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Synthesis and Characterization of Transparent Cadmium Sulphide (CdS) Thin Films By Chemical Bath Deposition Technique

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ABSTRACT

In the present manuscript we report the synthesis and characterization of transparent CdS thin films on glass and conducting (FTO) substrate by chemical bath deposition technique.As prepared samples were further characterized by X-ray diffraction (XRD), Scanning electron microscopy (SEM) and UV-VIS spectroscopy for the investigation of structural and optical properties of CdS respectively. XRD pattern recorded for the as prepared sample reveals the nanocrystalline cubic structure of CdS. From the SEM images it observed that the sample exhibits nanocrytalline CdS platelets like morphology. At low magnification structure seems like cabbage. For the study of optical properties of CdS absorption and transmission spectra were recorded. UV-VIS absorption spectra clearly gives the information that the absorption initiates at 524 nm and therefore band gap of CdS sample is ~ 2.36 eV. Similarly, from the UV-VIS transmission spectra, it is observed that transmittance of CdS thin film is approximately 99% above 400 nm.

Keywords: Nanocrystalline, X-ray diffraction, CBD technique, Platelets, Absorption spectra, Transmittance.

INTRODUCTION

Band gap is the fundamental property of semiconductor. Energy separation between the filled valence band and empty conduction band is called as band gap. The band gap of semiconductor increases with decrease in the particle size which is known as the quantum size effect. Currently size quantization effects of nanocrystalline semiconductors have vast attention towards metal-chalcogenide based systems in solar cell. CdX and PbX (X = S, Se, and Te) nanocrystalline thin films having relatively small band gaps and thus capable of harvesting photons in the visible and infrared region, are of great interest. The semiconductors have promising applications in biology, optics, and electronics and transport [1-4]. To synthesize nanocrystalline thin films with various particle size and shape several attempts have beenmade. CdS is a semiconductor with a direct band gap of 2.42 eV. It has interesting optical properties and applications in the field of light emitting diodes, solar cells, optoelectronics devices, photo catalyst, X-ray detectors, solar energy storing and in display devices [5-11]. It is used as a buffer layer in the formation of solar cell devices based on CIS, $CuInSe_2$, $CuInGaSe_2$, CdTe [12-14]. Now adays, CdS nanoparticles are used in Semiconductor Sensitized Solar Cells (SSSCs) to improve the performance of wide band gap semiconductor materials [15-18]. In SSSCs, CdS nanoparticle forms a thin layer on wide band gap semiconductors like ZnO, TiO_2 having nanostructured morphologies like nanorodes, nanotubes, etc. Chemical, physical and electrochemical methods are used for preparation of CdS thin films. They are such as vacuum evaporation [19], sputtering [20], spray pyrolysis [21], chemical bath deposition [22], electro-deposition [23], successive ionic layer adsorption and reaction method (SILAR) [24], screen printing [25]. Chemical bath deposition (CBD) is simple and economic. With the help of CBD method the thickness and transparency of thin film can be controlled easily.

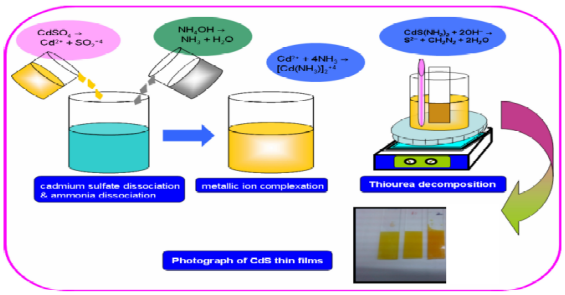
In the present study, we describe the synthesis and characterization of nanocrystalline CdS thin films via CBD technique. The films deposited at various time intervals at low temperature (~60^{O}C) using low precursor concentration. The prepared thin films are further investigated for their structural, surface morphological and optical properties.

METHODOLOGY

All chemical was purchased from s. d. fine-chemicals and used without any further purification. The cadmium sulfate ($CdSO_4 \cdot H_2O$) and thiourea ($H_2N \times CS \times NH_2$) were used as cadmium (Cd) and sulphur (S) precursors. Ammonia (NH_3) was used as complexing agent. For the deposition of nanostructured CdS thin film.

Cadmium sulfide films were prepared from cadmium sulphate and thiourea by CBD in alkaline solution. The typical procedure for the film growth is described as follows, drop by drop 25% NH_4OH solution is added into 500 ml beaker containing 150 ml of 1 mM $CdSO_4$ solution until the initially formed white precipitate is completely dissolved. The clean substrates are mounted vertically in the bath using Teflon holder, in such a way that the substrates are separated by 2 cm distance from each other & the wall of bath. Then 150 ml of 1mM thiourea [CS $(NH_2)_2$] is added in the bath solution. The temperature is gradually increased to 60^{O}C under magnetic stirring for all samples. The films removed from the bath after 20 min were highly transparent and uniform with well adhesion to the glass substrate and therefore used for further characterization. The deposited CdS films were rinsed with double distilled water and alcohol and allowed to dry at room temperature, in ambient air. Thicknesses of the thin films of the samples were found to in the range 549 to 1389 Å. Fig 1. show the schematic of CBD method for the preparation of CdS thin films.Thicknesses of the thin films of the samples were found to in the range 549 to 1389 Å.

