Electrodeposition of CdTe Thin Film Effect of Deposition Temperature from acetate precursor for Solar Energy Application.

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Abstract Cadmium telluride (CdTe) thin films were synthesized using a low-cost two electrode electrodeposition method in an acidic aqueous solution. The resulting solution contained 1.M cadmium acetate dihydrate (Cd $(CH_3OO)_2.2H_2O$) as the cadmium precursor and 1 ml of tellurium dioxide (TeO_2) as the tellurium precursor. The temperature of the electrolyte solution was increased from 50 to 85 °C. The X-ray diffraction results showed that the CdTe thin films have a polycrystalline cubic zinc blend and a hexagonal structure. The results further indicated that the intensity of the peaks increased with the deposition temperature and the crystallite size increased from 21 to 34 nm. The scanning electron microscopy images showed that the surface morphology changed with an increase in deposition temperature. Energy dispersive spectroscopy confirmed the presence of all the elements in the desired compound and its analysis showed that the composition of Cd and Te varied with temperature. The UV-Vis results indicated that the optical band gap decreased with an increase in deposition temperature.

1. Introduction

Semiconductor materials play an important role in energy conversion processes. In particular, chalcogenide group (II-IV) compound semiconductor are used for solar cell applications [1]. Cadmium telluride (CdTe) thin film is the best material as an absorber layer owing to its novel physical and chemical properties, such as a high absorption coefficient, direct band gap, and energy band gap, which is near the ideal energy band gap of the absorber material, environmental stability, variable conductivity and growth. Due to these, CdTe is used for different applications such as imaging detectors [2], LEDs [3] and solar cells [4].

Different physical and chemical growth techniques are used for the deposition of CdTe thin films. Each deposition technique has its advantages and disadvantages. The electrodeposition method is the best for solar energy production because of its scalability, manufacturability, self-purification, low cost, waste reduction, simplicity and production of both N and P type conductivity by varying the deposition voltage [5].

Thin films of CdTe were deposited by electrodeposition from different cadmium precursors, such as $Cd(NO_3)_2$ [6] , $CdSO_4$ [7] and $CdCl_2$ [8] as reported by different research groups, and the results showed that the quality and properties of the film varied with the precursor. The quality of CdTe thin film depends on the deposition parameters, such as the deposition time period, electrolysis bath temperature, concentration of ions in the electrolyte bath, pH of the electrolytic solution, stirring rate and growth voltage. Optimization of these parameters on CdTe thin films allows growth for desired applications [9].

The absorber layer depends on the thickness, whereas the film thickness depends on the current density. Even if the current density is not constant during deposition, it depends on the temperature of the solution, the concentration of Te in the solution and the cleaning of the glass substrate. When the temperature increases, the motion of the ions in the electrolyte bath increases and the solubility of the solvents increases [10]. When the current density was high the deposition rate increased, and the crystallinity of the film increased. Therefore, it is important to study the effect of deposition temperature in detail.

The main aim of this study was to investigate the effect of the deposition temperature on the quality of CdTe thin films grown by electrodeposition. The structural, optical, morphological, and compositional properties of CdTe thin films using cadmium acetate dihydrate as a Cd precursor and the effect of deposition temperature on solar energy application have not yet been reported using the two electrode electrodeposition method.

2. Materials and Method

Electrochemical deposition of CdTe thin films was performed using an electrolyte solution containing 1.0 M cadmium acetate dihydrate [$Cd(CH_3OO)_2.2H_2O$], with 98% purity, as the cadmium precursor and 1 ml tellurium dioxide TeO_2 with 99% purity as the tellurium precursor. Both chemicals were laboratory reagent grade $Cd(CH_3OO)_2$ $2H_2O$ purchased from Emsure, Germany and TeO_2 purchased from Sigma Aldrich and used as the electrolyte solution. Prior to electrodeposition takes place the four glass substrates/FTO were cut into small size 2.5 x 2.5cm^2 and washed ultrasonically in laboratory soap solution in deionized (DI) water for 30 minutes. Finally, the substrates were washed with ethanol, acetone and methanol, respectively and rinsed with deionized water between washing and drying in air.

