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Influence of reaction temperature on the Structure, Morphology and Optical properties of Cobalt doped Vanadium Oxide thin films

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Abstract

Cobalt doped vanadium oxide thin films were prepared by the simple sol gel method to investigate the basic properties with respect to the variation of reaction temperature with the help of various analysis like X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and UV-Vis Spectroscopy. The appearance of high intensity peaks in XRD results, it was the perfect evidence that the prepared thin films have high crystalline nature and the crystallite structures were identified as orthorhombic. In the SEM analysis, the flake-like morphology is identified when the reaction temperature is increased. From the Tauc plot, the optical bandgap were calculated and it was in the range of 2 and 2.2 eV. Thus, this range of bandgaps shows that the prepared thin films can be used in the various semiconductor applications.

Keywords: *Sol gel, Dip Coating, Thin film, Co doped V_2O_5, band gap.*

1 Introduction

In the recent decades, vanadium pentoxide has become considerably attractive and interesting, due to its enormous physical properties. V_2O_5 is used in various applications like electrochromic displays, solar cell, catalysis, gas sensors, optical devices and also color filters[1]. The interesting properties of V_2O_5 are strongly related to the vacancies which lead to the changes in the electronic structure to the crystal relations. Many factors like preparation methods, crystallinity and surface areas influence the functional properties of the non-structural thin films. In the last two decades, various techniques were used for the growth of thin films, which including pulsed laser deposition[2], ultrasonication method[3], atmospheric pressure chemical vapor deposition (APCVD)[4], sputtering[5,6], sol-gel process[7], thermal decomposition[8], chemical bath deposition[9] and SILAR[10] deposition are used in the thin films preparation[11]. In comparison with the above-mentioned methods, the sol-gel dip coating method was easily affordable, simple, low cost and as well as less complex. While comparing with other materials, vanadium pentoxide thin films are quite interesting due to the low cost, availability, easy synthesis, good electrical, optical properties and biocompatibility.

M. panagopoulou et.al., have prepared Mg doped V_2O_5 thin films by RF magnetron reactive sputtering onto glass substrates. While doping the Sn and Mg into V_2O_5 the cyclic stability has improved and the storage capacity of the lithium ion has enhanced when compared with the pure vanadium pentoxide thin films [12]. P. Justin et.al., have discussed about the preparing of carbon supported V_2O_5 by the solid state reaction under and IMH (Intimated Microwave Heating) method the Pt- V_2O_5/c catalyst have a higher catalytic activity and so it acted as an better poison resistance to the synergistic effect between V_2O_5 and Pt[13]. S.Y. Zham et.al., have discussed about the Cr doped V_2O_5, which was prepared by the sol-gel method. While the doping of chromium into the vanadium pentoxide, the electrochemical performance increases due to the lithium diffusion [14].

2 Experimental Sections

The cobalt doped vanadium pentoxide thin films were deposited by the sol-gel method. The 0.1M of vanadium pentoxide and 0.01 M of cobalt nitrate were dissolved with the 30ml of hydrogen peroxide and 30 ml of distilled water. The solution was continually stirred for 30 min. After that the solution was maintained at a constant temperature (50° C) to attain the sol with required viscous nature. Using the chromic acid, the glass plate to be used as substrate was cleaned well and rinsed with the Deionized water several times, finally the substrates were agitated with acetone. The cleaned glass plates were dried and dipped into the solution. Similar procedure was followed by varying the reaction temperature as 70° C to prepare different set of thin films.

