Materials Science in Semiconductor Processing 24 (2014) 260–264

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

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

Short Communication

Effect of zirconium oxide nanoparticles on surface morphology and energy storage of electrochemical capacitors

Mahdi Nasibi [a,b,*], Mahdi R. Sarpoushi [a], Rouhallah Hesan [c], Mohammad Ali Golozar [d], Masoud Moshrefifar [c]

[a] Technical Inspection Engineering Department, Petroleum University of Technology, Abadan, Iran
[b] Health and Safety Engineering (HSE) Office, NIOPDC, Yazd Region, Yazd, Iran
[c] Materials and Mining Engineering Department, Yazd University, Yazd, Iran
[d] Materials Science and Engineering Department, Isfahan University of Technology, Isfahan, Iran

ARTICLE INFO

Available online 15 April 2014

Keywords:
Supercapacitors
Nanomaterials
Morphology
ZrO_2

ABSTRACT

In this study, the effect of mixing zirconium oxide nanoparticles and carbon black particles on surface morphology and electrochemical performance of prepared electrodes were investigated. Scanning electron microscopy was used to characterize microstructure and nature of nanocomposites. Charge stored (q) on different nanoparticle containing electrodes was calculated and the effect of surface morphology on charge storage was discussed. It is concluded that charge stored on the electrode shows an n-like change by increasing nanoparticle content of electrodes. Addition of nanoparticle increases q^*_O/q^*_T (from 0.05 to 0.18) which confirms the higher current response and higher voltage reversal at the end potentials.

1. Introduction

Electrochemical capacitors (ECs), with a combination of high power density and high energy density, can be used as a complementary energy-storage device along with a primary power source, such as a battery or a fuel cell, for power enhancement in short pulse applications [1]. High cycle life, high energy efficiency and high self-discharge rate are some of the supercapacitors characteristics [2,3]. Today, many laboratories are actively engaged in development of well-known type of supercapacitors, viz., electrochemical double-layer, pseudo and hybrid supercapacitors, and most research has been focused on development of different electrode materials [4,5]. For practical applications, an EC must fulfill the following technical requirements: high specific capacitance, long cycle life and high charge/discharge rate. Today, using nanoparticles is of interest in order to improve these parameters. So, nanoparticles distribution quality on the electrode surface is of most important parameters [6]. In our previous work, we investigated the effect of different mixing processes of electrode material on dispersion quality of nanoparticles which change their electrochemical performance. In this work, we investigate the effect of nanoparticle contents of the electrode material on microstructure and nature of prepared electrodes using scanning electron microscopy, and potentiodynamic polarization techniques. At the end, quantitative measurements were reported for further investigations.

2. Experimental

2.1. Materials

High purity (> 99%) nano-sized zirconium oxide (ZrO_2) particles (< 100 nm), nickel foil (99.99% with 0.125 mm

* Corresponding author. Tel.: +98 9113708480; fax: +98 6314423520.
E-mail address: mahdi.nasibi@gmail.com (M. Nasibi).

http://dx.doi.org/10.1016/j.mssp.2014.03.037
1369-8001/

thickness) and polytetrafluoroethylene (< 2 μm) were purchased from Aldrich, USA. All other chemicals used in this study were purchased from Merck, Germany. Carbon black particles (< 2 μm) were purchased from Degussa, Germany. In order to prepare electrodes, the mixture containing different wt% ZrO_2 and carbon black (CB) and 10 wt% polytetrafluoroethylene (PTFE) was well mixed in ethanol to form a paste and then was pressed onto the nickel foil (25 MPa), which served as a current collector (surface was 0.785 cm^2). The typical mass weight of electrode material was 30 mg. The used electrolyte was 2 M KCl.