The deposition voltage was adjusted to 1250 mV and, the pH of the electrolyte was 2.00 ± 0.02 using either dilute HCl or ammonium hydroxide (NH_4OH) at room temperature. The temperature of the electrolyte solution bath was adjusted to 50, 60, 70, 85°C with moderate stirring during the deposition using a magnetic stirrer.

The source of the electrolyte solution as electrical power used for the 2-electrode system was a computerized Gill AC potentiostate (ACM Instruments, United Kingdom). Insulating polytetrafluoroethylene (PTFE) was used to attach the glass/FTO substrate to a high purity graphite rod, which served as the working electrode (cathode).

Before CdTe thin film deposition, the cadmium acetate solution in 400 ml was electro purified for 48 h with a deposition voltage less than the Cd element deposited, which was determined by cyclic voltammetry. Te containing solution was prepared by dissolving 2g of TeO_2 in 30 ml diluted HCl solution and stirred for 2 h since Te is insoluble in water and soluble in acidic media. 1 ml of the TeO_2 solution was added to the Cd containing solution and stirred for 300 min to maintain uniformity in the solution.

3. Results and discussion

The structural properties of the CdTe thin films were investigated using a Bruker D8 Advance X-ray diffractometer (XRD) measurement with a monochromatic wavelength of 1.5416 Å. The X-ray generator voltage and current were maintained at 40 kV and 40 mA, respectively. The XRD measurements were carried out by setting the incident angle from 20 to 70° to identify the degree of crystallinity and the crystal structure of the CdTe layers grown on the glass/FTO. The data analysis shows that CdTe thin film growth by the electrodeposition method has a (111) preferential orientation. As shown in figure 1 the intensity increased with an increase in the deposition temperature from 50 to 85°C, while the crystallite size increased from 21 to 34 nm. The maximum peak intensity was observed at 85 °C. It was observed that the best crystalline film was obtained at the higher temperatures that is restricted by the boiling point of water at 100 °C. Overall, it was observed that the prepared CdTe thin films had both cubic and hexagonal polycrystalline structures. The result agrees with the JCPDS data 752086 for a cubic zinc blend structure and 800090 for the hexagonal structure. The peak (111) is located at an angle of 24.7 and the other peaks at 28.23, 40.32, 47.3, 57.76 and 63.7 with phase of (200), (220), (311), (400) and (331), respectively. The hexagonal structure having 41.3 and 50.6 with (110) and (015). Therefore, CdTe was found in a mixed polycrystalline phase which is in agreement with other reported results.

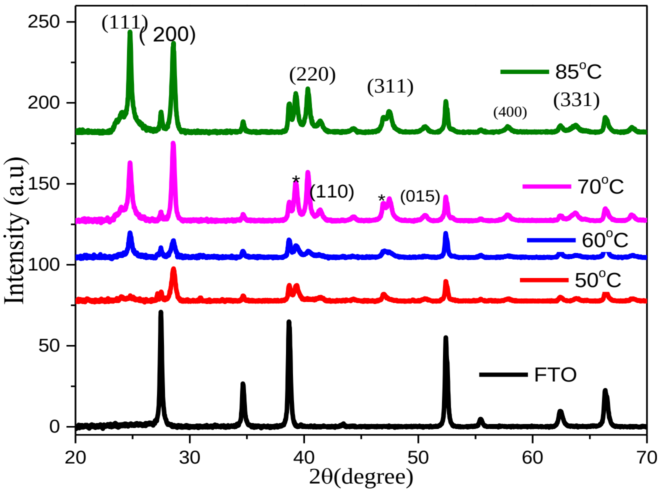

Figure 1: XRD spectra of CdTe thin films (unannealed) deposited at different temperatures

