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A MODIFIED FEEDER IN FLASH EVAPORATION TECHNIQUE AND FABRICATION OF CdS THIN FILMS

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A modification was made on feeder in flash evaporation technique in order to have a better control on materials transferring into the boat in comparison with its old versions (vibrating feeder). This new feeder was employed to fabricate CdS thin films on ITO coated glass substrates of different thicknesses. The specimens were characterized using x-ray diffraction and UV-Visible spectrophotometer. The structural characterization indicated that the grown CdS films had hexagonal phase, a suitable phase of CdS for solar cell applications. The results showed a slight change in the band gap of the CdS films upon annealing with no effect on their stable phase.

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Keywords: CdS, Thin films, Chalcogenbide, Flash evaporation technique, UV-Vis

1 Introduction

CdS thin films are well known materials for their applications in photovoltaic devices, solar cells (glass/ITO/CdS/CdTe, glass/ITO/CdS/CIGS) and photo-detectors [1-3]. They can be deposited by different deposition techniques, such as sputtering [4, 5], molecular beam epitaxy (MBE) [6], chemical bath deposition [7-10], spray pyrolysis [11], thermal evaporation [12-15], flash evaporation [16], pulsed laser deposition [17] and dip coating technique [18]. Comparing with some sophisticated techniques, vacuum thermal evaporation is very simple and inexpensive method which can be used for large area thin film deposition. The problem associated with this technique is maintaining the stoichiometry in the deposition of materials composed of elements having different vapor pressures such as Cd and S in CdS. Hence flash evaporation technique (FET) has been used by many researchers to overcome the said problem [16, 19 and 20].

In this technique, one can transfer the starting materials from someplace to an ablaze boat through a vibrating feeder. The disadvantage of vibrating feeder itself is that its vibration power weakens after some times which affects its functioning in materials transferring. Therefore, the whole materials transferring feeder of FET was replaced by the one designed by this group. It is unique in the sense that it helps the operator to have a better control in materials transferring into the boat in comparison with old and common flash evaporation technique.

In addition, there are some more advantages such as: a) possibility to produce multilayer structures, b) ability to use a variety of material forms such as powder, grains, wires and pellets and c) ability to have better control of material falling rate from cone towards hot source.

2. Specifications of the new feeder

Fig. 1 shows a sketch of the flash evaporation system in which the old version of feeder has been replaced by a new one. The mechanism of different parts in this figure have been described as following: No.1 shows a revolving disk having 10 bins(No.2).The number of bins can be designed according to the wish of operator or the deposition conditions. Each of the bins is in

the form of a frustum with two circular cross sections of 10 mm (top) and 2 mm (bottom) diameters.

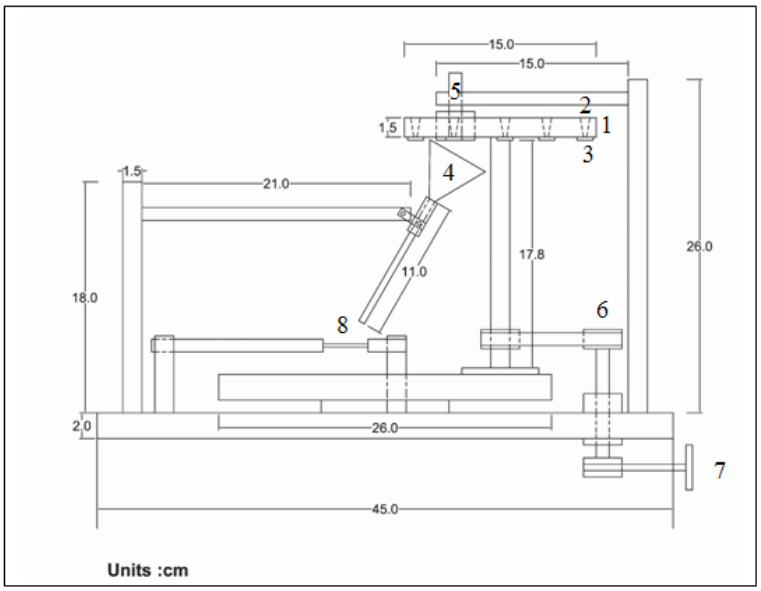

Fig.1: The complete evaporation section of the coating unit showing the different parts of new feeder; 1: revolving disk, 2: bin, 3: shutter, 4:cone, 5:barrier, 6: feedthrough 7: pulley 8: ablaze boat.

