INVESTIGATIONS ON ELECTRICAL PROPERTIES OF CADMIUM TELLURIDE THIN FILMS BY CHEMICAL BATH DEPOSITION TECHNIQUE

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The Cadmium Telluride (CdTe) thin films were prepared by chemical bath deposition (CBD) technique. The X-ray diffraction (XRD) analysis shows that the prepared samples are polycrystalline with cubic structure. Scanning electron microscopy (SEM) reveals that the grains are more uniformly distributed over the surface of the substrate for the CdTe films. The dielectric properties of CdTe thin films were studied in the different frequency range of 50Hz-5MHz at different temperatures. The frequency dependence of the dielectric constant and dielectric loss is found to decrease with increase in frequency at different temperatures. In addition, the electronic properties like valence electron plasma energy, average energy gap or Penn gap, Fermi energy and electronic polarizability of the CdTe thin films are also calculated.

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Keywords: CdTe Thin Films, XRD**,** SEM, Dielectric studies

1. Introduction

CdTe is a useful material for solar cell preparation. It is cheaper than silicon, especially in thin film solar cell technology. Cadmium telluride (CdTe) is a promising photovoltaic material for thin-film solar cells because of its near-optimum bandgap of ~1.5 eV and its high absorption coefficient. Small-area CdTe cells with efficiencies of more than 16% and commercial-scale modules with efficiencies of 11% have been demonstrated [1, 2]. However, the performance of CdTe cells has been limited by the conventional polycrystalline CdS/CdTe device structure. The CdTe thin-film solar cell has a large absorption coefficient and high theoretical efficiency. Moreover, large-area photovoltaic panels can be economically fabricated. Many fabrication techniques have been attempted for depositing CdTe thin films. Some are controlled atmosphere based techniques like sputtering [3], thermal evaporation [4], e-beam evaporation [5], Molecular-Beam Epitaxy (MBE) [6], Metalorganic Chemical Vapor Deposition (MOCVD) [7] etc. All these techniques are extremely expensive and require specialized equipment. In addition the size of the sample that can be coated is also limited because of the inherent in- homogeneous coating characteristics of the techniques. Many groups have attempted deposition of CdTe thin film by three electrode electro-deposition technique [8]. Though larger samples can be prepared by this method by having larger electrolyte bath and adjusting the counter electrode surface area, only one sample can be deposited at a time. The process will not have a high throughput in terms of thin film preparation. The Chemical Bath Deposition (CBD) technique has been widely used for depositing thin films [9].

In the present investigation, report the synthesis and characterization of CdTe thin films. The CdTe thin films subjected to study are characterized by X-ray diffraction, scanning electron microscopy (SEM) and dielectric studies. The scope of the present work is to study the dielectric properties of CdTe thin films as a function of the frequency and the temperatures. The electronic properties such as valence electron plasma energy, average energy gap or Penn gap, Fermi energy and electronic polarizability of the CdTe thin films required for the device application is also determined.

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2. Experimental

Chemical bath deposition technique (CBD) has been widely used to deposit films of many different semiconductors. It has proven over the years to be the simplest method available for this purpose, the typical components of a CBD system are a container for the solution bath, the solution itself made up of common chemical reactive salts, the substrate where the deposition of the film is going to take place, a device to control the stirring process and temperature, sometimes a water bath is included to ensure an homogeneous temperature. CdTe layers were deposited on commercial glass substrates of 1 mm thickness by the CBD technique. Cadmium acetate solution was prepared and ammonia was added drop wise until clear solution is obtained. Then tellurium oxide is dispersed in aqueous solution of sulphuric acid. Both solutions were magnetically stirred for 3 hrs under nitrogen atmosphere. Then two glass substrates were immersed into the solution for bath temperature 90°C.

3. Results and Discussion

3.1 Structural characterization

In order to determine the size and to study the structural properties of the synthesized CdTe thin films, the powder XRD analysis was performed. Structural identification of CdTe films was carried out with X-ray diffraction in the range of angle 2θ between 10º to 90º. Fig. 1 shows the XRD patterns for CdTe thin films, which were nanocrystalline in nature. The observed broad hump in XRD pattern is due to amorphous glass substrate. The well defined (111), (220), (311), and (331) peaks were observed in the XRD patterns. The (111) peak corresponds to phase of polycrystalline structure of CdTe. The strong and sharp diffraction peaks indicate the formation of well crystallized sample. It can be seen that the major peak (111) is strongly dominating the other peaks. The structure of CdTe deposited is predominantly cubic and reasonably crystalline.

