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Structural and Optical Properties of Thermally Evaporated Cdte Thin Films

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ABSTRACT
Background: The aim of this work is to analyze the structural and optical properties of thermally evaporated Cadmium Telluride (CdTe) thin films. **Objective:** The influence of deposition current flow on the properties of CdTe thin films have been extensively studied aiming to optimize the thermal evaporation process for CdTe thin films. The CdTe thin films were deposited on cleaned soda lime glass substrates by varying the deposition current ranging from 25 A to 35 A under the vacuum condition of 10^{-6} Torr. X-ray diffraction (XRD) and Ultraviolet visible (UV-Vis) spectrometry were used to analyze the structural and optical properties of the deposited films. **Results:** The highest crystallinity and the band gap (1.49eV) have been found for the film deposited at 30 A. Beyond this, the film crystallinity as well as bandgap decreased with the deposition current flow at 25 A and 35 A. **Conclusion:** However, by analyzing the results, it can be concluded that, CdTe has been found to be suitable for high quality absorber layers to fabricate a higher efficiency solar cells.

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INTRODUCTION

Thin film Cadmium Telluride (CdTe) based solar cells have been recognized as reliable alternative for manufacturing cost effective photovoltaic solar cells due to its excellent absorber characteristics (Aliyu, M.M., 2012; Aliyu, M.M., 2012). Cadmium Telluride (CdTe) is a promising material for solar cells as it has an ideal energy band gap (Eg) of 1.45 eV and larger absorption coefficient ($>5\times10^5$/cm) (Hadrich, M., 2009; Britt, J., C. Ferekides, 1993).

Small-area CdTe cells already achieved efficiency of 16.5% in laboratory and 11% in commercial modules (Islam, M.A., 2013). Among the II-VI semiconductor compounds, it has the highest average atomic number and the highest iconicity. It also has the largest lattice parameter, the least negative formation enthalpy and the lowest melting temperature (McCandless, B.E., R.S. James, 2005). All the above features of CdTe make it an ideal and attractive choice for thin film solar cells.

To fabricate the CdTe thin films, different deposition techniques have been used such as vacuum deposition (Khainar, U., 2003), electro deposition (Mathew, X., 2004), molecular beam epitaxy (Ringel, S., 1991), metal-organic chemical vapor deposition (Chu, T., 1992), closed-space sublimation (Hernández, G., 2004) and screen-printing (Nakano, A., 1986). Thermal evaporation technique is also used for depositing CdTe thin films. It has been the most suitable method owing to the very high deposition rate, low material consumption and low cost of operation (Singh, S., 2010). Hence an effort has been made in this paper to enhance the structural and optical properties of thermally evaporated CdTe thin films by varying the deposition current.

Experimental Procedure:

Commercially available soda lime glasses were cleaned in ultra-sonic bath degreased by methanol-acetone-methanol and de-ionized water for 5 minutes, respectively. Then the cleaned glasses were dried by dry N_2. After that, the glasses were attached in the substrate holder of the thermal evaporation chamber. A boat substrate distance of 4-6 cm was maintained throughout the experiment. The CdTe thin films were deposited onto ultrasonically cleaned glass substrates by thermal evaporation using high purity CdTe (99.99%). Vacuum condition was obtained inside the thermal evaporation chamber with the combination of rotary and diffusion

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pumps. The chamber was emptied at a pressure lower than 10^{-5} torr. After reaching a vacuum level of 10^{-6} torr, the amplitude of the dc current across the boat was gradually increased to heat CdTe powders to a greater temperature than the melting point. This allowed the evaporation of CdTe material. The deposition was carried out for 20 min.

RESULT AND DISCUSSION

XRD analysis:

To determine the structural and crystallographic properties of the films, X-ray diffraction patterns have been observed. The CdTe thin films grown by thermal evaporation method were characterized through XRD. The crystallographic effects on the CdTe thin films were observed from the (XRD) data taken by 'BRUKER aXS-D8 Advance Cu-Kα' diffractometer.

Figure 1 shows the XRD pattern for CdTe thin film prepared from thermal evaporation technique. From figure 1, it is clear that the films grown from thermal evaporation process exhibits crystalline nature with a preferential orientation along the (111) cubic plane and found at 2θ=23.8º but the variations in the peak height was observed. It is also clear from the figure that the CdTe thin films deposited at 30 A shows highest crystallinity. Comparatively lower crystallinity was found for thermally evaporated CdTe thin films deposited at 25 A and 35 A. The identification of the observed diffracted XRD patterns was done using the JCPDS data 00-015-0770 file of CdTe cubic structure.