3.1 Optical properties

Optical absorption measurements of the CdTe layers were carried out using a Carry 50 Scan UV–VIS spectrophotometer to estimate the band gap of the films. Figure 2 (a) shows the absorbance as a function of wavelength. Figure 2 (a) shows that the absorbance increased with an increase in the deposition temperature. The maximum absorbance was recorded at 85 °C. Figure 2 (b) shows the absorbance square vs. photon energy (hv). The band gap energies were calculated by plotting the absorbance square vs. energy (hv) and using the extrapolation of the (A^2= 0) tangent line is the band gap of the CdTe film. From the results, the energy band gap varied from 1.50 to 2.75 eV. When the deposition temperature was 50 °C the energy band gap was 2.75 eV which indicates that the CdTe thin film contained more Te and pinholes since Te have positive redox potential compared with Cd that is why it was deposited at low deposition voltage and at low temperature. Due to this reason Te is active in the solution which is deposited first on the substrate. At low temperature CdTe thin film is Te rich and there is vacancy of

Cd in the thin film. When the temperature was increased the band gap decreased and when the deposition temperature was 85 °C the band gap became 1.5 eV. The band gap energy varied with the deposition temperature.

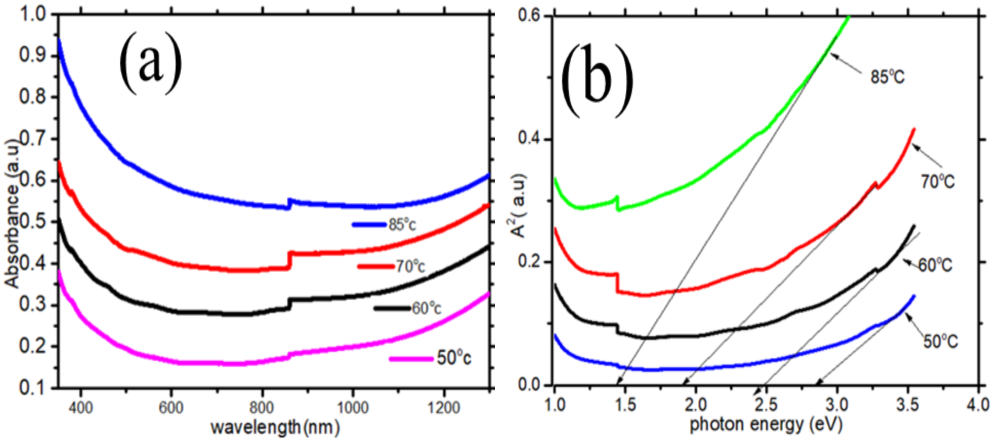

Figure 2: CdTe a) absorbance vs wavelength and b) A2 vs energy (eV)

3.2 Morphological property

SEM images were obtained to study the surface morphology, grain size and uniform coverage of the layer and four samples that were deposited at different temperatures from 50 to 85°C. The results confirmed that the glass (FTO) was uniformly covered by the CdTe thin film and as shown in figure 3 (a) at a low temperature of 50 °C the grain size was very small. As the temperature increases the increased 60°C in figure 3 (b) there is improvement of grain size. In figure 3 (c), a CdTe film with a better morphology was observed at 85 °C which supports the XRD results.