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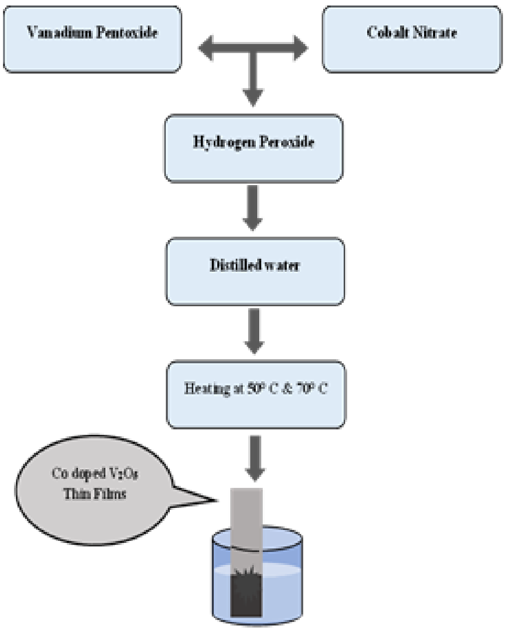

Fig. 1. Experimental procedure

3. Results and Discussion

3.1 Structural analysis

Fig 2a) shows the XRD patterns of the Co doped V_2O_5 thin films for the various reaction temperatures.

Both the XRD patterns reveal that the prepared thin films have good crystallinity. From the XRD patterns, the thin film deposited with the solution prepared at 70° C shows higher peak intensity when was compared to those prepared with solution at 50° C. The peaks were indexed and well matched with the JCPDS CARD No. 74-1486. Crystallites structures confirm the formation of Co doped V_2O_5 with an orthorhombic structure and the lattice parameters were a=8.3, b=11.0 & c=6.03 Å. These XRD results reveal that the crystallite size increases when the reaction temperature is increased.

Using Debye's Scherrer's formula given below, the crystallite size was calculated for the prepared thin films.

$$D = k\lambda/\beta \cos\theta$$

The crystallite size of the prepared thin films was found to be around 26 nm and 42 nm for the reaction temperature 50° C & 70° C.

Thus, crystallite size increases and degree of crystallinity also increases in the film which was prepared at 70° C but the microstrain decreases as can be witnessed in the fig 2.b). The microstrain value is found to be 0.19 and 0.06 for samples deposited at 50° C and 70° C respectively. Meanwhile, the dislocation density is calculated as 2.7×10^{14} lines/m and 14.79×10^{14} lines/m for the thin films prepared with at the reaction temperatures 50° C and 70° C respectively.

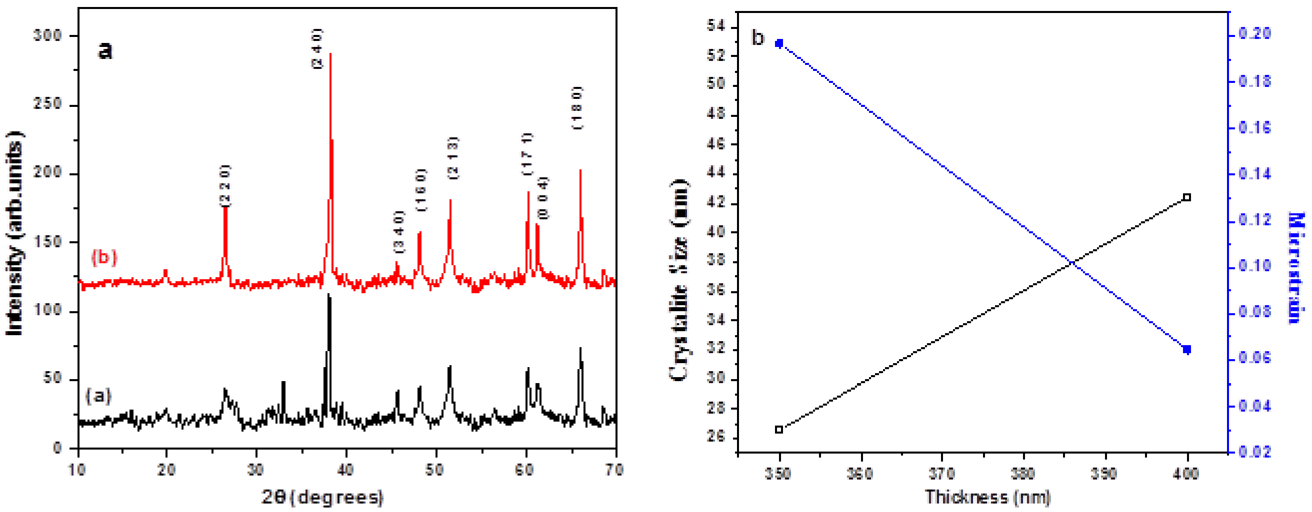

Fig. 2a) XRD pattern of Co doped V_2O_5 thin films prepared by the reaction temperature 50°C and 70°C b) Film thickness Vs Crystallite size and microstrain

