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Characterization of nanocrystalline CdS thin films deposited on FTO by CBD for photosensor applications

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ABSTRACT

Nanocrystalline cadmium sulphide (CdS) thin films were deposited on FTO coated glass substrate by simple and low cost chemical bath deposition (CBD) technique, and the structural, optical and photosensing properties were investigated. X-ray diffraction (XRD) technique has been used to identify the phases present in the deposited films and XRD studies confirmed the nanocrystalline mixed (hexagonal and cubic) CdS phase formation. The lattice parameters are calculated as a = 4.157 Å and c = 6.58 Å, which are in good agreement with the standard data. The surface morphology of the deposited films has been characterized using field emission scanning electron microscopy (FE-SEM) and observed that homogeneous and uniform CdS film is grown onto FTO coated glass substrate. The optical bandgap of the films has been studied using absorption spectra in wavelength range 400-900 nm by using double beam spectrophotometer and is estimated to be 2.15 eV. The I-V characteristics showed good photoresponse, and CdS thin films deposited on FTO coated glass substrate is useful for photosensor applications.

Keywords: Nanocrystalline thin film, X-ray diffraction, optical properties and photosensing properties.

INTRODUCTION

Metal chalcogenide materials in thin film form received considerable attention during the recent years because of their actual and potential applications in variety of optoelectronic devices. Among all of the chalcogenide materials, cadmium sulphide (CdS) thin films are considered as a promising semiconductor material for the development of many interesting applications such as photoconductor, photocatalysts and recently in solar cell, electrochemical cell, gas sensor, and photosensor etc. [1]. This is because CdS thin films have high transparency, wide and direct bandgap transition (2.42 eV), high electron affinity and n-type conductivity [2]. Different methods have been used to prepare CdS thin films which include chemical bath deposition (CBD), successive ionic layer adsorption and reaction (SILAR), sputtering, vacuum evaporation, spray pyrolysis, electrodeposition and pulsed laser deposition etc. [3-11]. Among all these methods, CBD method has been successfully utilized for the preparation of thin films of many metal sulphides, selenides, tellurides and oxides. Because CBD method is one of the chemical methods used for making uniform and large area thin films, which is based on immersion of the substrate into the solution containing precursors' of cations and anions. The interesting advantages and details of theoretical aspects of this method are greatly described in the review by Mane and Lokhande [12]. The aim of the present work is to prepare CdS thin film by chemical bath deposition technique onto FTO coated glass substrate. The structural, morphological, optical, electrical and photosensing properties of as-grown thin films are studied and results obtained are reported.

MATERIALS AND METHODS

Thin films of cadmium sulphide (CdS) have been grown by chemical bath deposition technique using cadmium chloride, thiourea and ammonia (AR grade). The CdS thin films were deposited on FTO coated glass substrate. For the deposition of CdS thin films; we used 10 ml of 0.05M cadmium chloride ($CdCl_2.2H_2O$) solution into 50ml glass beaker. This solution was stirred well, and then about 3.5ml of 30% aqueous ammonia (aq. NH_3) was mixed, followed addition of another 10ml of 0.05M thiourea ($CS(NH_2)_2$) solution. The mixture was stirred for a few seconds by a magnetic stirrer and then transferred to another beaker containing cleaned FTO coated glass substrates, clamped vertically into it. After few minutes later, the substrates were found to be covered with yellow deposits. The bath was covered to help to stabilize the temperature and reduce the loss of ammonia. After deposition, the substrate was taken out from the bath, washed with de-ionized water and was dried in air.

The surface morphology, chemical composition and crystalline properties of the films were analyzed by field emission scanning electron microscopy (FE-SEM) and energy dispersive X-ray spectroscopy (EDS) using S-48500 type-II (Hitachi High Technology Corporation Tokyo, Japan), and X-ray diffraction (XRD) using Bruker AXS, Germany (D8 Advanced), respectively. The optical properties of the films were determined by JASCO V-630 UV-VIS spectrophotometer. The photosensitivity property of CdS deposited on FTO coated glass substrate was studied by I–V characteristics in dark and under illumination (visible spectra) with different intensities using Keithley meter (Model no. 2400) over the range ±0.5 V.

