacitance. The reversible faradaic pseudocapacitors generate electrical charge from electrochemical faradaic reactions through redox faradaic reactions, and as a result, they have high specific capacitance but poor cycling stability [6–8]. Consequently, hybrid supercapacitors that combine the merits of EDLCs and PCs have emerged [9].

Generally, metal oxides and conductive polymers provide electric energy by storing it via redox faradaic reaction mechanisms, and carbon materials provide a good electron-transfer path for moving the generated energy [10–13]. Among other conductive polymers, polyaniline (PANI) has attracted substantial attention because of its relatively high environmental stability and controllable conductivity with three distinct oxidation states. The drawback associated with PANI is its poor cycling stability because of swelling and shrinking. This drawback can be overcome by coupling it with support materials, such as metal or metal oxide nanoparticles or carbon materials [14–18].

Such support materials must possess high electrical conductivity, and the structure should supply a good transfer path to support the movement of electrons to achieve effective transfer of the large amount of electric energy generated by the redox faradaic reaction mechanism between conductive polymers and electrolytes [19].

Abbreviations: G/PANI, graphene/polyaniline; CS, G/PANI chitosan-modified graphene/polyaniline; CS-G, chitosan-stabilized graphene.

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http://dx.doi.org/10.1016/j.synthmet.2017.03.005
0379-6779/