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Development of Novel Nanoparticulate Thin-Film Materials for the Fabrication of High Energy and Power Density Supercapacitor and Related Charge-Storage Devices.

Optimization of Electrochemical Properties of Nanoparticulate Manganese Oxide Thin Films.

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Abstract

Thin films of tetrapropylammonium manganese oxide (TPA-MO) were prepared on stainless steel foils by electrophoretic deposition (EPD) of preformed TPA-MO nanoparticles in stable colloidal suspensions. Nanocomposite thin films were prepared by the same EPD technique from colloidal mixtures of TPA-MO and graphite at predetermined molar ratios. Electrochemical characterization of these films were conducted with a 3-electrode configuration setup using cyclic voltammetry in 1M Na_2SO_4 aqueous electrolyte. Optimization of electrochemical properties was focused on enhancing the charge capacity, specific capacitance, cycling reversibility and stability of TPA-MO and TPA-MO/Graphite nanocomposite films through altering parameters such as sintering temperature, composition, relative film thickness and loading of active materials. Both optimized TPA-MO and nanocomposite thin films exhibited excellent capacitative behavior with their cyclic voltammograms almost perfectly rectangular in shape over the potential range of 0 to +1.0 V (vs SCE). Maximum charge capacities of 142 mF/cm^2 and 152 mF/cm^2 have been achieved for optimized TPA-MO and TPA-MO/Graphite (1%) nanocomposite thin films respectively. Optimized films also showed high cycling reversibility and stability as evidenced by the anodic/cathodic current ratios remained close to 1 and the net capacity loss of less than 30% upon cycling for 1,600 cycles. We envisage that further optimization could be achieved through optimization of microstructural parameters such as the porosity, specific surface area and pore size distribution of both the TPA-MO and nanocomposite thin films.

Keywords: Manganese oxide, charge capacity, specific capacitance, cycling reversibility and stability

Introduction

Electrochemical capacitors, referred to as ultracapacitors or supercapacitors, are energy storage devices that display high pulse-power capabilities (Innocenti and Yanko 1986; Sarangapani *et al.* 1990; Ashley 1995). This characteristic makes these devices attractive for several applications which require significant power output such as load-leveling devices for electric vehicles, where high power is needed for acceleration and climbing hills, or as back-up energy sources in electronic devices. Currently, most commercialized electrochemical capacitors are carbon-based systems that utilize activated carbon with a high specific surface area. While such systems are reliable, they are characterized by undesirably high internal resistances that arise from high contact resistance between the carbon particles. Consequently, the energy densities of these materials are generally quite low. Furthermore, the low density of activated carbon particles and