The high of bins is 1cm, equal to the thickness of the disk itself. The upper side of each bin is closed by a cap to avoid any contamination produced in the deposition process. It may be mentioned that the slope made to a bin avoids the sudden fall of all the starting materials, once the shutter (No.3) is removed. The shutter is a mechanical barrier placed below each bin which is screwed to the disk using a split washer. This will help to keep the shutter below the bin tightly. The shutter is removed when a bin is placed exactly at the top of the cone (No.4) .This is done by the help of a fixed barrier (No.5) connected to the body of the vacuum chamber which pulls over the bin shutter. The disk can be rotated clockwise and anticlockwise using a mechanical feedthrough (No.6) and the pulley (No.7) connected to it. Finally, the starting materials are transferred into an ablaze boat (No.8) through the cone. It is important to emphasize that all of the parts described above are made from stainless steel in order to avoid the degassing of the materials in vacuum situation. The growth rate of thin film in this process is highly dependent on the falling materials rate which is controlled by the diameter of the frustum bottom portion.

The presence of several bins in this design enables one to fabricate multilayer structures, since the bins can hold different materials. In addition, each bin can hold materials of different shapes such as powder, grains, wires and pellets.

3. Experimental

Thin films of CdS were fabricated by flash evaporation technique using modified feeder in a HindHivac coating unite (model 15F6) at pressures of less than 5×10^{-6} mbar onto ITO coated glass substrates at ambient temperature in vacuum chamber. CdS Powder of 99.99% purity supplied by Aldrich Company was evaporated from a molybdenum boat. The powder was placed in a bin of the disk. It was transferred into the boat heated up to the temperature about 1500K appropriate to evaporate the CdS powder.

CdS films of 40 nm and 800 nm thick were prepared. The deposition rate was about 5Å/s and film thickness was measured during the deposition using a conventional quartz crystal monitor (model DTM-101). The substrates were cleaned in acetone and methanol using ultrasonic bath and

then dried by nitrogen gas. Further, the substrates were subjected to glow discharge cleaning before deposition of CdS. The source-to-substrate distance was approximately 15 cm. After deposition, the films were removed from the coating chamber and exposed to the ambient atmosphere. The crystal structure of CdS films, as deposited and annealed at 300°C in vacuum at 10^{-6} mbar, was determined by x-ray diffraction (XRD). This study was carried out on an x-ray diffractometer (Advance Model D8) with high intensity Cuk_{α} radiation (λ=1.5406Å).

The optical transmission spectrum of as-deposited and annealed CdS thin films was obtained in UV-Vis spectrophotometer (Model UV-1650 PC).

4. Results and discussion

4. 1 Structural properties

The structure of 40 and 800nm thick CdS films was studied by XRD and the patterns of which are shown in Fig. 2. The presence of sharp peaks reveals the polycrystalline nature of the films.

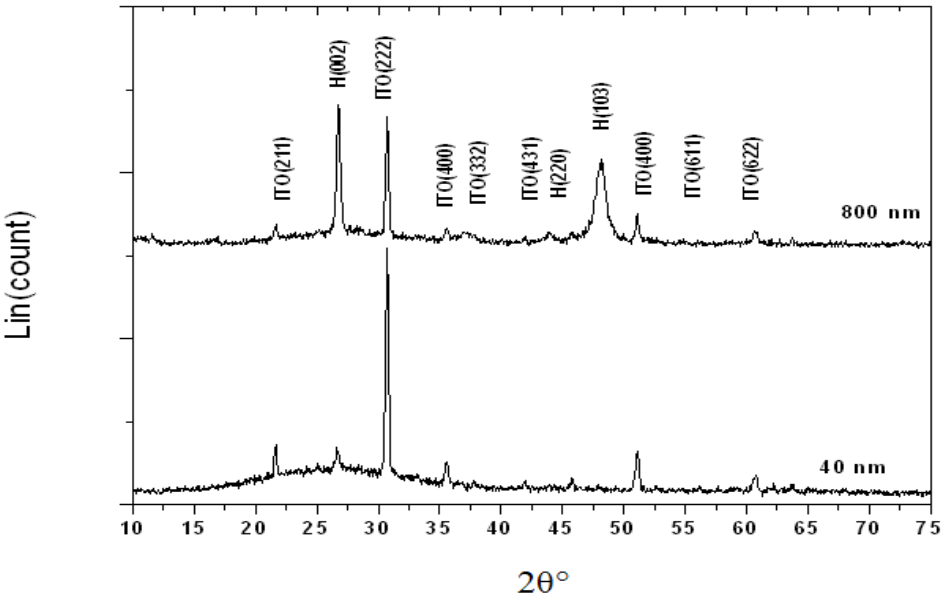

Fig.2: XRD patterns of 40nm and 800 nm CdS thin films.

