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Structural and morphological studies of CdS thin films grown by photochemical deposition

H. L. Pushpalatha¹, S. Bellappa² and R. Ganesha^{1*}

¹Department of Physics, Yuvaraja's College, University of Mysore, Mysore 570 005, Karnataka, India.

²Department of Chemistry, GSSS Institute of Engineering & Technology for Women, Mysore 570 016, Karnataka, India.

*Corres. author: rajeshaganesha@gmail.com

Abstract: Cadmium sulphide (CdS) thin films were deposited on glass substrate by a novel photochemical deposition (PCD) technique in which the substrate is held in an aqueous solution containing thiosulfate ions ($S_2O_3^{2-}$) and metal ions (Cd^{2+}). CdS film is deposited only in the UV- irradiated region of the substrate. The $S_2O_3^{2-}$ ions on absorbing UV photons release solvated electrons and sulphur atoms which react to yield CdS film. The deposited films were characterized by XRD, SEM, AFM and EDAX. The XRD data confirmed the films to be hexagonal. SEM exhibited *flower-stalk cluster* morphology. AFM yielded rms value of surface-roughness: 121 nm and Z-max: 1.7 μ m. EDAX confirms presence of cadmium (Cd) and sulphur (S).

Key words: CdS thin films; UV-photons; PCD; XRD; SEM; AFM; EDAX.

1. Introduction

CdS thin films have received continued attention as a potential candidate for application in electrochemical cells, semiconductor metal Schottky barrier cells and thin film solar cells[1]. Due to its wide band gap and good lattice match with p-type absorbers such as CdTe, CuInSe₂, InP etc., CdS is identified as a preferred material for application as optical window and n-type partner in the heterojunction thin film solar cells. In a novel technique viz. photochemical deposition (PCD) developed in 1997 by Goto, Masaya Ichimura and Arai[2], the necessity of a conducting substrate in electrochemical deposition[3] (ECD) and poor controllability of chemical reaction in chemical bath deposition[4] (CBD) are overcome. In PCD, the CdS compound formation is solely actuated by chemical reaction mediated by ultra-violet (UV) photons through photo excitation of the molecules in the solution. In this paper, a structural and morphological study of PCD-CdS thin films is presented.

2. Experimental

CdS thin films were deposited on ultrasonically cleaned glass substrate (2.5 x 2.5 x 0.145 cm³). 125 mL of aqueous solution comprising 75 mL of 0.2 M cadmium sulphate (CdSO₄) and 50 mL of 0.2 M sodium thiosulfate (Na₂S₂O₃) is taken in a glass container. The pH of the solution was adjusted to 3.6 by the addition of dilute sulphuric acid (H₂SO₄). The substrate was held in the bath solution with its plane horizontal at a depth of

3 mm in the container placed on the magnetic stirrer (Remi) with the stirring-rate 300 rpm at room temperature (28°C). Light from a high pressure mercury arc lamp (500 W) was focussed onto a region of 10 mm of the substrate using a spherical quartz lens. The deposition time was 1hour. Deposition occurred only on the illuminated region of the substrate.

2.1 Characterization techniques

The X-ray diffractogram of the films were recorded by XPERT PRO X-ray diffractometer using CuK_α radiation ($\lambda = 1.54056 \text{ \AA}$). Surface morphology of films was recorded using Carl Zeiss ultra 55 FESEM. Topography imaging and roughness quantification of the films was done using Bruker AFM with scanasyst in tapping mode. The composition of the films was found by EDAX using Oxford instruments attached to FESEM.

3. Results and discussion

3.1 Structural properties

X-ray Diffraction

The X-ray diffractogram of CdS thin films (Fig.1) exhibits hexagonal structure with sharp peaks indicating good crystallinity. Peaks at 2θ values of 24.9° , 27.5° , 28.8° , 38° , 43° , 47.6° , 55° , 61° , 71.6° and 75.6° correspond to (100), (002), (101), (102), (110), (103), (004), (104), (211) and (105) planes respectively are in agreement with standard data (JCPDS 6-314)[5]. The grain size of films calculated from Debye-Scherrer relation is 90 nm.

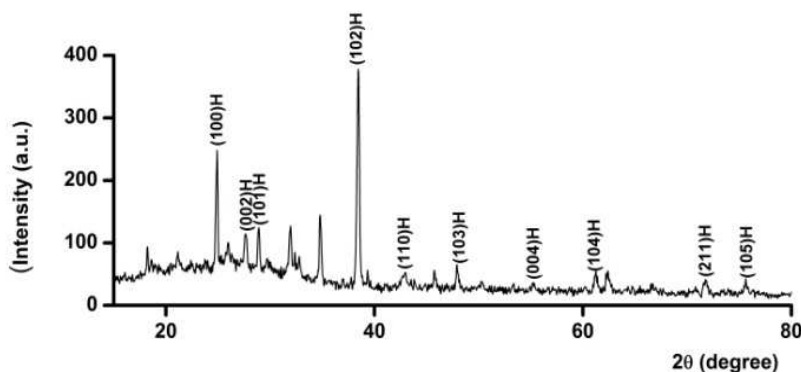


Fig. 1. XRD pattern of CdS thin films

Energy dispersive X-ray analysis (EDAX)

The EDAX spectrum exhibits peaks of cadmium and sulphur of CdS, oxygen of substrate (SiO_2) and carbon (contamination) with Cd:S = 9.90:3.65 indicating the films to be Cd-rich, may be due to the greater reactivity of Cd ions than S ions.