RESULTS AND DISCUSSION

1.1 Structural studies:

The crystalline size and crystal structure of the CdS nanocrystalline thin films were determined from X-ray diffraction pattern. CdS known to exist in either cubic or hexagonal structure or sometimes a mixture of both phases [3, 13, 14]. Fig. 1 shows X-ray diffraction pattern of CdS thin film deposited on FTO coated glass substrate. The XRD peaks indicate that the film is nanocrystalline in nature. The peaks at $2\theta=34.29^o$, 38.32^o and 62.15^o corresponds to SnO_2 because of the substrate (FTO) used. Other diffraction peaks in this XRD pattern was observed when $2\theta=27.05^o$, 52^o, 66^o and 78.88^o corresponding to the (0 0 2), (1 1 2), (2 0 3) and (2 0 4) reflections of the cadmium sulphide possessing hexagonal crystal structure, with lattice parameters of a = 4.157 Å and c = 6.580 Å which agrees with standard pattern (JCPDS card no. 41-1049). While some minor peaks have been observed at $2\theta = 29.84^o$ and 44.80^o corresponding to (2 0 0) and (2 2 0) reflections of cubic CdS (JCPDS card no. 80-0019). Thus from XRD studies, it is clear that CdS is a mixture of cubic and hexagonal phases, which agrees with the earlier report for CdS thin film [4].

The average crystallite size (D) was estimated using Scherrer formula [15];

$$D = \frac{k\lambda}{\beta \cos\theta} \quad (1)$$

Where K is the shape factor that was taken equal to 0.9, λ is the wavelength of X-ray source, β is the full width at half maximum (FWHM) of (1 1 2) and (2 0 3) peaks corresponding to hexagonal phase of CdS and θ is the Bragg's diffraction angle in degrees. The average crystallite size is found to be 34.76 nm.

1.2 Surface morphology and compositional studies:

Fig. 2 shows FE-SEM image of as-deposited cadmium sulphide thin films on FTO coated glass substrate. It shows that the substrate is well covered with the deposited material without cracks and pinholes. The field emission scanning electron microscopy (FE-SEM) study for CdS films on the FTO coated glass substrate reveals that the film formed is uniform and homogenous. The elemental analysis of CdS thin films deposited on FTO coated glass substrate was performed using EDS analysis and presented in fig.3. The analysis confirms the presence of Cd and S in the deposited film with Cd=59.87% and S=40.13%. It confirms that the film has been Cd rich. However, in addition to Cd and S, there are other peaks corresponding to Sn, O, F, etc. and can be attributed to those originating from FTO coated glass substrate.

1.3 Optical studies:

In order to obtain the information regarding the optical bandgap and the nature of transition involved, the optical properties of the CdS nanocrystalline thin films were studied using the UV-VIS spectrophotometer at room temperature. Fig. 4 shows the optical absorption spectra of CdS thin films in the wavelength range of 400-900nm. The theory of optical absorption gives the relation between the absorption coefficient α and the photon energy hυ, for direct allowed transition as,

$$\alpha = \frac{A\left(h\nu - E_g\right)^2}{h\nu} \quad (2)$$

where hυ is the photon energy, E_g is the optical bandgap, A is a constant.

In inset of fig. 4 shows a plot of $(\alpha h\upsilon)^2$ versus hυ which is linear at the absorption edge, confirming the direct bandgap material. The linear fit of the plot indicate the existence of the allowed direct bandgap transition. Extrapolation of the linear portion of the curve to $(\alpha h\upsilon)^2 = 0$ determines the optical bandgap E_g. The optical bandgap energy was found to be 2.15 eV, which is smaller than the value reported earlier [3] for chemical bath deposited CdS thin film which might be due to greater crystallite size of CdS and due to substrate used.

1.4 Electrical studies:

Fig. 5 shows I-V characteristics curve obtained from the as deposited CdS thin film for different illumination intensities. CdS thin film deposited on FTO coated glass substrate of area $1cm^2$ was selected and silver paste was applied (two Ag contacts separated by a distance of 1cm) to ensure the good neutral electrical contacts to the films. From I-V plot, decrease in resistivity was found with increase in illumination intensity. This suggests that the incident photon energy breaks some of the covalent bonds in the CdS semiconductor and as a result free electron-hole pairs are available for current conduction. The dark resistance is found to be 1.42×10^2 Ω.cm and it decreases to 0.88×10^2 Ω.cm (calculated from fig. 5) for light of intensity 10,100 Lux in the visible region. Smaller value of dark resistivity might be due to the conducting substrate used for the deposition of CdS thin film. This study shows that the CdS thin film deposited on FTO coated glass substrate is highly photosensitive and can be used in photosensor and /or optoelectronic devices.

