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Short communication

Electrochemical behavior of tin doped vanadium pentoxide thin films

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ABSTRACT

Tin doped vanadium pentoxide thin films have been prepared by sol -gel spin coating method on FTO and glass substrate. The structural and analytical studies such as XRD, cyclic voltammetry and ac impedance spectroscopy respectively have been carried over and the results are discussed. Structural properties studied using x-ray diffraction analysis reveals the amorphous nature of the vanadium pentoxide coated thin films. Cyclic voltammetry studies of the vanadium pentoxide coated FTO films were carried out in the potential range of 0.8 -1.2 V, using 1M lithium perchlorate in propylene carbonate as the electrolyte. The specific capacitance of tin doped vanadium pentoxide thin film has been measured from the CV curve and it was 236 F/g. The ac impedance spectra of the film electrode in 1M $LiClO_4$ + PC electrolyte were measured in a frequency range of 100 kHz to 0.01 Hz at a potential of 0.5 V with Ag/Agcl as reference electrode.

Keywords: V_2O_5; tin; FTO; thin film; elcetrode; XRD; CV; AC impedance.

INTRODUCTION

Batteries take a longer time to charge but can hold large amount of power (A.D.Pasquier et al,2003). Capacitors though charge easily, stores only a little amount of power (R.Kotz,et al,2000). Supercapacitor is an energy storage device that delivers high power density than batteries and high energy density than conventional capacitors (Z.Chen,et al,2009). Based on materials supercapacitors are classified as electrochemical double layer capacitor (EDLC) (using carbon materials) (A. Balducci et al,2015) and pseudocapacitors (using transition metal oxides) (F.Coustier et al,1999). Various transition metal oxides such as ruthenium oxide, nickel oxide, magnesium oxide, cobalt oxide, iron oxide and vanadium pentoxide have been tried as electrodes for supercapacitors (W.Dong et al 2000). Vanadium can exist in various valence states. Layered structure of the film enables easy intercalation of Li ions enhancing the pseudocapacitance behavior. Lao et al (Lao.Z.J.,Konstantinovet al 2006) reported the V2O5 powders to exhibit a specific capacitance of 262 F/g. This work reveals the results obtained on tin doped vanadium pentoxide thin films prepared via spin coating route.

Experimental Procedure

Appropriate amount of vanadium pentoxide powder (AR grade 99% purity) was dissolved in conc. HCl. The solution was heated and green powder was obtained. The powder is then cooled in a water bath overnight. The powder is then dissolved in 25 ml of 2-methoxy ethanol with the addition of 6 drops of conc. HCl. It is doped with 10 wt % of SnCl2 dissolved in a few drops of conc. HCl. This solution is stirred at 50º C for 30min. Finally the solution is aged for 5 hours. The sol-gel is then coated onto fluorine doped tin oxide (FTO) coated glass substrate by spin coating method at 2500 rpm for 25 s to get an uniformly coated 8 layered film. Each layer is dried at 300 ºC for 3min. Finally the coated films are annealed at 300º C for an hour in air. The X-ray diffraction (XRD) of the film was recorded using CuKα (λ=1.54Aº). The cyclic voltammograms and the impedance spectroscopy are recorded with electrochemical Workstation CHI660D. The Ag/Agcl served as the reference electrode while the platinum wire was used as the counter electrode and 1M of lithium perchlorate in propylene carbonate served as the electrolyte.

RESULT AND DISCUSSIONS

Structural Analysis

Fig .1shows the X-ray diffraction pattern of the tin doped vanadium pentoxide thin film. From the analysis it is observed that the films are amorphous in nature.

Electrochemical Analysis

The electrochemical studies of the Sn doped V2O5 film was carried out with a three electrode cell. The Sn doped V2O5 film was used as the working electrode with platinum wire as the counter electrode and Ag/Agcl as the reference electrode.1M of LiClo4 in propylene carbonate was used as the electrolyte. The

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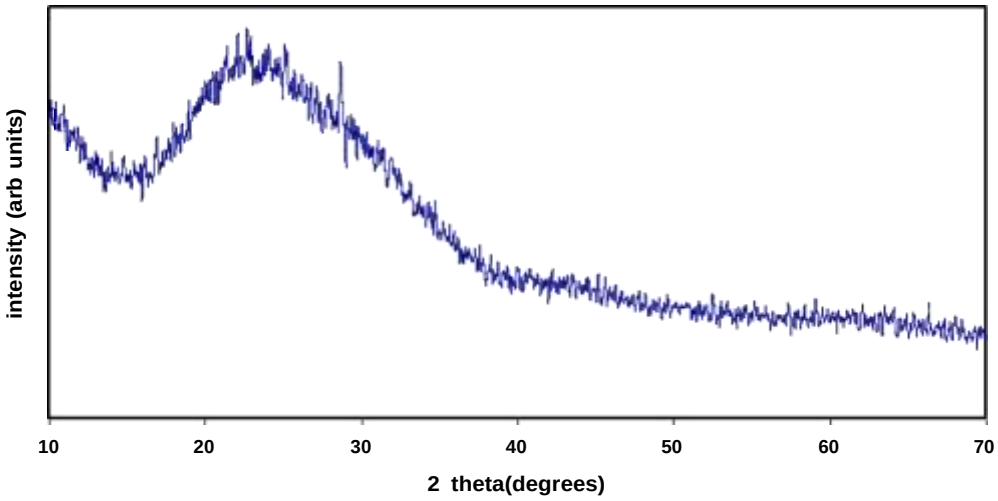

