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Research Paper

INFLUENCE OF GROWTH PROCESS ON THE PROPERTIES OF CHEMICALLY PREPARED CADMIUM SULPHIDE THIN FILMS

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ABSTRACT

Wide band gap II-VI group semiconductors has been widely studied due to their fundamental structural, optical and electrical properties. Cadmium sulphide (CdS) has emerged as an important material due to its applications in photovoltaic cell as window layers, multilayer light emitting diodes, optical filters, thin film field effect transistors, transparent conducting semiconductor for Optoelectronic devices, gas sensors, a buffer layer is widely used as an n-type hetero-junction partner in all chalcopyrite based thin film solar cell, light detectors, etc. It is an n-type material with an optical band gap of 2.4eV. CdS thin films were deposited by dip coating method on glass substrates. The influence of the growth process on the structural, optical and electrical properties of polycrystalline CdS thin films were characterized by X-Ray diffraction technique (XRD), Scanning Electron Microscope (SEM), Atomic Force Microscope (AFM), Ultraviolet – Visible spectroscopy and Hot probe method.

1. INTRODUCTION

For the last few decades it has been seen that extensive research on deposition and characterization of Cadmium sulphide (CdS) is done due to their potential application in the area of Optoelectronic device [1-16]. Its size and shape plays important role here, which are key factors determining their optical and electrical properties and overall functionality [5]. CdS has two types of crystal structures, Cubic zinc blend and hexagonal wurtzite.

Thin film solar-cells are attractive devices for conversion of electrical energy due to their consistently increasing conversion efficiency, lower production cost with development of new photovoltaic materials, uses natural solar energy [4]. There are various methods to grow thin film of certain materials on a substrate, various applications require different film grades, an introduction of continuous dip processed films thus expands our options [2]. An intelligent choice of CdS thin film material for a given application should be based on the knowledge of composition, structure and photoconductivity among other properties of the material [2]. At present there are hardly any data on multiple dip coated CdS films [2]. Thus dip coating method was selected to prepare CdS thin film.

A large number of studies have been carried out to obtain high quality CdS thin films by optimizing the parameters such as temperature, deposition time, concentrations of various reagents using different methods, including spray pyrolysis [6,12], Chemical Bath Deposition (CBD) [3,4,7-10,13-16], thermal evaporation [11], sol-gel deposition [12], screen printed [16] and dip coating [1,2]. However here dip coating technique for preparing CdS thin films is utilized. The influence of the growth process on the structural and optical properties of the thin films has been investigated.

2. EXPERIMENTAL DETAILS

CdS thin films have been grown using the dip coating method. Prior to the deposition of CdS, glass substrate was cleaned with Methanol, Acetone, Trichloroethylene and deionized (DI) water. The precursor solution for the dip-casting was prepared by dissolving Cadmium Acetate Dihydrate and Thiourea in methanol. The glass substrate was dipped into this solution and then kept at 473°K for 5 minutes to promote thermolysis. In heat treatment process, the metal salt and thiourea decomposes and gives raise to formation of CdS phase on the substrate. This process was repeated five times. The sample was prepared with this method by keeping S/Cd molar ratio equal to 0.7, indicating film is S-deficient & Cd-rich. This film was characterized using X-Ray diffraction technique (XRD), scanning electron microscopy, Atomic force microscopy and Optical Spectroscopy. The crystalline structure of the films was analysed using a D2 PHASER – The Second Generation Bench top X-Ray Diffractometer using CuKα radiation *lambda=1.54056 angstroms.* The surface topography and composition was studied using JSM-6010LA high performance SEM. PerkinElmer UV-VIS double beam spectrophotometer

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(LAMBDA-35) was used. Hot probe measurement showed n-type conductivity of Cadmium Sulphide thin films.

3. RESULTS AND DISCUSSIONS

3.1 Structural Properties

Prepared CdS films were uniform and yellow colored. The XRD pattern of prepared CdS film is shown in Figure 1. Diffractogram of the thin film shows sharp peaks at 2θ values of about 26.5°, 43.9° and 52.1° which are identified as the diffractions from (111), (220) and (311) planes by comparing with the d-values of standard cubic Cadmium Sulphide phase.

