OPTICAL AND STRUCTURAL PROPERTIES OF CADMIUM TELLURIDE THIN FILMS BY CHEMICAL BATH DEPOSITION METHOD

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Abstract:

Crystalline cadmium telluride thin films has been deposited using appropriate precursor solution containing cadmium sulphate, triethanolamine, sodium hydroxide, Ammonia and Sodium telluro sulphate in aqueous alkaline medium at 62 ±2^{0}C. The films were characterized by X-ray diffraction (XRD), scanning electron microscopy, Atomic absorption spectroscopy (AAS), optical absorption spectra and electrical measurements. The colour of formed film was found to be light gray. The crystalline phase of the deposited sample was cubic type. Optical absorption spectra showed the presence of direct transition with band gap energy 1.78 eV. The electrical resistivity of CdTe thin film was found to the order of 10^{-6} $(\Omega.cm)^{-1}$. Thermoelectric power (TEP) measurement showed n-type electrical conduction.

Keywords: *A. Chemical synthesis optical, structural, B n-type semiconductor.*

1. Introduction:

Cadmium telluride is a II-VI semiconductor compound which is considered of great importance due to its applications in optoelectronic devices, such as fabrication of photoelectrochemical (PEC) cells [1-2], non-linear optics devices [3], photoconductors [4-5], gas sensors [6], thin film transistors [7-8], gamma ray detectors [9], photoluminescence [10] etc. Thin films of CdTe have previously been prepared by various techniques such as electrodeposition [11-12], chemical vapour deposition [13], evaporation [14-15], sputtering [16], close-spaced vapour transport [17-18], screen printing [19], spraying [20] and chemical bath deposition [21].

Among these techniques, chemical bath deposition method is simple, inexpensive, easy, convenient and used for large area deposition. Cadmium telluride films are deposited using sodium tellurosulphate as a source of tellurium and structural, optical, Atomic absorption spectroscopy, morphological and electrical properties are presented.

2. Experimental details:

2.1 Deposition of CdTe thin film:

The chemical used, such as cadmium sulphate octahydrate ,liquor ammonia , Tellurium metal powder ,triethanolamine (TEA),sodium hydroxide and sodium sulfite (anhydrous) were of analytical grade. The glass substrate were cleaned using chromic acid, followed by rinsing in the ethanol and deionised water.

In actual experimentation deposition of CdTe thin films, cadmium sulphate octahedrate, complexed with TEA and sodium tellurosulphate where used as the source of tellurium ions, respectively. CdTe thin film was grown from following reactive precursor solution, 10 mL cadmium sulphate octahydrate and 5 mL of TEA were mixed with vigorous starring followed by addition of a mixture with ammonia and sodium hydroxyl solution to obtained pH 10.5. To this 10 mL Na_2TeSO_3 was added and finally diluted with 180 mL deionised water. Na_2TeSO_3 solutions were prepared above the reference [22] The reactive solution was kept in oil bath. The glass substrate were mounted vertically on a specially designed substrate holder and rotated in the reaction mixture with a speed of 70 ±2 rpm. The temperature of the bath was then allowed to increase slowly up to 62 ±2 ^{0}C. After 2 hours, the glass substrate were removed washed with distilled water several time, dried naturally and kept in desiccators over anhydrous calcium chloride .The resultant film was found to be homogeneous well adherent to the substrate and light gray in color.

2.2 Characterization of thin film:

The thickness of CdTe thin films was measured with commonly used weight difference method and it is found to be 0.509 ùm. The structural properties of the deposited CdTe thin film samples were recorded by a Philips PW-1710 XRD with Cuk_α radiation in the 2θ range from 10-80Ǻ.Scanning electron microscope (SEM) were used for the surface morphological studies. The optical absorption spectra were recorded in the wavelength range from 300-900 nm using UV-visible double beam spectrophotometer at room temperature with respect to identical uncoated substrate as a reference. The dc electrical resistivity and thermoelectric power measurements of CdTe thin films were carried out using a two probe method in the temperature 300-525 K. A quick drying silver paste was applied for better ohmic contact purposes.

3) Results and discussion:

3.1 Growth of thin film:

The deposition of CdTe thin film were made using reactive precursor solution containing sodium tellurosulphate as a source of telluride ions and cadmium ion complexed with (TEA) in a alkaline medium. In this growth process, triethanolamine act as a complexing agent for the cadmium ion. The growth of the film can be understood from the following reaction.

$Na_2TeSO_3 + OH^- \longrightarrow Na_2SO_4 + HTe^-$……………(1)

$HTe^- + OH^- \longrightarrow H_2O + Te^{2-}$……………(2)

Thin films formation is a thermally activated process. Thermal decomposition of metal complex releases metal ions. Sodium tellurosulphate hydrolyses in alkaline solution to yields Te^{2-} ions. The proposed overall growth reaction of CdTe thin film formation is given below –

$Cd^{2+} + nTEA \longrightarrow [Cd(TEA)_n]^{2+}$ …………………..(3)

$[Cd(TEA)_n]^{2+} + Te^{2-} \longrightarrow CdTe + (nTEA)$..............(4)

However such a growth process is found to be influenced by various other factors such as deposition temperature, time deposition etc.

3.1.1 Thin film deposition temperature:

At room temperature it forms clear solution and no film or, precipitate is observed. At low temperature, lower the kinetic energy of ions and avoids the precipitate. As the temperature increases slower, kinetic energy increases as a result decomposition of sodiumtellurosulphate and metal complex take place in alkaline medium favors the formation of CdTe thin film. The terminal layer thicknesses of the deposited films were measured with respect to different temperatures. The observed layer thickness increased almost linearly with increasing temperature up to 62 ±2^{0}C.