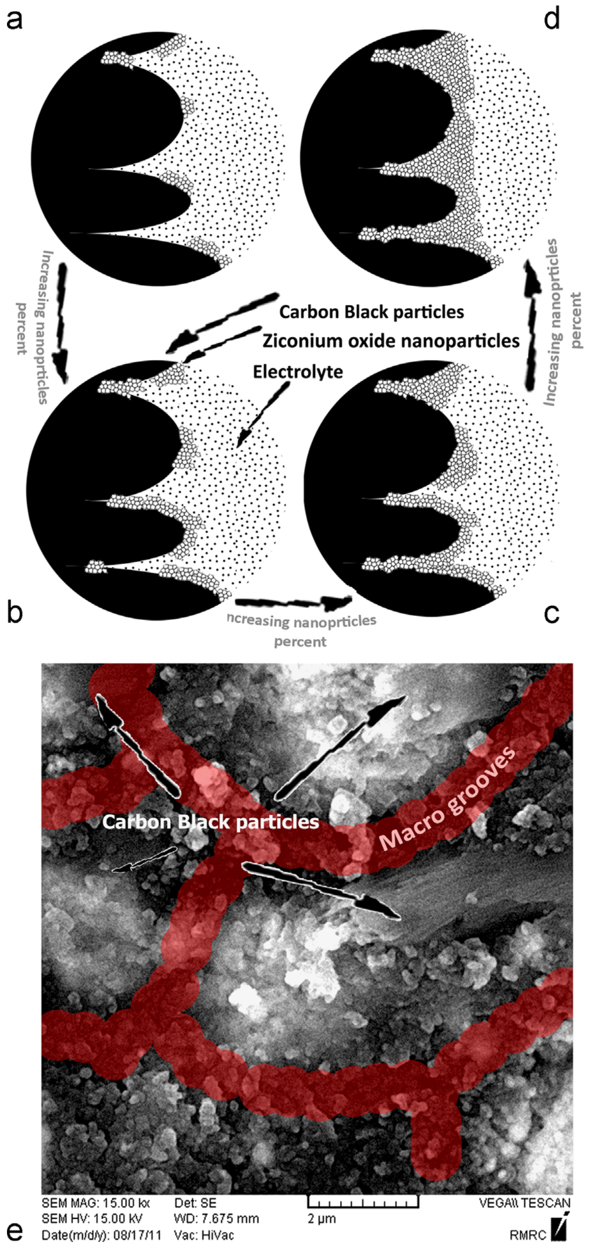

Fig. 1. (a–d) Schematic illustration of the surface changes by addition of nanoparticles into the electrode material and, (e) SEM image obtained from 30:60:10 electrode. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

2.2. Characterization

The electrochemical measurements were performed using an Autolab (Netherlands) potentiostat Model PGSTAT 302N. CV tests were conducted at various scan rates (s) with recording of potential response currents, I, which is related by $C=I/s$ where C is the capacitance of the electrode interface. The specific capacitance C (Fg^{-1}) of the active material was determined by integrating either the oxidative or reductive parts of the cyclic voltammogram curve to obtain voltammetric charge Q (C). This charge was divided by mass of active material m (g) in the electrode and width of the potential window of the cyclic voltammogram ΔE (V), i.e., $C=Q/(\Delta Em)$ [7]. The morphology and nature of the prepared electrodes were studied using scanning electron microscopy (TESCAN, USA).

3. Results and discussion

Nanoparticles distribution quality on the electrode surface is one of the key parameters which controls the electrical performance of nanoparticle containing electrodes for supercapacitors. Using macroparticles like used carbon black particles which store electrical energy through the double layer mechanism, will make macropores and macrogrooves with deep and hollow shapes on surface of the electrode. Using the nanoparticles will make nanopores with shallow shapes. Therefore, mixing the nanoparticles with macroparticles will have a significant effect on the morphology and nature of the prepared electrodes. One of the thinkable morphology changes by mixing of the nanoparticles with macroparticles is schematically illustrated in Fig. 1. In the absence of the nanoparticles, macrogrooves produced between CB particles and these grooves are exposed to the electrolyte for charge storage (Fig. 1(a)). As the nanoparticle content of

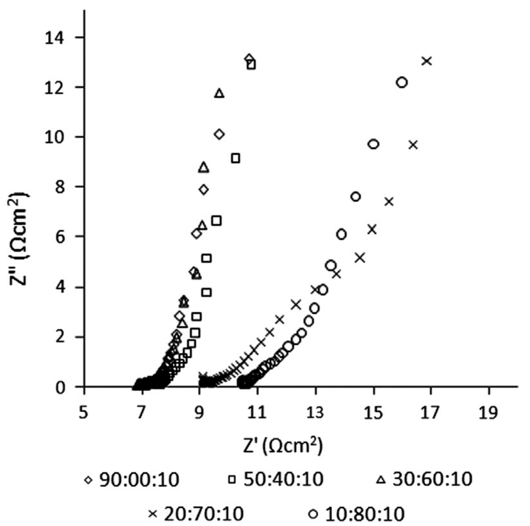

Fig. 2. Nyquist diagrams of different ZrO_2-content electrodes in 2 M KCl electrolyte.