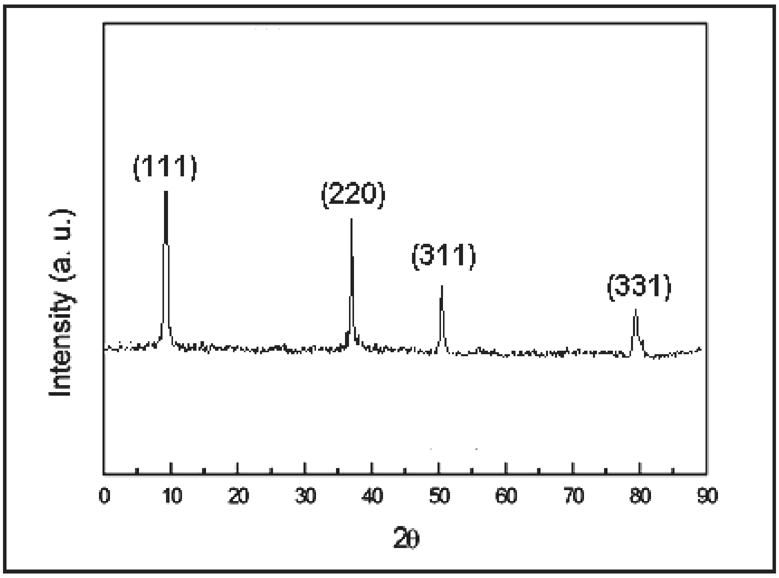

Fig.1.XRD spectrum of CdTe thin films

3.2 Surface morphology

Scanning electron microscope (SEM) was used for the morphological study of CdTe thin films. Fig. 2 shows the SEM images of the CdTe thin films. The CdTe thin films formed were highly agglomerated. The cube crystallites which have a mean particle size of ~ 12 nm are visible through the SEM analysis.

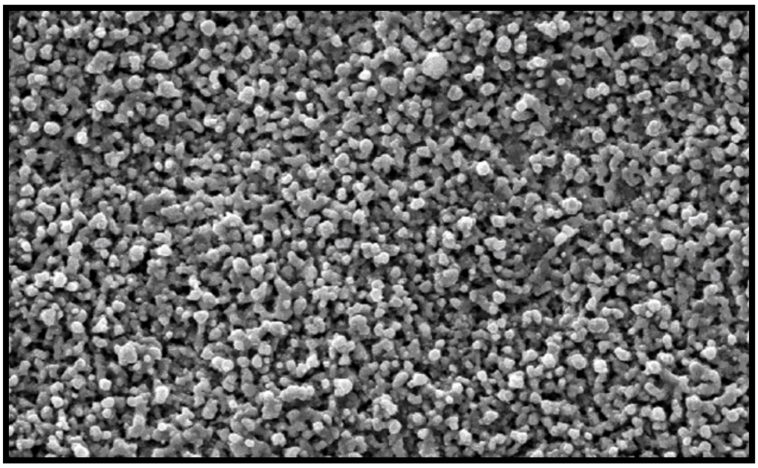

Fig.2 SEM micrograph of chemical bath deposition of CdTe thin film

3.3 Dielectric properties

The XRD patters of thin films have only one intense peak suggesting the noticeable disordered nature of the system, the same is also confirmed from the SEM micrographs. Structural information of thin films suggests simple or multifaceted defects such as defect centres, micro voids, imperfections, cracks, etc that may be present in the films. These defects play very important role in transport phenomena, as these defects originate the defect states like shallow and deep states which may act as donor or acceptors. Such type of states affect the transport phenomena in thin films to a great extent by acting as traps and recombination centres for carriers. These states may also lead to the probable formation of dipoles, which are responsible for the dielectric behavior. Transport of charge carriers between these sites, hop from a donor to an acceptor state. As a result, each pair of sites forms a dipole and contributes to distributed dielectric relaxation.