3.2 Morphological analysis

The surface morphology was analyzed using SEM (Scanning Electron Microscopy) for the prepared thin films. Fig. 3 shows the surface morphology of the thin films by varying the reaction temperature (50 & 70°C). The thin film prepared at the reaction temperature 50 °C (Fig 3.a) shows a very good uniform surface when it is compared to the film which was prepared at the reaction temperature 70 °C (Fig 3.b). While measuring the thickness, it reveals a thickness around 350 nm for the film which was prepared at the reaction temperature 50 °C and 420 nm for the thin film which was deposited at 70 °C. The thin film prepared at 70 °C shows some flake like morphology and that increases the roughness of the surface. The results reveal that the roughness of the surface increases as the reaction temperature increases.

3.3 Optical analysis

Fig 4a shows the UV-Vis transmission spectra which correspond to the thin films prepared at 50° C and 70°C. When the reaction temperature is increased, the transparency of the prepared thin films decreased. The thin films deposited from the solution prepared at 50°C shows transmittance percentage of 76 % while those deposited from the sol heated at 70°C shows a maximum transmittance of 68% only[15,16]. From the tauc plot, an optical bandgap was calculated so that we can conclude whether the prepared film is a semiconductor or insulator through the bandgap value. Fig 4.b shows the tauc plots. The optical bandgap energies for the film prepared at 50° C was 2.19 eV while it was 2.06 eV for the film which was prepared at 70° C respectively[17,18].

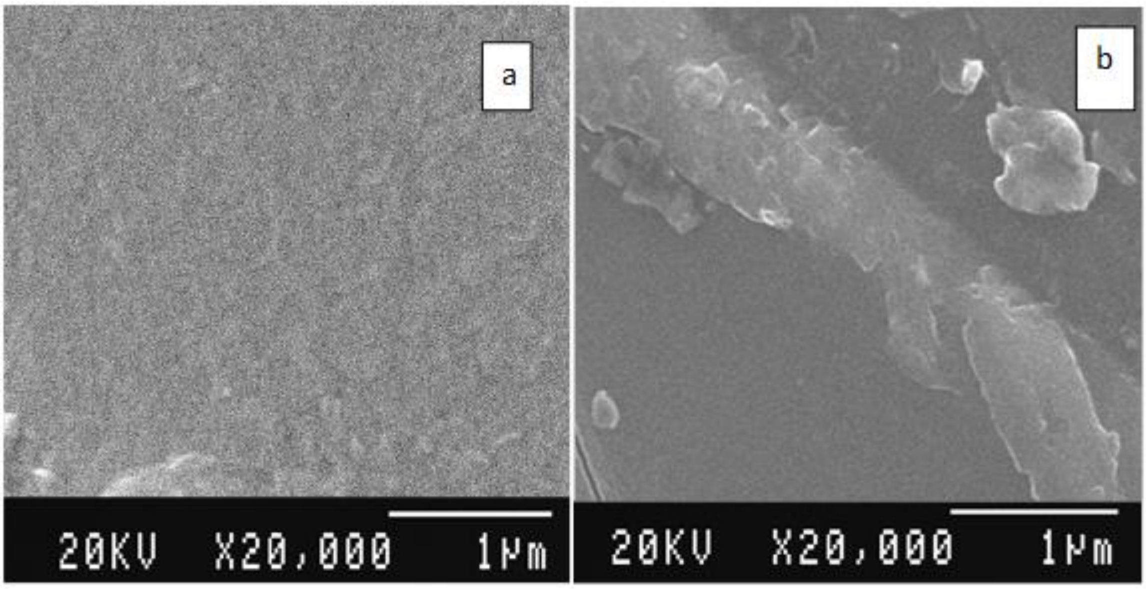

Fig 3. SEM image of V_2O_5 thin films prepared by the reaction temperature 50°C and 70°C