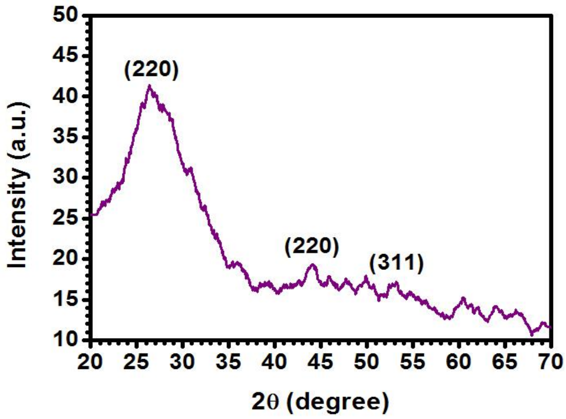

Figure 1 XRD pattern of CdS obtained with S/Cd molar ratio 0.7

The d-spacing for all samples can be evaluated from the position of the major peak at about 26.5° and by the Bragg condition,

$$n\lambda = 2d\sin\theta \tag{1}$$

Where, n is the order of diffraction, λ the wavelength of the incident X-ray, θ the diffraction angle, d the distance between the planes parallel to the axis of incident beam.

The average grain size of the crystallites has been calculated using Scherrer's equation,

$$D = \frac{k\lambda}{\beta\cos\theta} \tag{2}$$

Where, constant k is a shape factor usually = 0.94,
β is full-width at half maximum (FWHM) of the peak.

Using the size of crystallites, the dislocation density can be found

$$\delta = \frac{1}{D^2} \tag{3}$$

The lattice strain in the film can be found by,

$$\epsilon = \frac{\beta\cos\theta}{4} \tag{4}$$

The average crystallite size was found to be 1.5 nm Further the strain present in the film is 0.1033, indicates the stability of the crystal structure in the prepared film.

3.2 Surface Morphology

The surface morphology of the thin film plays a crucial role in any optoelectronic devices. In the present study the surface morphology of the prepared CdS film is observed by SEM as shown in Figure 2. Surface of the film appears like smooth and well adhered to the glass substrate. As discussed in the XRD section the film contains the nano-sized crystalline structure of the atoms, which is verified by the SEM.

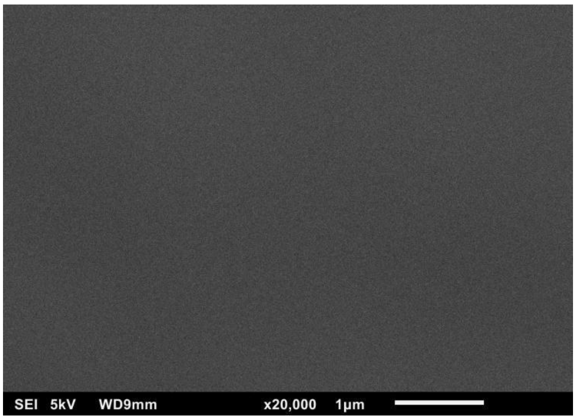

Figure 2 SEM micrograph of the CdS thin film at S/Cd molar ratio 0.7

Atomic force microscopy (AFM) is also known as Scanning Force microscopy (SFM), is a basic technique and inevitable for all nanoscopic research. The AFM image of CdS is shown in Figure 3. Surface topological features of CdS thin film are observed under AFM 3D pattern. Here the micrograph at 1μm*1μm exhibit a uniform surface with cone like grains covering the CdS surface can be seen for this sample.

Sa Average Roughness, Sq Root Mean Square Roughness, Sp Maximum Peak Height, Sv Maximum Valley Depth, Sz the Maximum Height of the Surface were measured by Automatic Force Microscope. Sp, Sv, and Sz are parameters evaluated from the absolute highest and lowest points found on the surface. Sp, the Maximum Peak Height, is the height of the highest point, Sv, the Maximum Valley Depth, is the depth of the lowest point (expressed as a negative number) and Sz the Maximum Height of the Surface), is found from, Sz = Sp – Sv. Here it is -31.3 nm.

The surface roughness, RMS average value and heights were determined by AFM analysis. The average roughness was found 5.9 nm and Root mean square roughness was found 8.6 nm. AFM observation showed rough distribution of CdS over the thin film.

