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High Performance Supercapacitive Behavior of Self-doped polyaniline/Manganese dioxide Nanocomposite

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Abstract

Self-doped polyaniline/Manganese dioxide (SDPA/MnO_2) nanocomposite has been prepared via in situ electrochemical oxidation of mixture of aniline, m-aminobenzoic acid (MABA) and Mn^{2+} using fast cyclic voltammetry (CV). Tunnelling electron microscopy (TEM) clearly revealed the formation of nanofiber structure under the experimental conditions. Based on the electrochemical results, this nanocomposite shows high specific capacitance of 551 F g^{-1} and high specific energy of 37.5 Wh kg^{-1} at a current density of 5 mA cm^{-2} in aqueous solution.

Keywords: Organic-inorganic nanocomposite; Self-doped polyaniline/MnO_2 nanocomposite; Supercapacitor.

Introduction

Nanostructured materials have opened a new opportunity for science and technology [1, 2]. Electroactive nanomaterials can improve the performance of electrochemical energy storage systems such as batteries [3] and supercapacitors [4]. supercapacitors are considered as one of the newest innovations in the field of high power electrical energy storage systems. The main strategy has been employed to improve the energy characteristics of the supercapacitors is the use of nano-sized materials because of their unique physical and chemical properties. High surface area of such materials make the supercapacitors have higher specific capacitance than micro-sized materials based supercapacitors [5]. It is due to more participation of higher percentage of the electroactive materials and rapid ion diffusion which results in fast redox switching. The other benefit of using nano-structured materials is increasing the working voltage window [6]. Recently, many attempts of scientists have been focused on preparation of various types of organic-inorganic nanocomposite in the energy storage fields. It is due to their potential for combining properties that are difficult to attain separately with individual components [7].

In continuation our recent studies on the electrical energy storage systems based on SDPA [4, 8] and metal oxides [9, 10] for energy storage systems, in this work, we introduce a new organic-inorganic nanocomposite (SDPA/MnO_2) and evaluate their capability as active material in the supercapacitor.

Experimental

High purity grade of MABA, H_2SO_4 and Na_2SO_4 were purchased from Aldrich and used as received without further purification. Aniline (Merck) was used after purification by distillation under reduced pressure prior to use. All the solutions prepared by using doubly distilled water.

All electrochemical experiments were carried out by an Autolab General Purpose System PGSTAT 30 (Eco-chemie, Netherlands). A conventional three electrode cell was used in order to synthesis and study the SDPA/MnO_2 nanocomposite material as working electrode. A Pt wire and Ag/AgCl (KCl, satureted) were utilized as the counter and reference electrodes, respectively.

The SDPA/MnO_2 nanocomposite and SDPA nanofiber films were potentiodynamically electrodeposited between -0.2 to 1.4 V vs. Ag/AgCl at scan rate of 250 mV s^{-1} for 100 cycles. Electrodeposition of the SDPA/MnO_2 nanocomposite was carried out onto the stainless steel in 0.1 M MnSO4, 0.1 M aniline monomer, 0.1 M m-aminobenzoic acid and 0.5 M H_2SO_4 solutions. Moreover, the electropolymerization of the SDPA was performed on stainless steel in 0.1 M aniline monomer, 0.1 M *m*-aminobenzoic acid and 0.5 M H_2SO_4.

Results and Discussion

Morphological studies

Fig. 1 shows TEM of the formation of SDPA/MnO_2 nanocomposite. The SDPA and MnO_2 are randomly dispersed in the whole of nanofiberous structure of the nanocomposite. Due to the presence of MnO_2 in this structure, agglomeration of nanofibrous structure during charge-discharge process and swelling-shrinkage of SDPA is prevented.

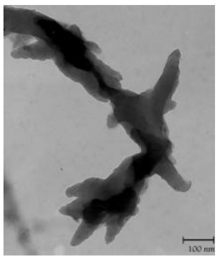

Fig. 1 TEM image of SDPA/MnO_2 nanocomposite.

Electrochemical studies

Fig. 2 shows the cyclic voltammograms of the SDPA/MnO_2 nanocomposite and the SDPA in a three electrode cell and potential ranges of -0.2 to 0.8 V vs. Ag/AgCl, at scan rate of 20 mV s^{-1} in aqueous solution. As it is seen, the CV curves of the SDPA/MnO_2 and SDPA electrodes show two redox peaks could be attributed to reversibly charge/discharges processes of the SDPA component. However, SDPA/MnO_2 nanocomposite shows more electroactivity than the SDPA.

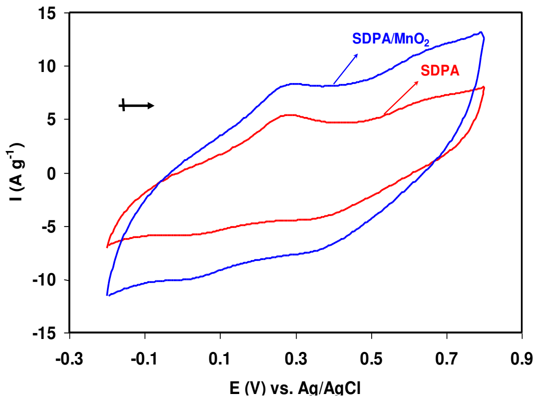

Fig. 2 Comparative CVs of the SDPA/MnO_2 nanocomposite and the SDPA in the three electrode cell at scan rate of 20 mV s^{-1}.

CV studies also were used to evaluate the capacitive behaviour of the system. The specific capacitances (C_{single}) of the SDPA/MnO_2 nanocomposite or the SDPA electrodes in the three electrode system (F g^{-1}) were calculated based on the following equation:

$$C_{single}(F\,g^{-1}) = \frac{I_{avg}}{sm} \qquad (1)$$

where, I_{avg} is the average current (A) at cathodic branch of CV curve, s is the potential sweep rate (V s^{-1}) and m is amount of active materials in each of the supercapacitor electrode [11]. Based on the Eq. 1, the specific capacitance of the SDPA/MnO_2 nanocomposite was obtained 551 F g^{-1}.

Conclusions

Nanostructured of the SDPA/MnO_2 material was prepared by the cyclic voltammetry at scan rate of 250 mV s^{-1}. The application of this nanocomposite was evaluated as supercapacitor material. The nanocomposite has minimal degradation due to the presence of MnO_2. The specific capacitance of the SDPA/MnO_2 nanocomposite is 551 F g^{-1}.

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