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Facile synthesis of TNT-VO_2(M) nanocomposites for high performance supercapacitors

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ABSTRACT

In this work, we report the synthesis of titania nanotube (TNT) -VO_2(M) nanocomposites through a combined potentiostatic anodisation-hydrothermal procedure and its application in supercapacitors. Structural, morphological and chemical characterisations were done by XRD, FE-SEM and XPS analyses and electrochemical characterisations were done by CV, GCD and EIS. The TNT-VO_2(M) nanocomposites exhibited very high capacitive performance as compared to their individual components, due to the synergistic contribution from both. Altered morphologies for composites were obtained at varying hydrothermal temperatures under similar conditions. The TNT-VO_2(M) nanocomposite which is formed at 180 °C, TNT-V180 with VO_2(M) nanorings over TNT showed the best CV performance in three electrode configuration with specific capacitance values ~152.21 $mFcm^{-2}$ at scan rate 5 mVs^{-1} and confirmed by GCD and EIS. The open porous morphology with maximum available surface aided more charge accumulation at the electrode-electrolyte interface and better redox interaction with electrolyte ions resulting in its unique synergistic capacitive behaviour compared to others. The asymmetric supercapacitor fabricated with TNT-V180 as the negative electrode and active carbon (AC) as the positive electrode delivered a very high specific capacitance of 246.67 $mFcm^{-2}$ with an ultra-high energy density of 111 $\mu Whcm^{-2}$ at 180 μWcm^{-2} power density.

1. Introduction

Supercapacitors found widespread applications in electronics, vehicles and industrial power and energy management owing to its excellent power density, long life cycle, easiness in assembling and low maintenance cost [1–5]. Supercapacitors can be divided into electrical double layer capacitors (EDLCs) and pseudocapacitors based on their mechanism of charge storage [6]. Even if pseudocapacitive (faradaic) materials deliver much lower electrical power than that of EDLC (non-faradaic) materials, they hold great promise in improving the energy density. A hybrid capacitor is another class of devices that combine both EDLC and pseudocapacitor materials.

Transition-metal oxides (TMOs) with multiple oxidation states/structures are well established pseudocapacitive materials with very high theoretical specific capacitance as compared to that of conventional carbon based materials [7,8]. TMOs charge/discharge by one or both of the two faradaic mechanisms, i.e. cation adsorption/desorption and intercalation/de-intercalation coupled with reversible redox reactions of metal ions at or near the electrode/electrolyte interface. Among TMOs, best performance is reported for ruthenium oxide due to its highly reversible redox reactions, wide potential window, good thermal stability, metallic-type conductivity and long cycle life [9–11]. However, the application of RuO_2 based electrodes is limited owing to their high cost and low abundance. Hence studies are being directed to explore low-cost alternative to RuO_2 like MnO_2 [12–15], MoO_3 [16–19], Fe_2O_3 [20–23], CoO [24], NiO [25–27], etc. and their various composites [28–31] with appreciable theoretical capacitances. Vanadium oxides, VO_x are promising candidates for battery and super capacitor applications owing to their special lamellar structure, high specific capacity, variable oxidation states, flexibility, low cost, non-toxic chemical properties and easy procedure for synthesis [32–34]. The electronic structure, transport properties, oxidation state, charge density and phase transitions of different vanadium oxides are expected to vary with the composition. Among the various oxides of vanadium, V_2O_5 is quite extensively investigated for energy storage applications [35,36]. Vanadium oxide, VO_2, has been reported to show better performance compared to the well-known V_2O_5 due to its higher electronic conductivity, high charge storage capability and a wide potential window arising from a mixed-valence, the low band-gap, structural stability due to the increased edge sharing and the consequent resistance to lattice shearing during cycling. However there are few reports of VO_2 as a supercapacitor electrode

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