Both of the films showed preferential growth of film crystallites at 2θ=26.84° which coincides with (002) diffraction line of the CdS hexagonal phase and cubic (111) planes. The low-intensity peaks which represent the (102), (110) and (103) orientations were improved by increasing film thickness. The other peaks of cubic phase CdS did not appear in the XRD patterns of both the samples.

In general, CdS films grow in cubic, hexagonal or even in mixed phase [5, 9, 10, 16], but the above deposited samples showed hexagonal phase only. It is worth noting that for solar cell applications, the hexagonal phase CdS films are preferable due to their excellent thermal stability when compared with CdS films of cubic phase [3, 8].

Increasing film thickness from 40nm to 800nm not only intensified the characteristics peak of CdS, but also led to the appearance of more peaks in the XRD pattern due to improvement of its crystallinity.

One can also find a significant change in the peak intensity of (103) plane in the XRD pattern. Murali has also reported a similar XRD pattern of CdS films but through heating the substrate during the FET deposition process [16]. It is interesting to note that the said peak has not

been observed in the XRD pattern of CdS thin film prepared using conventional thermal evaporation technique [10]. Therefore, it can be considered as another advantage of employing the new feeder to get the same structure without a need to heat the substrate.

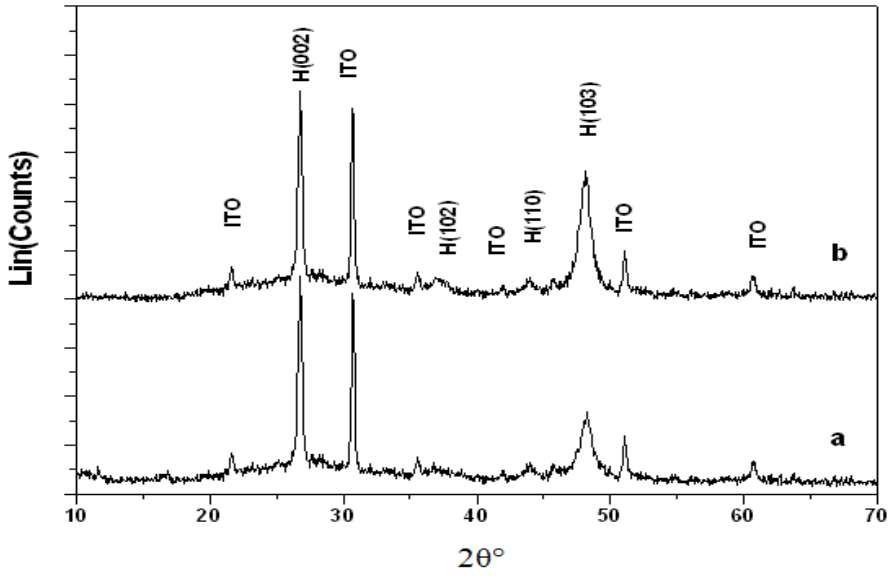

Fig.3: XRD patterns of 800 nm CdS thin films deposited a) as deposited, b) annealed at 300°C.

In order to study the annealing effect on the crystal structure of CdS thin films, they were heat treated in the 10^{-6} mbar vacuum tube inside furnace at 300°C for 1h. After annealing, the films were left in vacuum condition to reach the ambient temperature gradually. Fig. 3 shows the XRD patterns for 800nm thick CdS films, as deposited and annealed at 300°C. The change in the intensity of (103) peak is found more significant.

4.2 Optical properties

The optical transmittance spectra of 40nm and 800nm CdS films, as-deposited and annealed at300°C, have been shown in Fig. 4. The transmission of thinner one at the absorption edges is higher, as expected.

Also one can observe the reduction in transmission for 800nm CdS film due to annealing. It seems to be natural because annealing increases the grain size of CdS crystallites leading to a decrease in transmission.

