International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.3, pp 1952-1955, May-June 2014

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Optical and Structural properties of radiant heated and vacuum annealed electron beam deposited CdS thin films

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Abstract: This paper describes the optical and structural properties of Cadmium Sulphide (CdS) thin films deposited onto glass substrate by vacuum evaporation assisted with (RH) and without radiant heater (VA). The RH and VA thin films showed high transmittance of 87% at 680 and 550 nm respectively. The optical band gap was estimated using transmittance measurements and found to be decreased with VA thin film. RH thin film revealed maximum absorption coefficient compared to VA thin film. The XRD analysis confirmed that the films reveal hexagonal and cubic (002) orientations. The crystallite grain size was found to be 15.5 and 16.7 nm for RH and VA films respectively.
Keywords : Polycrystalline CdS; Vacuum; e-beam; Optical; XRD.

Introduction and Experimental

Among wide range of semiconductors, cadmium sulphide (CdS) is considered as one of the prominent material for applications in opto-electronic devices [1,2]. This material has also proved to be an efficient window material in solar cells [3]. There are many techniques adopted for deposition of CdS thin films, among these vacuum depositions is most preferred due to its versatile and stoichiometric effects. There are various reports on different annealing process over CdS thin films deposited by different methods [4-6]. In spite of the importance of annealing process the structural properties also leads to optical variation which is linked with various physical parameters. The CdS thin films subsist either in cubic or hexagonal phase, or even a single predominant phase with share the cubic and hexagonal phases. Lee et al.[4] reported that CdS thin films deposited by radiant heater has shared both cubic and hexagonal phases where as Narayanan et al.[7] observed the transition of cubic to hexagonal on thermal annealing for CBD deposited CdS thin films. However, the most flexible and existing annealing processes is to be decided which in turn directly proportional to other physical parameters to obtain desired properties for specific application. In the present study, CdS thin films are deposited by vacuum evaporation at 130 °C using radiant heater and without radiant heater subsequently annealed under vacuum at 250 °C after deposition.

The 99.99% pure CdS powder was procured from Sigma Aldrich; molybdenum crucible was used as sample holder. The CdS thin films were prepared over soda lime glass by e-beam mediated physical vapor deposition technique. The substrate holder is aided with radiant heater (RH) in order to heat the substrate to 130 °C. The obtained thin film was about 300 nm under standard rate of deposition (3-5 A°/sec). The deposited samples without radiant heater were annealed in a vacuum chamber (VA) at 250 °C for about 30 min without disturbing the vacuum conditions before and after the deposition processes. The optical properties of CdS thin films were determined by VIS-NIR Spectrophotometer (Ocean Optics, USA). The structural properties of the films were determined by using a Philips X-ray diffractometer with monochromatic Cu-Kα radiation (λ= 1.54 A°).

Results and Discussion

The optical transmission spectra of RH and VA CdS thin films has shown the sharp fall in transmittance at the band edge at 550 nm indicating the increased band gap value (Figure 1). The maximum transmittance revealed by both the films is about 87% which is better than the existing reported result [8]. The film tends to exhibit transparency from 480 nm which is considered as the weak absorption region. The shift in maximum transparency in RH films at 680 nm (550 – VA film) is due to immediate densification of the film at the time of deposition, this cause change in the thickness of the film compare to post annealed (VA) thin films. This behavior is clearly revealed by slightly increased interference effect in RH thin films which confirms that annealing has unique importance in interference effect between the glass and the film state line. However, both the films exhibit maximum transparency in visible wavelength which is much needed in solar photovoltaic applications.

