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Short Communication

Electrochemical investigation of graphene/nanoporous carbon black for supercapacitors

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ABSTRACT

In this paper, mixing effect of nanoporous carbon black (NCB) and graphene nanosheets (GNS) on surface morphology and electrochemical performance of prepared electrodes were investigated. 80:10:10 (NCB:GNS:PTFE) prepared electrodes show a maximum specific capacitance as high as 10.22 F g^{-1} in 3 M NaCl electrolyte. Addition of nanoporous carbon black increases outer to total charge stored (q_O^*/q_T^*) on the electrode from 0.024 to 0.037 which confirms the higher current response and higher voltage reversal at the end potentials.

1. Introduction

Carbon base materials due to their different allotropes (graphite, graphene, nanotubes, etc.), various microtextures (more or less ordered) owing to the degree of graphitization, and ability for exist under different forms (from powders to fibers, foams, fabrics and composites) represent a very attractive material for electrochemical applications, especially for the storage of energy. Apart from it, carbon materials are environment friendly [1]. Graphene consists of a 2D layers of sp^2 hybridized carbon atoms bonded together and the shape that is resulted from a “honeycomb” lattice, notable for its high regularity. Graphene exhibits superior electrical conductivity, high surface areas of over 2600 m^2/g and a broad electrochemical window [2].

Among different energy storage systems, supercapacitors are recognized as highly attractive energy storage devices [3]. High cycle life, high life time, high energy efficiency and high self-discharge rate are some of the characteristics of supercapacitors [4,5]. Depending on the charge-storage mechanisms, supercapacitors can be classified in three types: Electrochemical double layer capacitors (EDLC), faradic pseudo-capacitors and hybrid capacitors [6,7]. EDLCs store the electric charge directly across the DL of the electrode [6]. Since no chemical action is involved, the effect is easily reversible with minimal degradation in deep discharge or overcharge and the typical life cycle is hundreds of thousands of cycles [8]. In this paper, the double layer capacitance and pseudo-capacitance characteristics of different GNS/NCB electrodes were investigated. The aim of this work is to fabricate GNS/NCB electrodes using mechanical pressing as a fast and easy method and characterizes the effect of sheet-like and nanoporous structures on charge storage ability of the prepared electrodes.

2. Experimental

2.1. Materials

Graphene nanosheets (60 nm Flakes, multi-layered) with the specific surface area of 15 m^2/g and purity of 98.5% were

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purchased from graphene supermarket and polytetrafluoroethylene (<2 μm) from Aldrich company. Nanoporous (<10 nm in diameter) carbon black (NCB) micro-sized particles (<2 μm) were purchased from Degussa, Germany. All other chemicals used in this study were purchased from Merck. In order to prepare the electrodes, the mixture containing different wt% NCB, GNS and 10 wt% polytetrafluoroethylene (PTFE) were mixed well in paste form in ethanol by ultrasonic wave for about 30 min. After drying the paste and powdering, the prepared complex was pressed onto a 316 L stainless steel plate (50 MPa) which served as a current collector (surface area was 1.4 cm^2). Typical mass load of the electrode material was 45 mg. The used electrolyte was 3 M NaCl.

2.2. Characterization

The electrochemical behavior of prepared electrode was characterized using CV and EIS tests. Electrochemical measurements were performed using PGSTAT 302 N Model Autolab (Netherlands). CV tests were performed within the range of −0.45 and +0.3 V (vs. SCE), using scan rates of 10, 20, 50, 100 and 200 mV s^{-1}. EIS measurements were also carried out in frequency range of 100 kHz–0.01 Hz at open circuit potential with an AC amplitude of 10 mV. The specific capacitance can be estimated from the voltammetric charge surrounded by the CV curve according to the following formula [9,10]:

$$C = \frac{q_a + |q_c|}{2m\Delta V} \quad (1)$$

where q_a, q_c are the sum of anodic and cathodic voltammetric charges on positive and negative sweeps, respectively, m is the mass of active material (regardless of mass of PTFE) and ΔV is the potential window of CV. The morphologies and structures of the samples were observed by a scanning electron microscope (TESCAN, USA).

3. Results and discussion

Specific surface area and conductivity are two important parameters to prepare highly efficient electrodes for supercapacitors. Carbonaceous materials possess both high specific surface area and high conductivity. But, only some parts of the surface are always accessible by electrolyte ions to be adsorbed, because the porosity influences the ions diffusion. 3D porosity structure of electrode material will lead to high specific surface area due to high ratio of volume to mass, and high surface area of electrode material which is achieved via

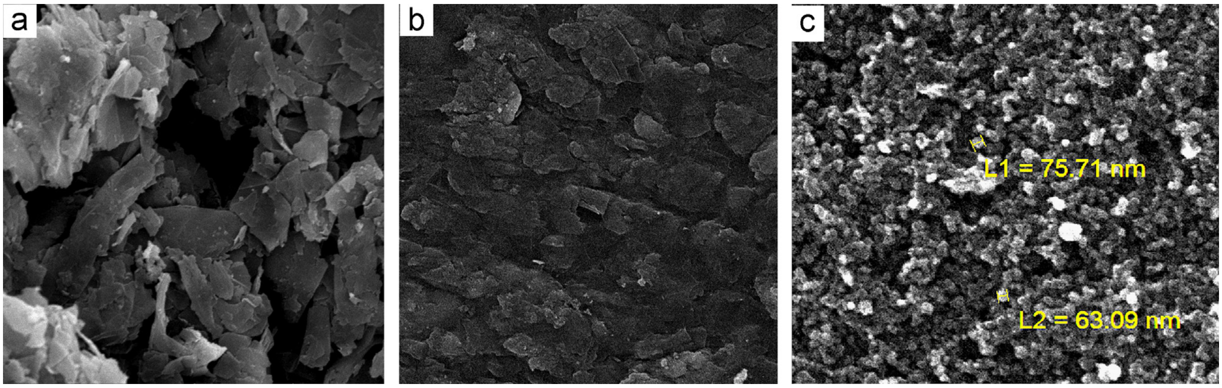

Fig. 1. Scanning electron microscopy image obtained from 90:10:10 (a), 60:30:10 (b) and 0:90:10 (c) electrodes.

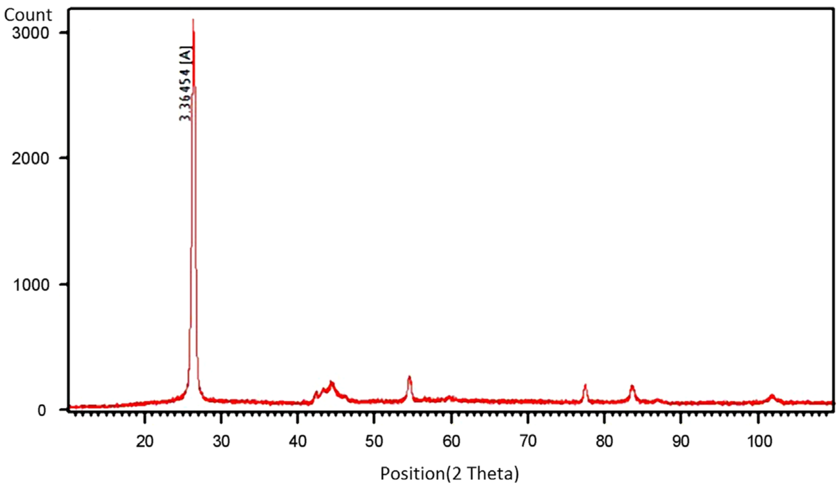

Fig. 2. XRD pattern obtained from graphene.