Figure 1. Schematic of Chemical Bath Deposition



$$CdSO_4 + NH_4OH \leftrightarrow Cd(OH)_2 + (NH_4)_2SO_4$$
$$Cd(OH)_2 + 4NH_4OH \leftrightarrow Cd(NH_3)_4^{2+} + 2OH^- + 4H_2O$$
$$H_2N - C - H_2N - C = H_2N - C = NH$$
$$H_2N - C - H_2N + OH^- \leftrightarrow H_2N - C = NH + SH^-$$
$$Cd(NH_3)_4^{2+} + SH^- = CdS\downarrow + NH_4^+ + 3NH_3$$

RESULTS AND DISCUSSION

- **X-ray diffraction studies:-**

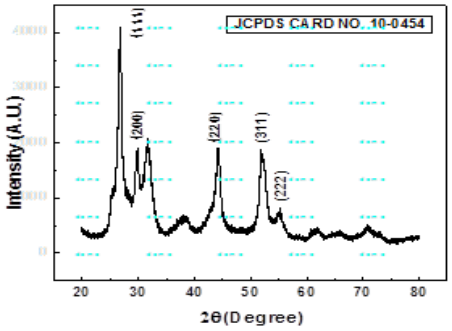


Figure 2. XRD spectra of Cadmium Sulphide (CdS) thin film prepared on glass substrate and

Figure 2 above shows XRD spectra recorded for CdS sample on glass substrate. From this XRD pattern it is observed that the diffraction peaks belonging to planes (111), (200), (220), (311) and (222) were observed at angles 26.76, 29.78, 44.14, 51.88 and 55.10 degrees and are well matching with the cubic phase (with the JCPDS card no.10-0454). From XRD pattern the crystalline nature of the synthesised sample is confirmed. The particle size of the prepared sample was calculated using equation Debay Scherrer's equation given below

$$D = \frac{0.9\lambda}{\beta COS\theta}$$

Where D is the size of nanostructure, β is the broadening of diffraction line measured at half of its maximum intensity (FWHM) and λ is the wavelength of X-ray (1.5406 Å). The calculated particle size of nanostructure is 16 nm.

Scanning electron microscopy (SEM):-

Figure (a) and (b) shows scanning electron micrographs of CdS thin films prepared by CBD method. From figure it is clearly observed that the sample exhibits nanocrystalline CdS platelets like morphology. At low magnification structure seems like cabbage. The density of these platelets is uniform throughout the sample. The platelets' are having size of 1µm and thickness 10-15 nm. The films are having throughout uniform structure and no cracks are observed in the film.

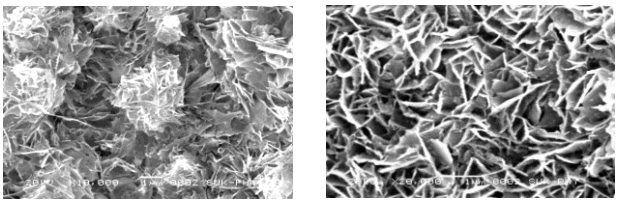


Figure 3. (a) and (b) Scanning Electron Microscopy (SEM) micrograph of Cadmium Sulphide (CdS) thin films prepared on glass by CBD method

UV-VIS Spectroscopy studies:

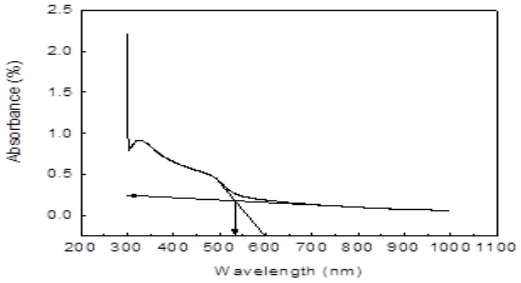


Figure 4. (a) UV-VIS absorption spectra

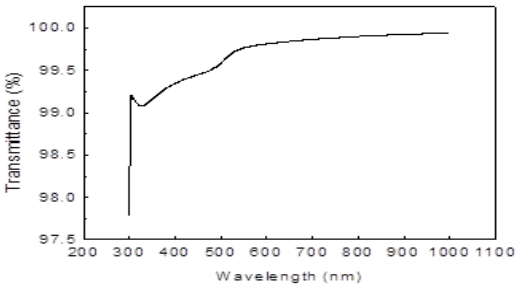


Figure 4.(b) UV-VIS transmission spectra of Cadmium Sulphide (CdS) thin films prepared on glass by CBD method

Above Figure3 (a) and 3 (b) shows absorption and transmission spectra recorded for CdS thin films in the wavelength range 300 nm and 1000 nm. From figure (a) it is clearly observed that the absorption initiates at 524 nm. and therefore, band gap of CdS sample is ~ 2.36 eV. From figure (b) it is clearly observed that the transmittance of CdS film deposited by CBD method is approximately 99% above 400 nm.

CONCLUSIONS

Transparent CdS thin films were successfully deposited on glass substrate by chemical bath deposition technique. XRD pattern recorded for the as prepared sample confirms the nanocrystalline cubic structure of CdS. From the SEM images it observed that the sample exhibits nanocrystalline CdS platelets like morphology. At low magnification structure seems like cabbage. For UV-VIS absorption spectra clearly gives the information that the absorption initiates at 524 nm and therefore band gap of CdS sample is ~ 2.36 eV. Similarly, from the UV-VIS transmission spectra, it is observed that transmittance of CdS thin film is approximately 99% above 400 nm.

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