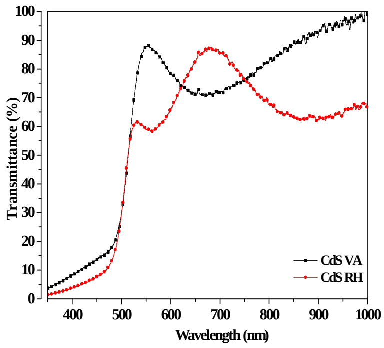

Figure 1: Transmittance spectra of RH and VA CdS thin films

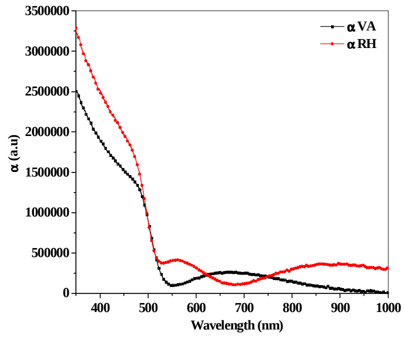

Figure 2: Absorption coefficient of RH and VA CdS thin films

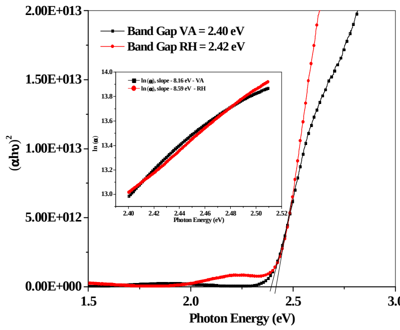

Figure 3: Estimated band gap of RH and VA CdS thin films

Figure 2 shows the absorption coefficient of CdS thin films. Although, both VA and RH films confirmed identical absorption edge while RH films revealed maximum absorbance compared to VA thin films. The dip at 550 and 680 nm wavelengths for VA and RH films respectively indicates the increased transmittance at that wavelength (Figure 1).

Figure 3 shows the graph of $(\alpha h\nu)^2$ v/s $h\nu$ belongs to subjected CdS thin films. The calculated band gap values are in agreement with the earlier reported values [4] and the optical band-gap was found to be 2.42 and 2.40 eV for RH and VA thin films. The inset of figure 3 represents the variation in ln (α) versus photon energy which gives the Urbach tail width, which determines the level of disorderness in the thin films [9]. The tail width of the films can be calculated by the slope of the straight line portion of the plot. The maximum tail width exhibit by RH thin film of 8.59 eV, whereas VA film revealed 8.16 eV. The decreased tail width is the perceptible for change in crystallinity which is evident from figure 4.

Figure 4 (a & b) shows the XRD pattern of VA and RH CdS thin film. Both the film exhibit dominant XRD peak with a sharing of hexagonal and cubic (002) orientations at 2θ=26.56º. The intensity of the (002) peak was found to be more intense after annealing towards nano-crystallinity compared to rest of the orientations. Other than (002) orientation VA CdS film exhibits (103) and (112) orientations at 2θ=48º, 51.9º respectively. This indicates that the hexagonal phase three planes are present for the VA annealed thin films. This also confirms the preferred growth direction of the film along the c-axis perpendicular to the substrate [10].

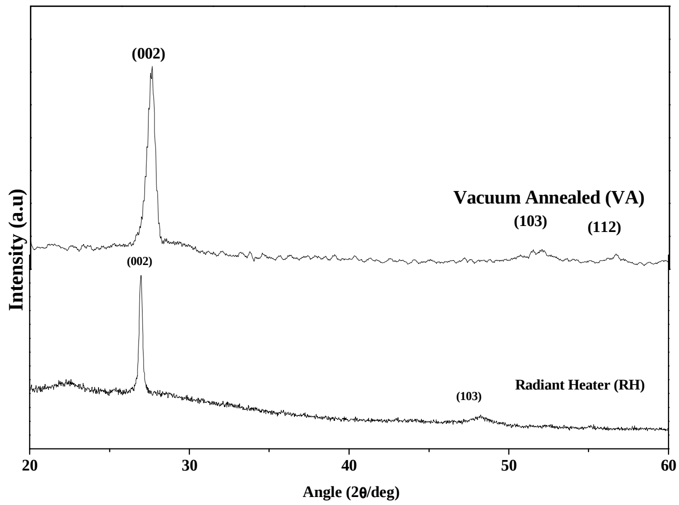

Figure 4: XRD pattern of VA and RH CdS thin films

The $CdCl_2$ treated magnetron sputtered thin film done by Lee et al. showed hexagonal phase with two prominent peaks at 26.56 and 48º, at 51.9 and 54.7º was due to $CdCl_2$[9]. Reported results indicate that these additional peaks of CdS thin films may be the effect of further treatments like, $CdCl_2$ with annealing process. Present investigation was carried out at 250 ºC in presence of vacuum showed all the three prominent peaks at 26.56, 48, and 51.9 was confirmed by JCPDS (#80-0006) it realized the further tedious process is not necessary after deposition. As low the grain size helps in reducing the pin holes [11] to have a strong correlation, the grain size calculated for (002) plane was found to be 16.4 nm and 14.5 nm for VA and RH thin films respectively, obtained grain size was much lower than the reported values [5]. Subjected CdS films exhibited nano-crystalline nature with high transmission at 550 nm and 680 nm with wide band gap were most useful in opto-electronic applications.

Conclusions

The obtained RH and VA thin films showed maximum transmittance in visible region (680 & 550 nm) with band gap almost equal to bulk material, where as VA thin film possess good structural variance with three prominent peaks of polycrystallinity with hexagonal phase. These results are direct evidences for CdS thin films towards opto-electronic applications.

Acknowledgment:

Authors would like to acknowledge BRNS–DAE, Govt. of India for the financial support (Sanction No. 2011/34/19/BRNS/1714).

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