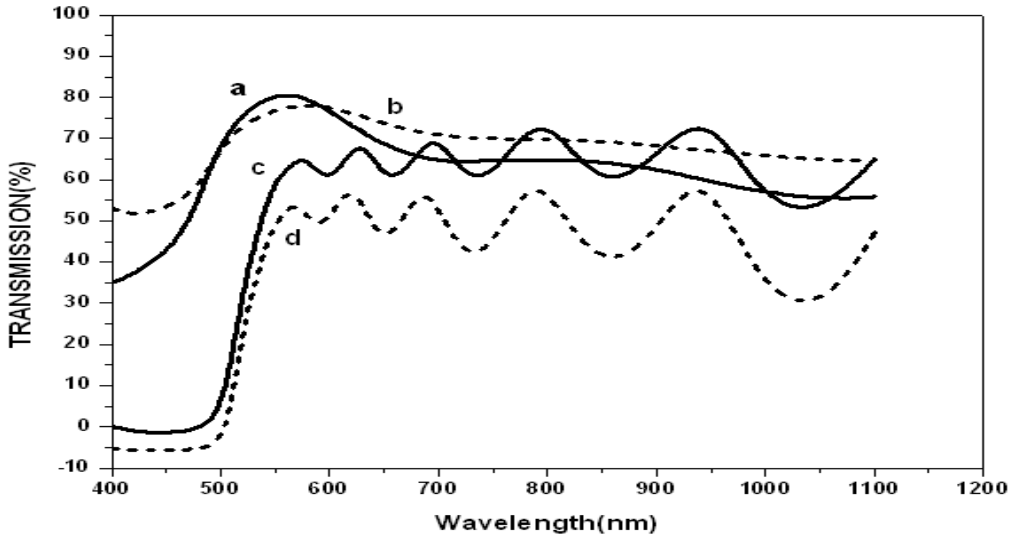

Fig.4: Optical transmittance spectra of CdS films (a) 40nm as deposited, b) 40 nm-annealed at 300°C, c) 800nm as deposited, d) 800 nm-annealed at 300°C.

From the absorbance data, the absorption coefficient α was calculated using Lambert Law [21]:

$$Ln(I_0/I)=2.303A=\alpha d \quad (1)$$

Where I_0 and I are the incident and transmitted light intensities respectively, A is the optical absorbance and d is the film thickness. The absorption coefficient, α, is found using the following relation [21].

$$\alpha= [A_0 (h\nu-E_g)^{1/2}]/h\nu \quad (2)$$

Where A_0 is a constant related to the effective masses associated with the bands and E_g is the band gap energy. $(\alpha h\nu)^2$ versus hν has been drawn using Eq.(2) and the results of which are given in the Figs. 5-a and 5-b.

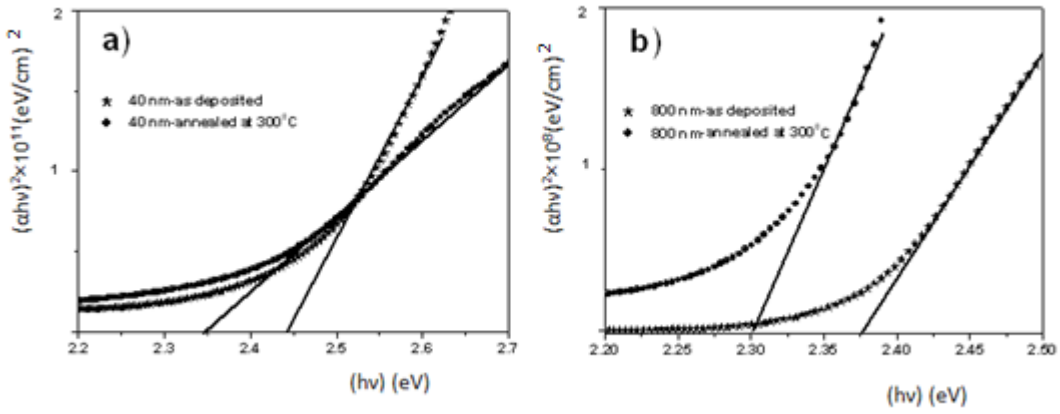

Fig.5 a and b: Graphs of $(\alpha h\nu)^2$ Vs hν for 40 nm and 800nm thick CdS films.

Extrapolating the linear portion of the curves to the x-axis (α=0) gives the band gap. From these Figures, the band gaps of the as –deposited 40nm and 800nm CdS films were found to be about 2.42eV and 2.36 eV and the same for the annealed films at 300°C were found to be about

2.39eV and 2.31eV respectively. It is clearly seen that annealing results in reduction of band gaps in all the specimens. Another finding is that the band gap value of all the films is less than that of single crystal CdS, i. e. 2.42 eV. As mentioned by Sahay et al, it may be attributed to the creation of allowed energy states in the band gap at the time of film preparation [21].

It is worth noting that Metin et al have argued that the temperature-dependent parameters affecting the change of band gap are reorganization of the film, sulfur evaporation and self-oxidization of the film [9].

5. Conclusions

Materials feeding part (feeder) in Flash evaporation technique was modified to gain better control in materials transferring into the boat during the thin film deposition process. Flash evaporation technique using this new feeder was employed to deposit CdS thin film successfully. Hence it seems that the new design can be used to deposit other chalcogenides such as CdSe, CdTe, ZnS, etc.

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