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International Journal of Recent Scientific Research

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 7, Issue, 12, pp. 14887-14890, December, 2016

Research Paper

PREPARATION AND CHARACTERIZATION OF CADMIUM SULPHIDE NANOCRYSTALLINE THIN FILM GROWN BY CHEMICAL METHOD

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ARTICLE INFO

Article History:

Received 15th September, 2016
Received in revised form 25th October, 2016
Accepted 23rd November, 2016
Published online 28th December, 2016

Key Words:

CdS thin film, Dip Coating, XRD, SEM, Optical properties.

ABSTRACT

CdS thin films were prepared on a glass substrates using dip coating method. The influence of the preparation technique on the structural, optical and electrical properties of polycrystalline CdS thin films were characterized by X-Ray diffraction technique (XRD), Scanning Electron Microscope (SEM), Ultraviolet – Visible spectroscopy and Hot probe method. The XRD pattern reveals the formation of CdS thin films with the preferred orientation (111), (220) and (311) planes confirms the cubic structure of CdS films. Surface morphology of thin film was studied using Scanning Electron Microscopy (SEM). The optical properties of the deposited film were characterized by UV-VIS spectrometry and show the presence of direct transition with band gap energy of 2.56 eV. The hot probe method shows n-type conductivity of the prepared CdS film.

1. INTRODUCTION

Cadmium sulphide (CdS) is an important wide band gap II-VI group chalcogenide semiconductor due to its direct band gap transition with band-gap energy at room temperature of 2.4 eV, [1,4,7,9,11] high photoconductivity, high electron affinity and electronic band gap tunability [5]. The size and shape of CdS plays important role here, which are key factors determining their optical and electrical properties and overall functionality [5]. Hence it is necessary to control the size and shape of the nanocrystals which is crucial for their implementation in proposed applications [5]. The size and shape of a growing crystal can be tailored after understanding of its crystal symmetry and growth habits [5]. 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 [1-16]. 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 which uses natural solar energy [4].

There are many method of growing 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]. There are hardly any data on multiple dip coated CdS films [2]. Therefore, it gave me thought to prepare, compare and analyse the properties of multiple dip coated CdS thin film. At present, 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. Xiang hui Zhao [3], Koigala subba ramaiah [4], Fouad Ouachtari [7-8], C. Gopinathan [14], studied CdS thin films prepared by chemical bath deposition, Jin Hyeok Kim [5] on photo-electrochemical performance, Anbarasi M [6] by spray pyrolysis technique, changing S/Cd molar ratios. Here, the same study is carried out using dip coating method.

2. EXPERIMENTAL DETAILS

CdS thin films have been deposited using the dip coating method. Prior to the deposition of CdS, glass substrate was cleaned with Methanol, Acetone, Trichloroethylene and De-ionized (DI) water. The precursor solution for the dip-casting was prepared by dissolving Cadmium Acetate Dihydrate and

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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 1.7, indicating film is Cd-deficient & S-rich. This film was characterized using X-Ray diffraction technique (XRD), scanning electron 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 (LAMBDA-35) was used. The hot probe method shows n-type conductivity of the prepared CdS film.

3. RESULTS AND DISCUSSIONS

3.1 Structural Properties

CdS films prepared were uniform and Yellow colored. Fig. 1 shows the XRD pattern of prepared CdS film. 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 (CdS) phase.

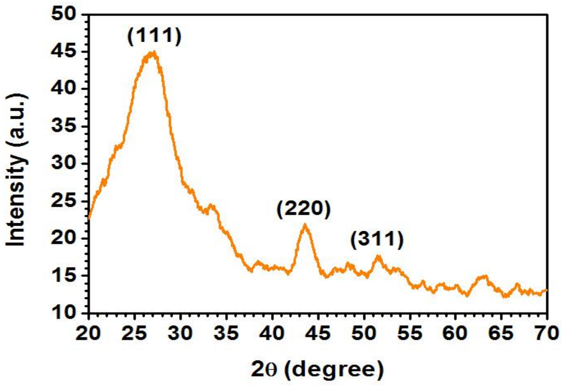

Figure 1 XRD pattern of CdS obtained with S/Cd molar ratio 1.7

Here 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,

$$n\lambda = 2d\sin\theta \quad (1)$$

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.