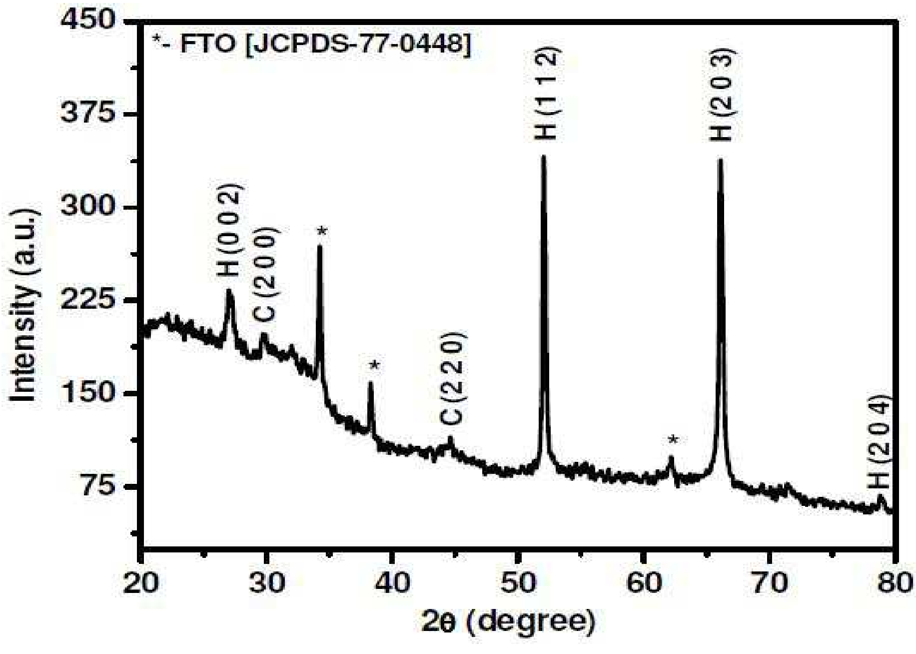

Fig. 1 X-ray diffraction (XRD) pattern of CdS thin film deposited on FTO coated glass substrate