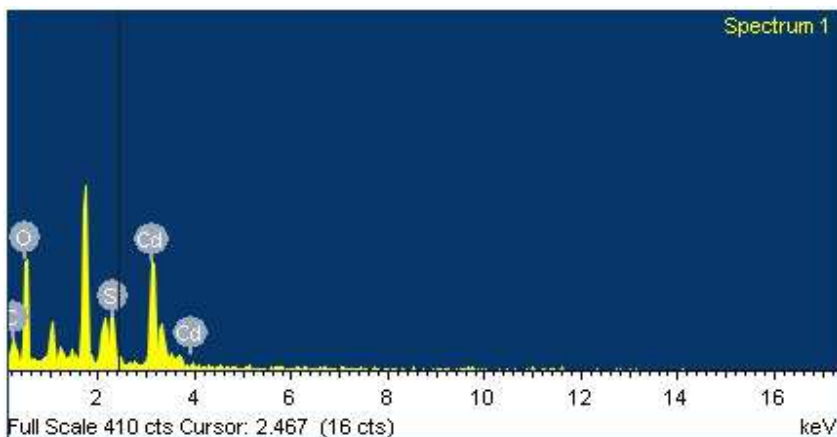


Fig. 2. EDAX spectrum of CdS thin films

3.2 Morphological studies

Scanning electron microscope (SEM)

The SEM micrograph of the CdS films (Fig. 3) at a magnification 50 Kx reveals the films to be dense with uniform surface coverage on the substrate over which loosely adherent grains are seen exhibiting *flower-stalk cluster* morphology with clusters of size ~ 107 nm.

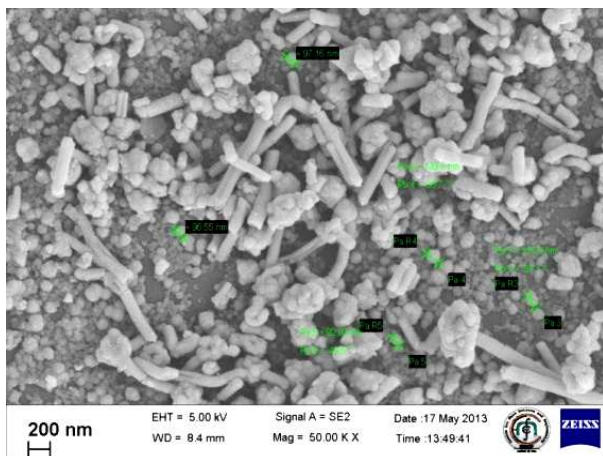


Fig. 3. SEM image of CdS thin films

Atomic Force Microscopy (AFM)

AFM picture of CdS thin films (Fig. 4) provides the values of rms roughness $R_q = 121$ nm, average roughness $R_a = 96.1$ nm and the Z-max is $1.7\mu\text{m}$. The grains of relatively larger size are seen to be distributed over the surface uniformly.

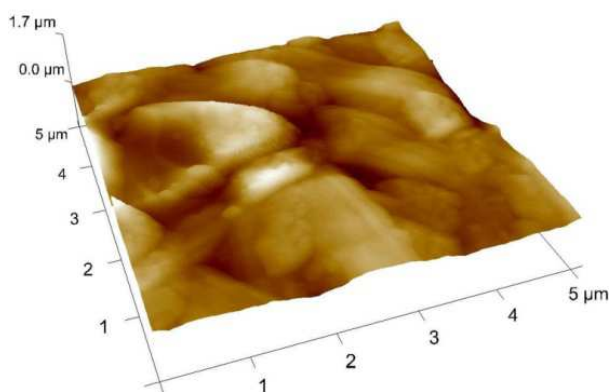


Fig. 4. AFM picture of CdS thin films

Discussion

The grain size in the films calculated from XRD data is comparable with the SEM data. The initial dense deposition of the films due to heterogeneous nucleation (ion-by-ion mechanism) followed by loosely adherent clusters due to homogeneous nucleation (cluster-by-cluster mechanism) resulted in thin films with uniform surface-coverage. The surface analysis of the films by AFM reveals high value of surface roughness and maximum thickness of $1.7\mu\text{m}$. The surface roughness of the films is thickness-dependent[6]. The films composition analysis using EDAX confirms relatively higher percentage of Cd compared S due to the formation of CdO along with CdS. The higher value of Oxygen peak is due to glass substrate.

Conclusion

CdS thin films were deposited by novel PCD technique. The films have hexagonal structure. The grain size calculated from XRD data is of the order of the value obtained in SEM micrograph. The composition analysis by EDAX confirmed the presence of Cd and S. The surface roughness of the films by AFM is found to be 121nm.

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