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Annealing studies of CdS thin films grown by Chemical bath deposition

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Abstract: Cadmium sulphide (CdS) thin films were deposited on glass substrate by chemical bath deposition (CBD). The films were annealed in air at 300°C for one hour. Both the as-deposited and annealed films were characterized by XRD, UV-visible spectrophotometer, EDAX and Photoluminescence study. A mixed phase of hexagonal and cubic structure of the as-deposited film was confirmed by XRD. On annealing, the films were confirmed to be purely hexagonal. A band gap of 2.35 eV of the as-deposited films and 2.29 eV of the annealed films were derived from UV-VIS spectral data. Photoluminescence (PL) spectrum exhibits green and red emission peaks. EDAX spectral analysis reveals composition of the film before and after annealing.
Key words: CdS thin films; CBD; Annealing; Structural properties; Optical properties.

1. Introduction

Cadmium sulphide (CdS), one of the most promising II–VI compound semiconductors, has wide application in various optoelectronic[1], piezo-electronic and semiconducting devices[2,3]. Among various methods to prepare CdS thin films, CBD[4] happens to be the most widely used technique in the industry and in the research area which is fast, simple, and a low cost technique.

2. Experiment

Commercial glass slides (75 x 25 x 1.45 mm^3) were used as substrate. Aqueous solutions of 1M $CdSO_4$, 1M thiourea and 10M NH_4OH were used to prepare CdS thin films. AR grade reagents were used. The cleaned substrates were kept in the bath maintained at temperature 80°C and pH = 11. After deposition of CdS for one hour, the substrates were removed, cleaned and dried. The films were air annealed at 300°C in a polymer furnace for one hour.

2.1 Characterization techniques

The X-ray diffractogram of the films were recorded by X-PERT PRO X-ray diffractometer operated using CuK_α radiation (λ = 1.54056 Å). The UV-VIS spectra were recorded by GBC-CINTRA 40 in the wavelength

range 200-900 nm. The room temperature PL spectra (27°C) were recorded by HR800 (Horiba Jobin Yvon) using Ar laser (λ =514 nm). The elemental composition of the CdS thin films was estimated by EDAX analysis.

3. Results and discussion

3. 1 Structural properties

X-ray diffraction (XRD)

The XRD plot of the films before annealing{Fig. 1(a)} and after annealing {Fig. 1(b)} reveal a mixed phase of cubic and hexagonal (polymorphism) in the as-deposited films and a pure hexagonal phase in the annealed films. The annealed film has improved crystallinity. The grain-size calculated using Debye-Scherrer formula is found to be increased from 15.5 nm to 47.8 nm due to annealing owing to grain-boundary diffusion[5].

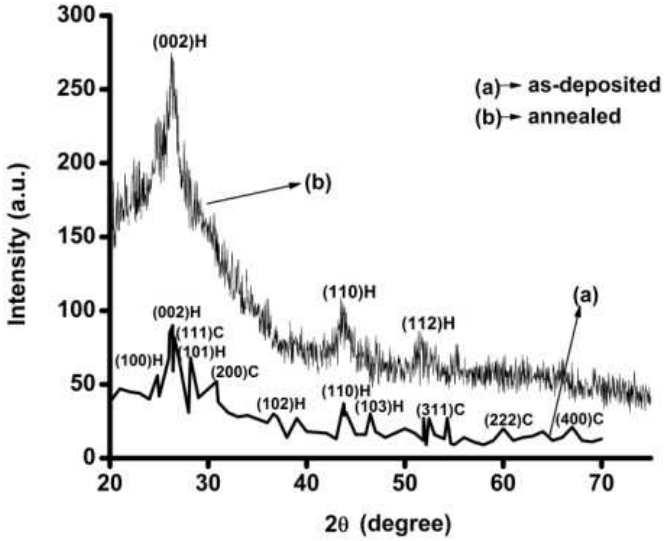

Fig. 1. XRD patterns of as-deposited (a) and annealed (b) CdS thin films

Energy dispersive X-ray analysis (EDAX)

The EDAX spectrum (Fig.2) of the CdS thin films shows peaks of cadmium and sulphur with appreciable intensity. The oxygen-peak is due to substrate (SiO_2). The average atomic percentage ratio Cd:S = 60.45:29.13 before annealing and Cd:S = 19.01:17.88 after annealing.