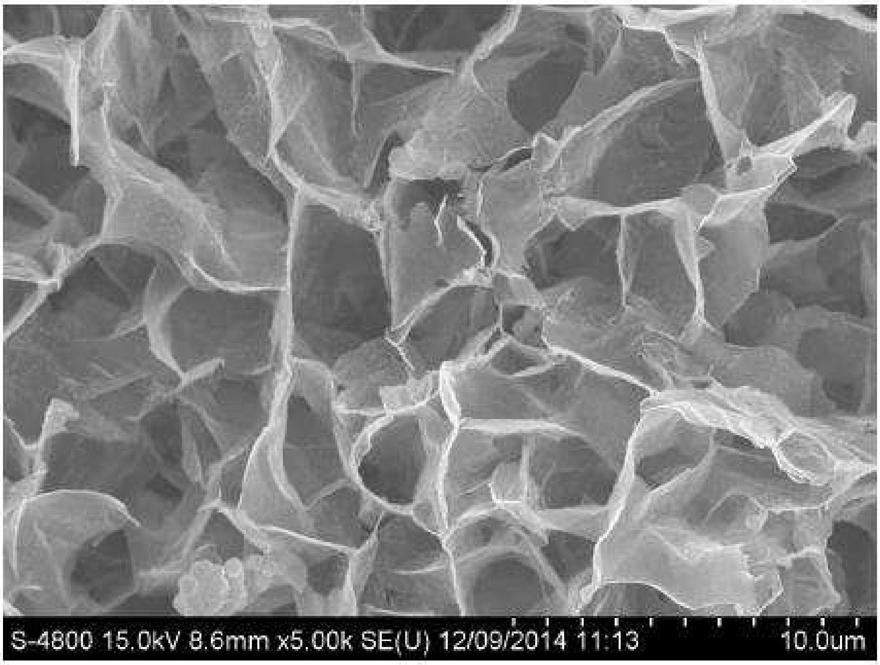

Fig. 2 FE-SEM image of CdS thin film deposited on FTO coated glass substrate

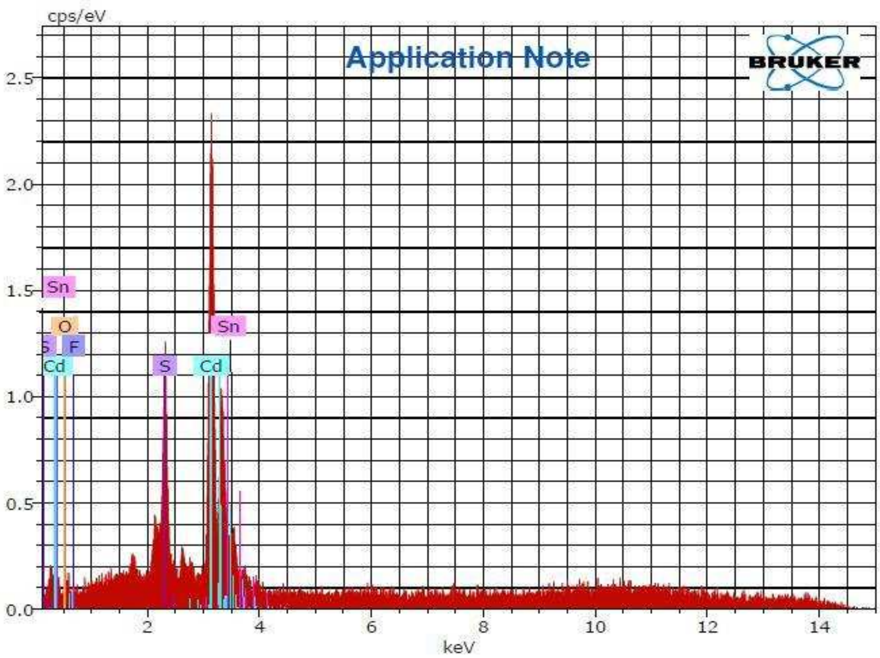

Fig. 3 Typical EDS pattern of CdS thin films deposited on FTO coated glass substrate

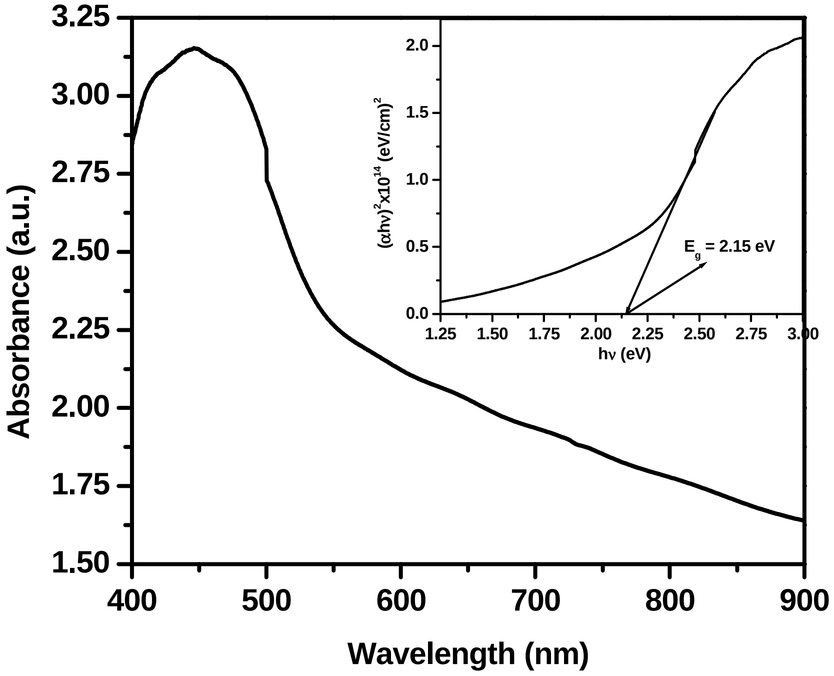

Fig. 4 Absorbance with respect to wavelength for CdS thin films deposited on FTO coated glass substrate