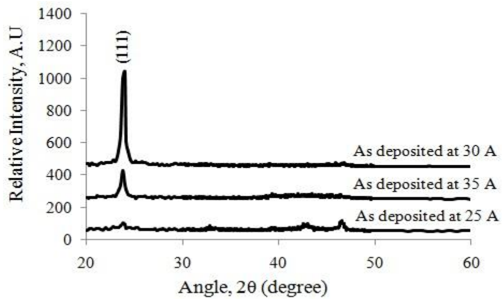

Fig. 1: XRD spectra of CdTe thin films deposited at 25 A, 30A and 35 A.

Optical properties analysis:

UV-VIS spectrometry is used to see the optical properties such as transmission, absorption and optical band gap of the prepared films. A blank FTO coated glass slide was placed in one of the beam directions during the scanning process while the glass slide with the deposited CdTe film was inserted in the other beam direction. In this way, the absorption and transmission spectra recorded by the spectrometer were observed from the CdTe thin films deposited on the FTO coated glasses.

The transmission spectra are shown in Figure 2, which was recorded for wavelengths ranging from 350 to 1100 nm. The films exhibit a transmittance below 10% along the visible range which confirms that, the films are very suitable as a good quality absorber for photovoltaic applications.

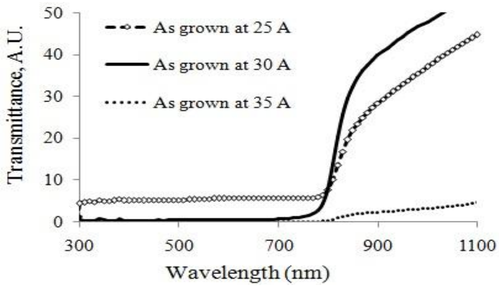

Fig. 2: Transmission spectra for CdTe film deposited at 25 A, 30 A and 35 A.

To compute the band gap, the optical absorbance data was used. The band gap energy was obtained by extrapolating the straight line portion of the graph to zero absorption coefficients. The intercept on the energy axis indicates the value of energy band gap (Mariappan, R., 2012). The band gap of CdTe thin films is calculated from the following equation (Altaf, M., 2002).

$$\alpha = A(h\gamma - Eg)^{1/2} / h\gamma \quad (1)$$

where, α is the absorption co-efficient; A is constant; *hγ* is photon energy and *Eg* is the band gap. The graphs of $(\alpha h\gamma)^2$ vs hγ are plotted in Figure 3. The band gap has been found 1.47, 1.49 and 1.43 eV for the films deposited at 25 A, 30 A and 35 A.

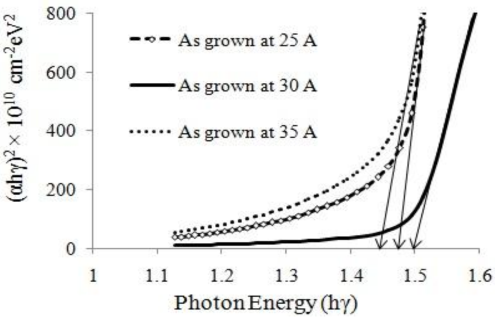

Fig. 3: Graph of (α*h*γ)2 versus photon energy *h*γ for CdTe thin films grown at 25 A, 30 A and 35 A.

Conclusion:

The structural and optical properties of CdTe thin films grown by thermal evaporation technique have been investigated elaborately by X-ray diffraction (XRD) and Ultraviolet visible (UV-Vis) spectrometry analysis. The XRD pattern reveals that the films grown by thermal evaporation process shows crystalline property with a preferential orientation along the (111) cubic plane and has been found at 2θ=23.8º. The highest crystallinity was observed for thermally evaporated CdTe thin films deposited at 30 A and comparatively lower crystallinity was obtained for thermally evaporated thin films deposited at 25 A and 35 A. 1.47, 1.49 and 1.43 eV are the band gap values that have been found approximately for the films deposited at 25 A, 30 A and 35 A, respectively. It has also been observed that the deposition current has a great influence on the films characteristics. By analyzing the structural and optical properties, it can be said that, CdTe is a good choice for a good quality absorber layer for CdS/CdTe solar cells.

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