Doped Transition Metal oxide/CNT: New Heterostructures for Supercapacitor Applications

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INTRODUCTION

The rapid technological progress of the world in the 19th and 20th century could largely be attributed to the extensive use of electricity in the form of small devices such as light bulbs and extending to very large applications such as those in powering large mechanical units in industrial plants. In an increasingly mobile world however, a large number of mobile applications still rely heavily on mechanical and thermal energy generation and storage which are both inefficient and unclean. There is therefore, a pressing need for ‘mobile energy ‘and this makes it imperative for the development of charge storage devices capable of delivering energy in a manner suitable for mobile applications such as automobiles and electronic devices i.e. rapidly over an extended period of time with minimal loss over time(1, 2). The need to tailor energy storage devices to suit such applications is highlighted by the current targets established by the Department of Energy(3) for the same i.e. 7.5 Wh/kg at 625 W/kg lasting upto 15 years. It is this incessant demand that is the driving force fueling various current and emerging technologies including lithium ion batteries, supercapacitors and fuel cells. Supercapacitors hold a unique place among these energy storage devices on account of their high power density and long cyclability. Supercapacitors are electrochemical charge storage devices capable of delivering large bursts of charge over a very short period of time. It is due to this unique capability that supercapacitors occupy a very important role in the growing alternative energy field. High surface area carbons, hydrated ruthenium oxide (4-6) and MnO_2 are among the primary materials being considered for supercapacitor applications(7-10). Bulk oxide materials are limited due to their electrical conductivity for various electronic and electrochemical applications

We have previously demonstrated excellent charge storage behavior of thin film vanadium oxide-vertically aligned carbon nanotubes (VACNT) composite electrodes. However the overall capacitance of vanadium oxide based capacitors is limited on account of poor electronic conductivity of the oxide. Doping of oxides is a straightforward approach to increase the inherent electronic conductivity which would then be reflected in the increase in charge storage and rate capability. Thus, in this study, we report capacitor behavior of nanoscale doped vanadium oxide and doped oxide/carbon heterostructures. Tailoring the particle size, crystallinity and porosity are of paramount importance to achieve high capacitances at high scan rates. In order to gain a fundamental understanding into charge storage in doped oxide materials, we deposited films of a number of doped transition metal oxides on carbon nanotubes and used various materials and electrochemical characterization techniques including X-ray photo-electron spectroscopy (XPS), cyclic voltammetry and electrochemical impedance spectroscopy. Figure 1 shows the electrochemical results of these different configurations. Results of these studies will be presented and discussed.

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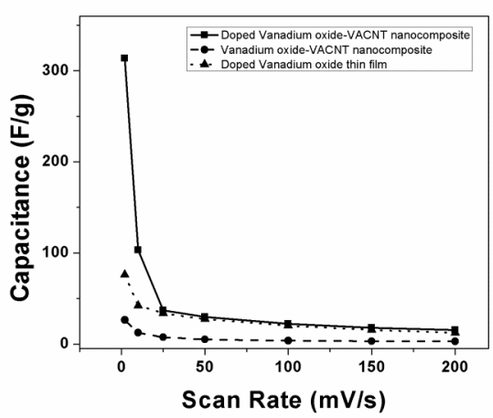

Figure 1: Effect of doping on capacitor behavior of oxide materials