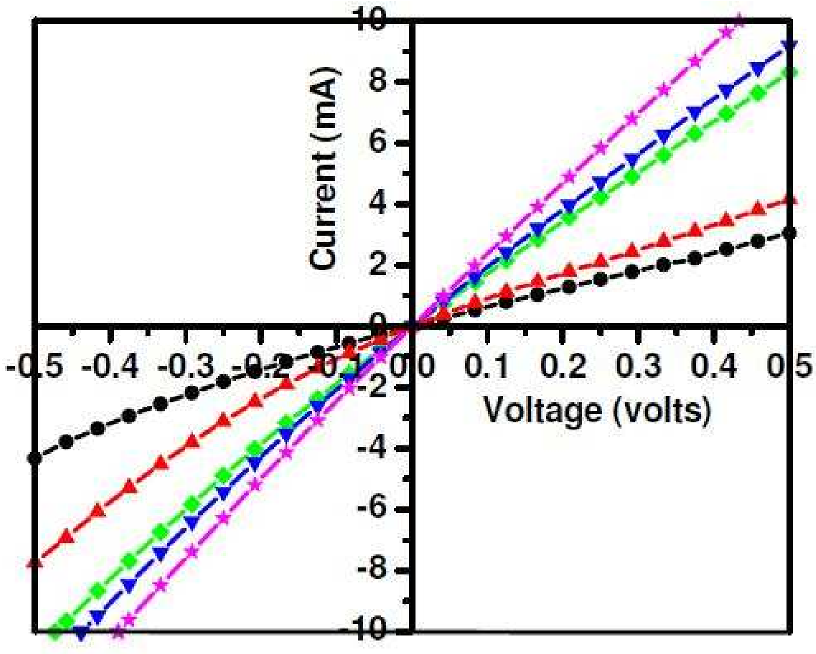

Fig. 5 Current–voltage (I–V) characteristics curve obtained from CdS thin films deposited on FTO coated glass substrate with different illumination intensities

CONCLUSION

CdS thin film was deposited onto FTO coated glass substrate by using CBD technique. The salient conclusions arising from this study are summarized below:

1. XRD studies reveal nanocrystalline nature of the films with mixed (cubic and hexagonal) crystal structures.
2. The CdS thin films deposited on FTO/glass substrate present excellent adherence, uniform deposition, homogeneous morphology and nanocrystalline properties, confirmed by FE-SEM and XRD analysis.
3. EDS analysis showed that Cd rich CdS thin film has been deposited on FTO/glass substrate.
4. Optical absorption study revealed direct bandgap nature and bandgap is found to be of the order of 2.15 eV.
5. Electrical studies showed that the films are semiconducting and can be used in photosensor and /or optoelectronic devices.

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REFERENCES

[1]Singh V, Chauhan P, *Journal of Physics and Chemistry of Solids*, **2009**, 70, 1074.
[2]Rmili A, Ouachtari F, Bouaoud A, Louardi A, Chtouki T, Elidrissi B, Erguig H, *Journal of Alloys and Compounds*, **2013**, 557, 53.
[3]Liu QQ, Shi JH, Li ZQ, Zhang DW, Li XD, Sun Z, Zhang LY, Huang SM, *Physica B.*, **2010**, 405, 4360.
[4]Barote MA,Yadav AA, Masumdar EU, *Physica B.*, **2011**, 406, 1865.
[5]Lokhande CD, Sankapal BR, Pathan HM, Muller M, Giersig M, Tributsch H, *Applied Surface Science*, **2001**, 181, 277.
[6]Salata OV, Dobson PJ, Hull PJ, Hutchinson JL, *Thin Solid Films*, **1994**, 251, 1.
[7]Pathinettam Padiyan D, Marikani A, Murali KR, *Phys. B: Condens. Matter*, **2005**, 357, 485.
[8]Ikhmayies SJ, Ahmad-Bitar RN, *Phys. B: Condens. Matter*, **2009**, 404, 2419.
[9]Yadav AA, Barote MA, Masumdar EU, *Solid State Sci*., **2010**, 12, 5.
[10]Yadav AA, Barote MA, Dongre PM, Masumdar EU, *J. Alloys Compd*., **2010**, 493, 179.
[11]Ullrich B, Sakai H, Segawa Y, *Thin Solid Films*, **2001**, 385, 220.
[12]Mane RS, Lokhande CD, *Materials Chemistry and Physics*, **2000**, 65, 1.
[13]Ravichandran K, Philominathan P, *Applied Surface Science*, **2009**, 255, 5736.
[14]Soundeswaran S, Senthil Kumar O, Dhanasekaran R, *Materials Letters*, **2004**, 58, 2381.
[15]B. Cullity, Elements of X-ray Diffraction, Addison-Wesley Company Inc., London, **1978**, 99 pp.