Figure 1: X-ray diffraction pattern of Sn doped V_2O_5 thin film

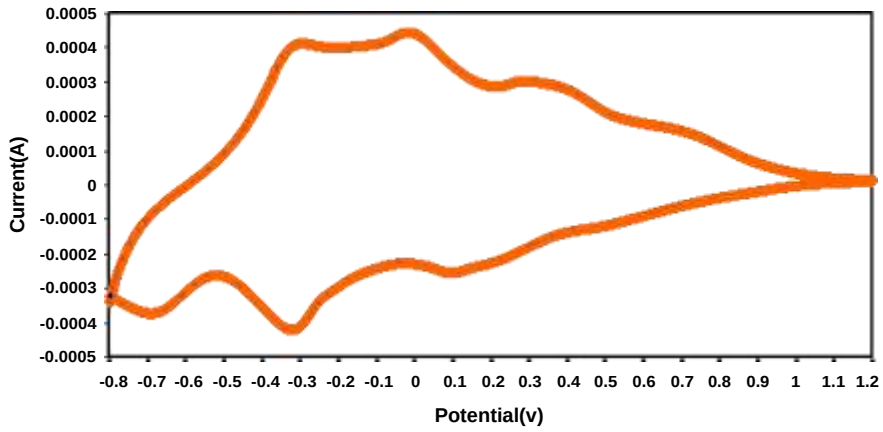

Figure 2: Cyclic Voltammogram of Sn doped V_2O_5 thin film

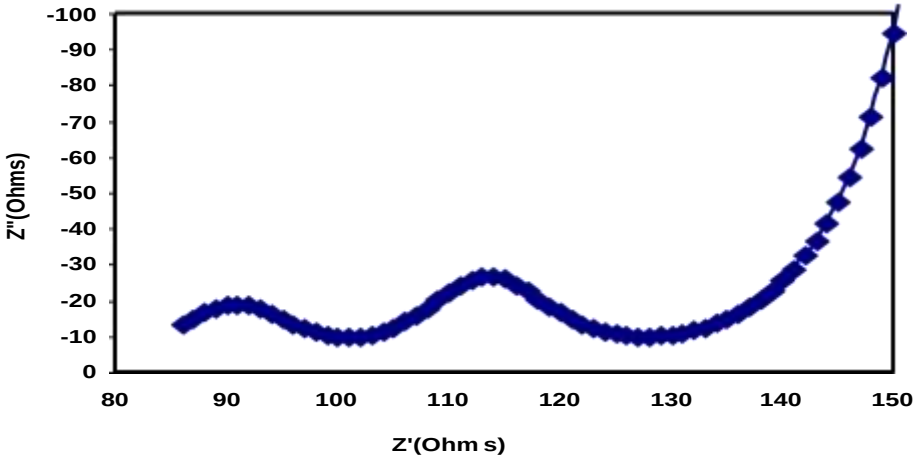

Figure 3: impedance spectra of the thin film electrode

potential window is -0.8 to 1.2 V and the scan rate is 50 mV/s.

The shape of the cyclic voltammogram shows the pseudocapacitance behaviour of the tin doped vanadium pentoxide thin films. From the cyclic voltammogram the specific capacitance of the film is calculated using

$$C = \frac{Q}{m\Delta V}$$

where C is the specific capacitance in (F/g), m is the mass of the active material in gms and ΔV is the scan rate in (mV/s)(J.Yan et al 2010). The specific capacitance of the Sn doped vanadium pentoxide film of thickness 202 nm is 236 F/g.

AC impedance

To understand the behaviour of the films and to obtain the charge transfer resistances of the films, ac impedance spectrum of the tin doped vanadium pentoxide

films was studied. Low resistance and high capacitance is preferable for energy storage devices (W.Chen et al 2002). In the electrochemical impedance spectra, at the high frequency region the intercept at the real axis is the combined resistance of the bulk electrolyte resistance, electrode resistance and the electrode/electrolyte interface resistance. The semicircle in the high frequency region corresponds to charge transfer resistance (R_{ct}). The semicircle in the high frequency region shows the resistance due to the discontinuity at the solid oxide- liquid electrolyte interface, arising from the difference between electronic and ionic conductivity respectively. The semicircle in the medium frequency region corresponds to Rct due to Faradic redox process involving the exchange of Li^+ ions (Sumanta Kumar Meher et al 2011).

The ac impedance spectra of the film electrode of the film in 1M $LiClO_4$ + PC electrolyte were measured in a frequency range of 100 kHz to 0.01 Hz at a potential of 0.5 V. The straight line corresponds to the diffusive resistance of the Li^+ ions within the film, exhibiting the capacitative behaviour as observed from the CV studies.

CONCLUSION

The amorphous Sn doped V_2O_5 film of thickness 202nm is found to exhibit a specific capacitance of 236 F/g enabling the film to find application as electrode in supercapacitor.

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