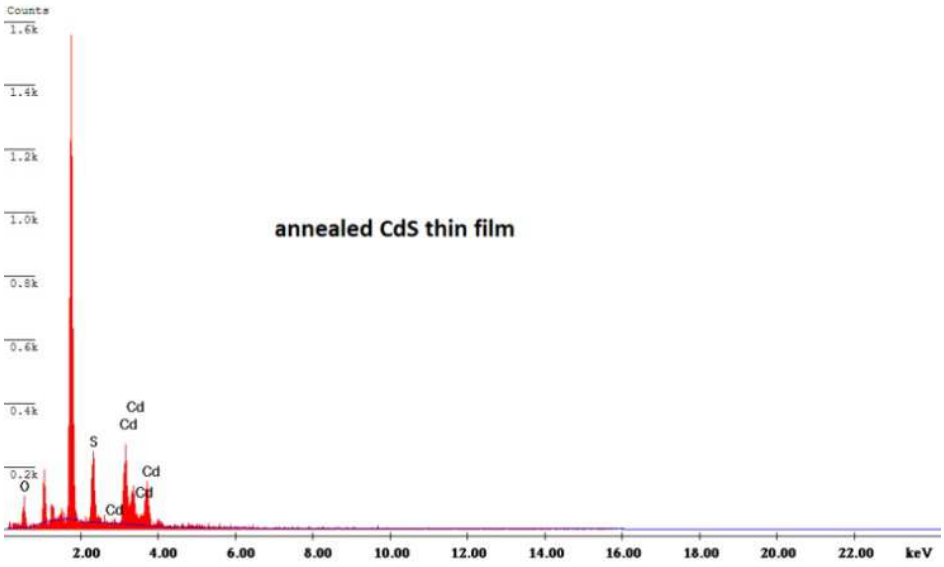

Fig. 2. EDAX spectrum of annealed CdS thin films

3.2 Optical properties

UV-Visible spectrophotometer

The UV-VIS spectral data is used to plot $(\alpha h\nu)^2$ vs hν (Fig. 3). On extrapolating the linear portion of the plot $\{(\alpha h\nu)^2 = 0\}$ yielded the band gap value of 2.35 eV before annealing 2.29 eV after annealing indicating a decrease in the band gap due to annealing[5].

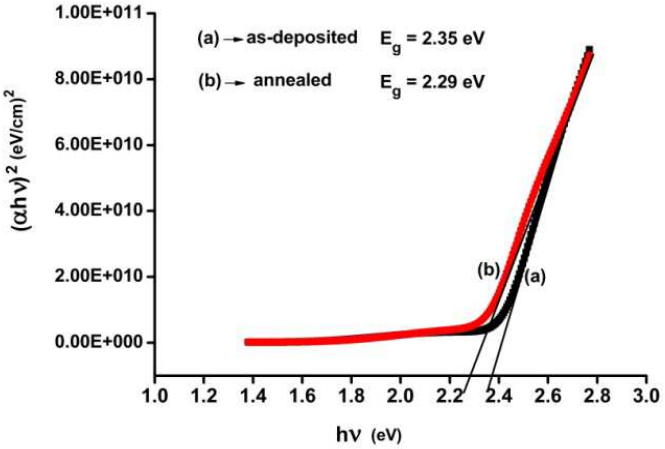

Fig. 3. Variation of $(\alpha h\nu)^2$ vs hν of as-deposited (a) and annealed (b) CdS thin films

Photoluminescence analysis

The PL spectrum (Fig. 4) of the CdS thin films exhibits two broad emission bands at 2.28 eV and 1.72 eV. The green band at 2.28 eV is due to donor-acceptor transition[6]. The red band at 1.72 eV is due to the transition of the electrons from deep level to valence band. An increase in intensity (almost double) is observed for the green emission while a slight increase is observed for red emission.

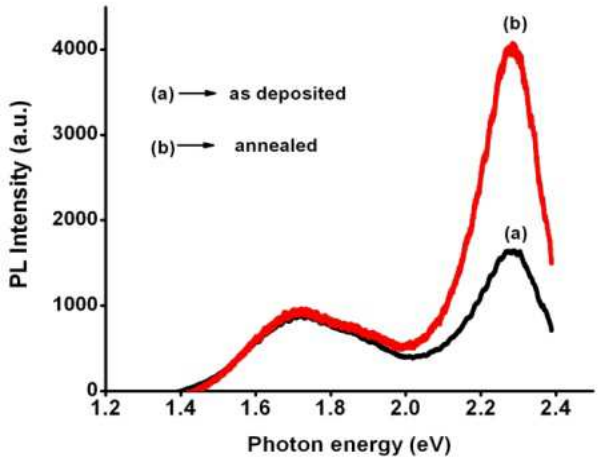

Fig. 4. Photoluminescence spectra of as-deposited (a) and annealed (b) CdS thin films

Discussion

Annealing the thin films leads to structural transformation from cubic phase to stable hexagonal phase with improved crystallinity and grain size. The band gap of the films is found to decrease slightly on annealing. This is due to the transformation of the disordered state of the film to relatively ordered state.

Conclusion

CdS thin films obtained by CBD at bath temperature 80°C with pH = 11 were annealed in air at 300°C. On annealing, XRD data confirmed pure hexagonal phase of the films, slight decrease in the band gap and

appreciable increase in intensity of the green band luminescence. The atomic percentage values of Cd and S derived from the EDAX data confirms the transformation from the disordered state to a relatively ordered state in the film.

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