In the present studies of the dielectric constant and the dielectric loss of the CdTe thin films were studied at different temperatures using the HIOKI 3532 LCR HITESTER instrument in the frequency region of 50 Hz to 5 MHz. The dielectric constant was measured as a function of the frequency at different temperatures as shown in Fig.3, while the corresponding dielectric losses are depicted in Fig.4. Fig. 3 shows the plot of the dielectric constant (ε_r) versus applied frequency. It is observed (Fig.3) that the dielectric constant decreases exponentially with increasing frequency and then attains almost a constant value in the high frequency region. This also indicates that the value of the dielectric constant increases with an increase in the temperatures. The net polarization present in the material is due to ionic, electronic, dipolar and space charge polarizations [10]. The large value of the dielectric constant is due to the fact that CdTe thin films acts as a nanodipole under electric fields. The small-sized particles necessitate a large number of particles per unit volume, resulting in an increase of the dipole moment per unit volume, and a high dielectric constant. The dielectric loss studied as a function of frequency at different temperatures is shown in Fig.4. These curves suggest that the dielectric loss is strongly dependent on the frequency of the applied field, similar to that of the dielectric constant. The dielectric loss decreases with an increase in the frequency at almost all temperatures, but appears to achieve saturation in the higher frequency range at all the temperatures. In the low frequency region, high energy loss is observed, which may be due to the dielectric polarization, space-charge and movement of electrons in rotational fashion at low frequency range.