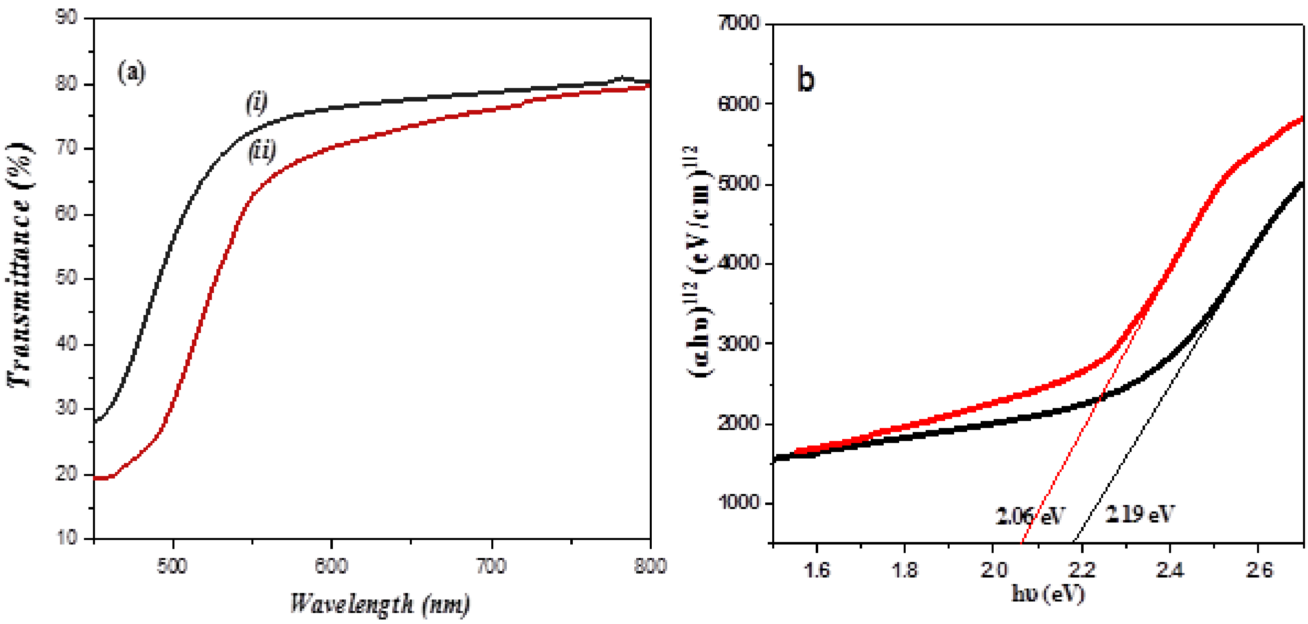

Fig. 4(a) Optical transmittance spectrum of Co doped V_2O_5 thin films prepared by reaction temperature i) 50°C and ii) 70°C (b) Tauc plot.

4. Conclusion

Cobalt doped vanadium pentoxide thin films were successfully deposited on the glass Substrates by the simple sol gel dip coating method and their properties were investigated by varying the reaction temperature. The prepared thin films show a very good crystalline nature and the crystallite structure was identified as orthorhombic from the XRD. The thin film surfaces were investigated using SEM analysis that revealed the increase in surface roughness as the reaction temperature is increased. The optical bandgap of the material seem to decrease when the reaction temperature increases. The bandgap values were in the semiconductor range, this suggests that the prepared CO doped V_2O_5 thin films can be used in the optoelectronic applications.

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