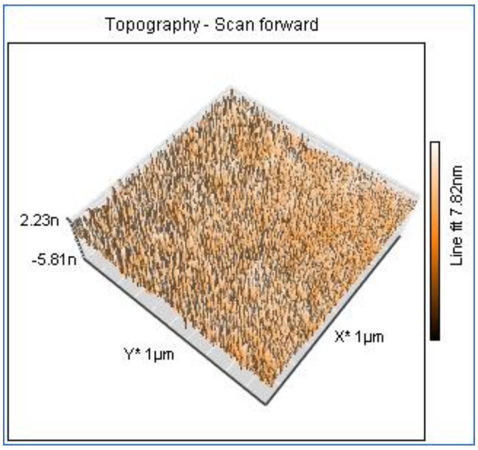

Figure 3 AFM 3D image of the CdS thin film at S/Cd molar ratio 0.7

3.3 Optical Properties

The optical properties of CdS film was observed using the Transmission spectra of the film, which is measured using UV-VIS spectrophotometer. The transmission spectrum of the CdS film is shown in Figure 4.

The transmission behaviour of the films clearly indicates its value of transmission around 45% above 520 nm which gradually increases and reaches 70% at 900 nm wavelength. The observed value closely matches with the reported value of CdS thin films prepared by different method [3,6,7,8,9,11,13,16]. From the values of transmission spectra, optical band gap was determined using Tauc relation,

$$(\alpha h\nu)^2=B(h\nu-E_g)^m$$

Where,
E_g is the energy band gap and B is constant.

Here, considering direct band gap nature of the material, the value of m is taken to be 0.5.

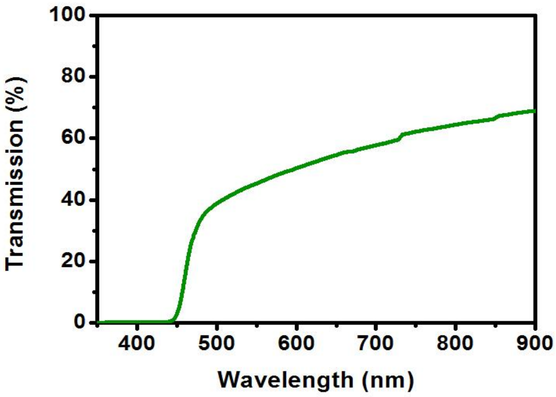

Figure 4 Transmission spectrum of the CdS film as a function of wavelength

The Tauc plot drawn using the above mentioned equation is shown in Figure 5. The extrapolation of Linear portion of the $(\alpha h\nu)^2$ to zero indicates the band gap of the film.

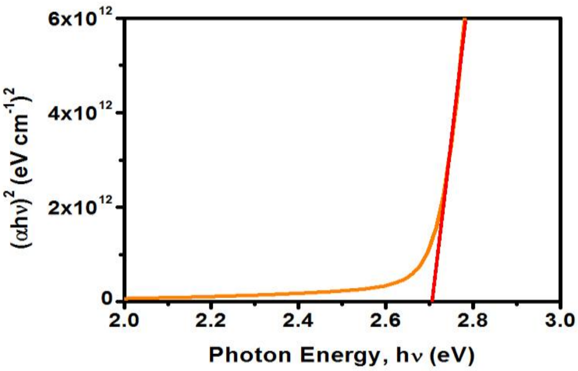

Figure 5 Plot of $(\alpha h\nu)^2$ as function of energy for CdS thin film

As per the extrapolation of the linear part of the curves to the intercept on horizontal axis, the band gap of sample is about 2.71 eV, which is in good agreement with the bulk value CdS [3,6,7,8,11,16]. This high value of transmission and the ~ 3 eV band gap can be very much useful in the field of optical sensor and solar cell.

4. CONCLUSION

XRD results have confirmed that CdS films grown by dip coating has a cubic structure. CdS thin film shows sharp peaks at 2θ values of about 26.5°, 43.9° and 52.1° which are identified as the diffractions from (111), (220) and (311) planes by comparing with the d-values of standard cubic Cadmium Sulphide phase. The SEM shows the uniform CdS film over the glass substrate. The CdS film exhibited good optical properties with a relatively high transmittance of around 45% above 520 nm which gradually increases and reaches 70% at 900nm. Optical band gap is about 2.71 eV. Hot probe shows N-type conductivity.

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