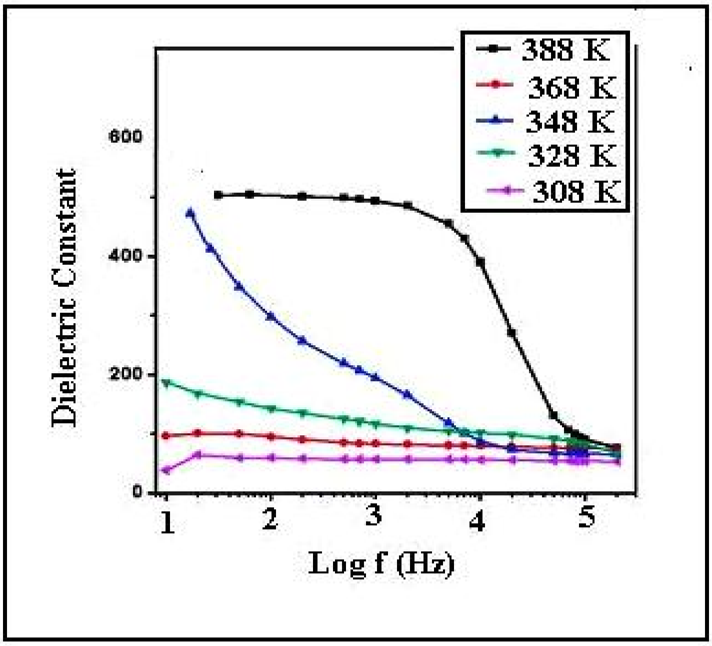

Fig.3. Dielectric constant of CdTe thin films, as a function of frequency

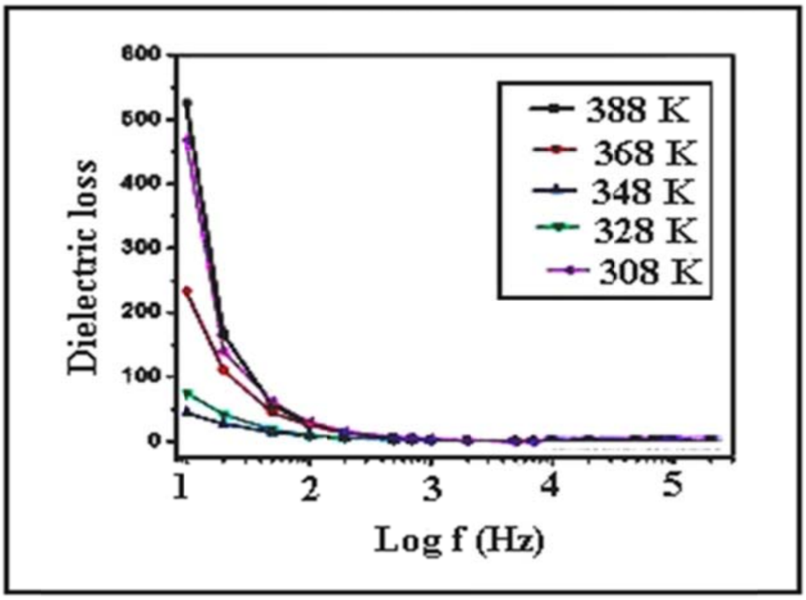

Fig.4. Dielectric loss of CdTe thin films, as a function of frequency

In the proposed relation, only one parameter viz, the high frequency dielectric constant is required as input, to evaluate electronic properties like valence electron plasma energy, average energy gap or Penn gap, Fermi energy and electronic polarizability of the CdTe thin films. The theoretical calculations show that the high frequency dielectric constant is explicitly dependent on the valence electron Plasma energy, an average energy gap referred to as the Penn gap and Fermi energy. The Penn gap is determined by fitting the dielectric constant with the Plasmon energy [11]. The valence electron plasma energy, $\hbar\omega_p$, is calculated using the relation [12],

$$\hbar\omega_P = 28.8\left(\frac{Z\rho}{M}\right)^{1/2} \qquad (1)$$

According to the Penn model [13], the average energy gap for the CdTe thin films is given by

$$E_P = \frac{\hbar\omega_P}{(\varepsilon_\infty - 1)^{1/2}} \tag{2}$$

where $\hbar\omega_P$ is the valence electron plasmon energy and the Fermi energy [11] given by

$$E_F = 0.2948(\hbar\omega_P)^{4/3} \tag{3}$$

Then we obtained the electronic polarizability α, using a relation [13, 14],

$$\alpha = \left[\frac{(\hbar\omega_P)^2 S_0}{(\hbar\omega_P)^2 S_0 + 3E_P^2}\right] \times \frac{M}{\rho} \times 0.396 \times 10^{-24} cm^3 \tag{4}$$

where S_0 is a constant given by

$$S_0 = 1 - \left[\frac{E_P}{4E_F}\right] + \frac{1}{3}\left[\frac{E_P}{4E_F}\right]^2 \tag{5}$$

The value of α obtained from equation (4) closely matches with that obtained using the Clausius-Mossotti relation,

$$\alpha = \frac{3}{4}\frac{M}{\pi N_a \rho}\left[\frac{\varepsilon_\infty - 1}{\varepsilon_\infty + 2}\right] \tag{6}$$

Considering that the polarizability is highly sensitive to the bandgap [15], the following empirical relationship is also used to calculate α,

$$\alpha = \left[1 - \frac{\sqrt{E_g}}{4.06}\right] \times \frac{M}{\rho} \times 0.396 \times 10^{-24} cm^3 \tag{7}$$

where E_g is the bandgap value determined through the UV absorption spectrum. The high frequency dielectric constant of the materials is a very important parameter for calculating the physical or electronic properties of materials. All the above parameters as estimated are shown in Table 1.

Table.1 Electronic properties of the CdTe thin films

Parameters	**Value**
Plasma energy ($h\omega_p$)	15.01 eV
Penn gap (E_p)	1.51 eV
Fermi Energy (E_F)	10.82 eV
Electronic polarizability (using the Penn analysis)	11.28 x 10^{-24} cm^3
Electronic polarizability (using the Clausius-Mossotti relation)	11.34 x 10^{-24} cm^3
Electronic polarizability (using bandgap)	11.18 x 10^{-24} cm^3

4. Conclusion

The XRD studies show that, films prepared are in nanocrystalline range and also diffraction peaks are found. The size and morphology of the CdTe thin films were characterized using scanning electron microscopy (SEM). The dielectric constant and dielectric loss of the CdTe thin films are measured in the frequency range of 50Hz-5MHz at different temperatures. The dielectric studies reveal that both the dielectric constant and dielectric loss decrease with an increase in frequency. Electronic properties such as plasma energy, Penn gap, Fermi energy and electronic polarizability of the CdTe thin films, which are required for device application, have been calculated.

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