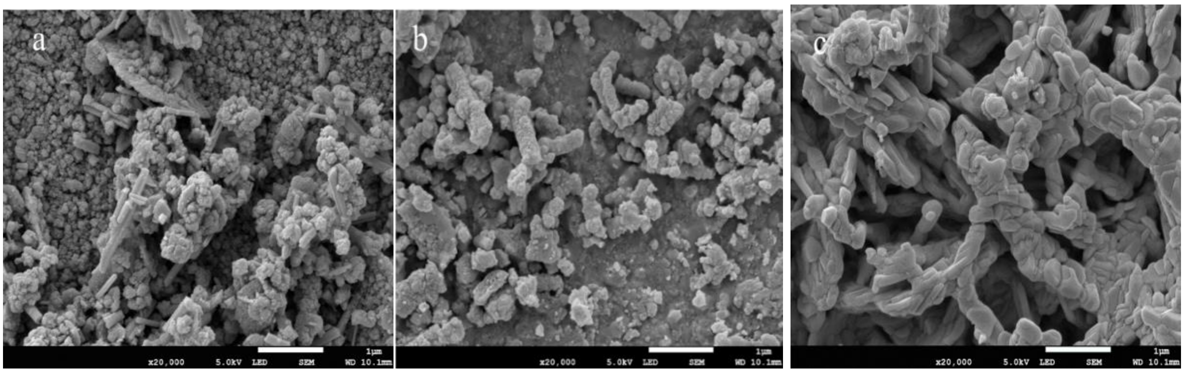

Figure 3: SEM images of CdTe thin films as deposited at (a) 50 °C, (b) 60 °C and (c) 85 °C

3.3 Compositional properties

EDS measurements were used to investigate the elemental composition of CdTe thin films grown at four different temperatures. The results showed that for the required compound (i.e., CdTe) both Cd and Te were present. As shown in figure 4 the Cd increased with an increase in temperature. In contrast the Te decreased with an increase in temperature. By nature, acidic media remove Cd and the film is Te rich and basic media remove Te and the film became Cd rich. During growth the electrolyte solutions are in acidic media which remove the Cd from the surface of the film and as deposited CdTe thin film always Te concentration is greater than Cd. To solve this problem, we use post deposition treatment by inserting the Film in $CdCl_2$ solution, then dry in air and then temperature treatment at 400^{o}C at 15 m. which makes equal composition (50, 50) % of elemental Cd and Te. For this study a better CdTe thin film were obtained when the deposition temperature was 85 ^{o}C.

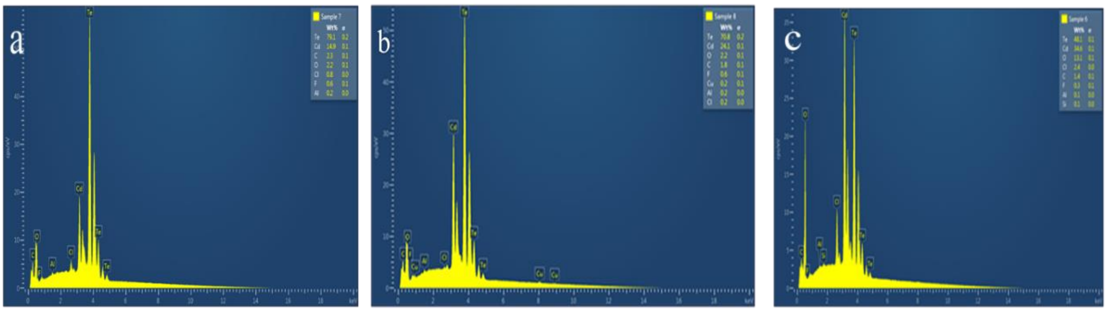

Figure 4: EDS spectra of CdTe thin films (unannealed) deposited at (a) 50 ^{o}C (b) 60 ^{o}C (c) 85 ^{o}C

4. Conclusion:

CdTe thin films were successfully grown by the electrodeposition using a cadmium acetate and tellurium dioxide as Cd and Te sources, respectively. The thin films were deposited at different temperature. The XRD results indicated that the crystallinity of the films and the crystal sizes increased as the temperature increased, and this agrees with other published results. The SEM results showed that the morphology of the thin films improved as the temperature was increased. The EDS results revealed that as the temperature increased the concentration of Cd increased while that of Te decreased. The UV-VIS measurements indicated that the energy band gap decreased as the temperature increased. Further analysis confirmed that the quality of the films increased with temperature. Therefore, it is important to study the effect of temperature for thin film growth for the desired applications.

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