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

$$D = \frac{k\lambda}{\beta\cos\theta} \quad (2)$$

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,

$$\delta = \frac{1}{D^2} \quad (3)$$

The lattice strain in the film can be found by,

$$\epsilon = \frac{\beta\cos\theta}{4} \quad (4)$$

The average crystallite size was found to be 1.6 nm Further the strain present in the film is 0.0995, 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 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.

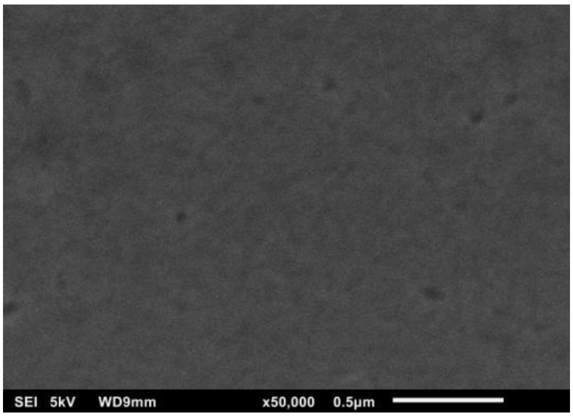

Figure 2 SEM micrograph of the CdS thin film at S/Cd molar ratio 1.7

3.3 Optical Properties

The optical properties of CdS film were observed using the Transmission spectra of the film, which is measured using UV-VIS spectrophotometer. The transmission spectrum of CdS film as a function of wavelength is shown in Figure 3.

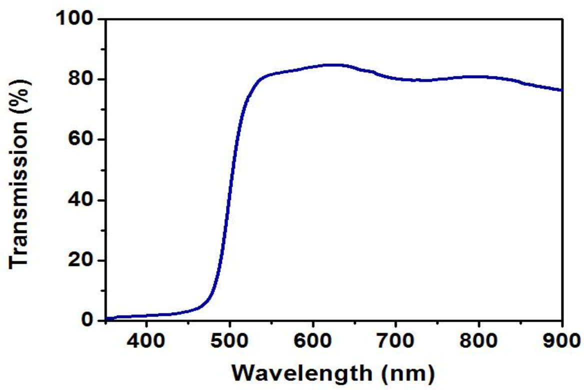

Figure 3 Optical Transmission spectrum of CdS film as a function of wavelength

The transmission behaviour of the film clearly indicates its high value of transmission, 80% above 530 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.

The Tauc plot drawn using the above mentioned equation is shown in Figure 4. The extrapolation of Linear portion of the $(\alpha h\nu)^2$ to zero indicates the band gap of the film.

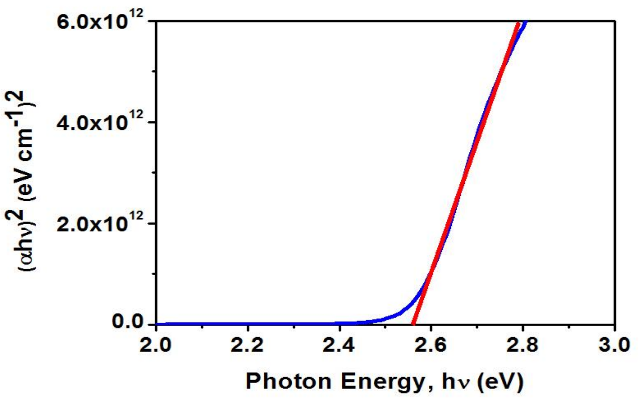

Figure 4 Plot of $(\alpha h\nu)^2$ as function of energy for CdS thin film

As per the extrapolation of the linear part of the curves to the intercept on horizontal axis, the band gap of sample is about 2.56 eV, which is in good agreement with the bulk value CdS [3,6,7,8,11,16]. This high value of transmission and the ~ 2.6 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 have 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 80% in visible region, and the optical band gap is about 2.56 eV. Hot probe shows n-type conductivity. This film shows its potential use for n-type layer in many optical wavelength selective detector, solar cells, photo-detector, etc.

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How to cite this article:

Samir G. Pandya., 2016, Preparation and Characterization of Cadmium Sulphide Nanocrystalline Thin film grown by chemical method. *Int J Recent Sci Res.* 7(12), pp. 14887-14890.