RuOx/polypyrrole nanocomposite electrode for electrochemical capacitors

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1. Introduction

The rapid development of portable electronics and electrical vehicles has stimulated interest in energy storage devices. Electrochemical capacitors (ECs), with their high specific-power/energy density and long cycle life, are one of the most important subjects in the high power source field. To obtain ultrahigh power performance and maintain the high capacity of ECs, the electric resistance of the electrode materials has to be carefully considered, which is generally promoted by introducing electronic conductors such as carbon black, carbon nanotubes (CNTs) and carbon fibers [1–4].

Activated carbon (AC)/CNTs [4], transition metal oxides [5–10], and conducting polymers [11–15] were the active electrode materials used in supercapacitor applications. In the case of AC and CNT electrodes, the capacitance is determined by the interfacial area between the electrolyte and electrode. The function of transition metal oxide and conducting polymer electrodes are based on the redox reaction at the interface of electroactive species [1–3].

Among the many transition metal oxides used as the electrode materials for supercapacitors, such as RuOx, NiOx, MnOx and IrOx, the most success has been achieved using ruthenium oxide, due to its advantages of a wide potential window of highly reversible redox reactions, remarkably high specific capacitance, long cycle life and metallic type conductivity [5–10]. Though hydrous ruthenium oxide exhibits excellent pseudocapacitive behavior with a large capacitance and good reversibility, the low abundance and high cost of this precious metal are major limitations to its commercial application [11].

Conducting polymers have attracted lots of research interest due to their high electrical conductivity, low cost, and high redox active properties [1–3,11–16]. Polyaniline, polypyrrole and their derivatives are the most promising and widely studied conducting polymers [16]. Although they have good electrical properties, conducting polymers suffer from poor cycleability. This is ascribed to their poor mechanical properties [4,17] and the chemical instability during repeated redox processes [5,11]. In addition to these drawbacks, the poor sustainability of conducting polymers towards over-oxidation aggravates the situation.

In the search for new materials, composites play an important role. As a multicomponent system, composites combine the properties of their constituents, which make it possible to overcome the drawbacks of the individual substances [17–20].

In recent studies, the utility of very low quantities or thin layers of RuO2 deposited on carbon, carbon aerogels, carbon nanotubes (CNTs), and conducting polymers has been studied for their charge-storage behaviors [6,7,17–20]. By doing so, the quantity of RuO2 required has been minimized and, at the same time, a higher specific capacitance has also been achieved [17–20].

In a previous work, we successfully fabricated polypyrrole (PPy) nanorod array electrodes having a much larger surface area than PPy film electrodes and demonstrated that their specific capacitance was greatly improved due to their large surface area [15]. In this study, a PPy nanorod was prepared using an anodized aluminum oxide template, and RuOx was deposited on the surface of the PPy nanorods by the electrochemical deposition technique. The procedure used for the preparation of the RuOx-PPy nanocomposite was investigated by SEM and EDX. The capacitive performance of the RuOx-PPy nanocomposites was evaluated as a function of the amount of RuOx. The maximum specific capacitance of the RuOx-PPy nanocomposite electrode was 419 mF cm−2/681 F g−1.

In this study, ruthenium oxide–polypyrrole (RuOx-PPy) composite nanostructures were prepared as electrode materials for electrochemical capacitors. PPy was electrochemically polymerized in the pores of an anodized aluminum oxide (AAO) template. RuOx was further deposited on the surface of the PPy nanorod array by an electrochemical method. The morphology and composition of the RuOx-PPy nanocomposites were observed by SEM and EDX. The capacitive performance of the RuOx-PPy nanocomposites was evaluated as a function of the amount of RuOx. The maximum specific capacitance of the RuOx-PPy nanocomposite electrode was 419 mF cm−2/681 F g−1.