Above higher temperature, the reaction gives precipitation rather than film formation. This was indicated by the precipitate in the reaction container as a result layer thickness of CdTe thin film was found to be decreased as shown in fig.1 (a).

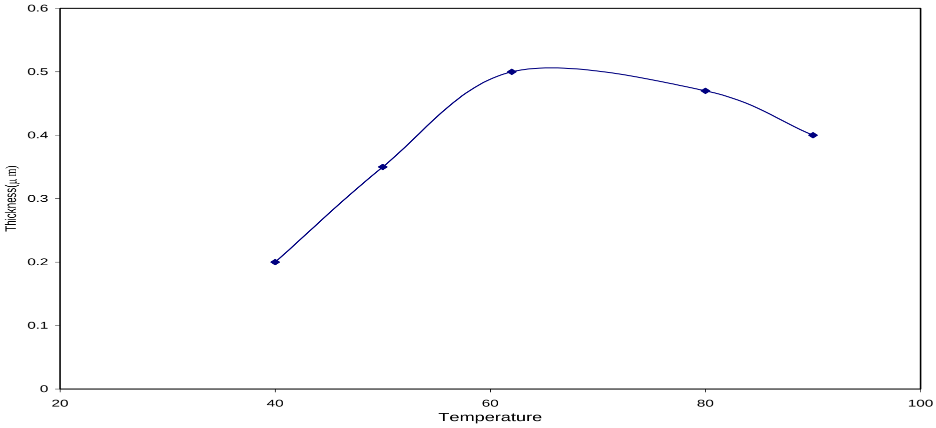

Fig. 1a: Variation of the film thickness with deposition temperature.

3.1.2 Thin film deposition time:

In time growth process, no film formation occurs within the first half an hours. This is the induction period required to form nucleation centers on the substrate. The presence of period suggests that ion-by–ion growth mechanism. This study revealed that homogenous CdTe films have been deposited at 150 min.The thickness was measured every 20 min and plotted against time as shown in Fig 1 (b).

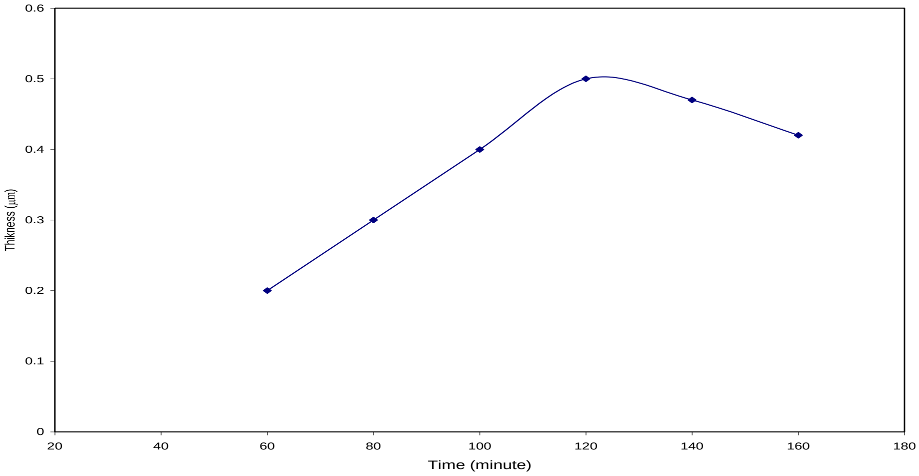

Fig. 1b: Variation of the film thickness with deposition time.

Speed of rotation 7 0±2 rpm was selected to deposit CdTe thin films. At lower speed, thick non- adherent films deposited and higher speed very thin film was deposited. The terminal thickness was found to be 0.509 ùm.The best conditions in the deposition process for yielding quality film at 62 ±2^{0}C and 150 min respectively.

3.2 X-ray and Morphological Studies:

The crystallographic studies of as deposited CdTe thin films were examined by X-ray diffractometer. Literature survey revealed that CdTe has monostrcutural phase such as cubic type. The XRD pattern of as deposited films shows very poor crystallinity. The XRD pattern of an as deposited and annealed CdTe films is shown in fig.2a and 2b.

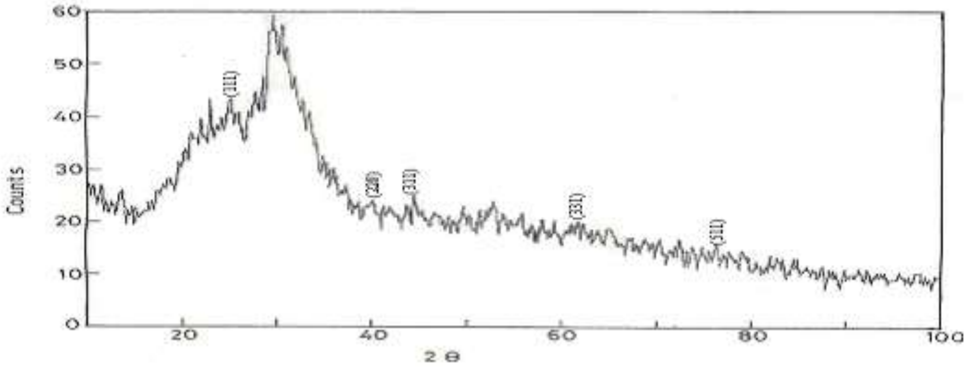

Fig. 2a: XRD pattern of ‘as deposited’ cadmium telluride thin film.

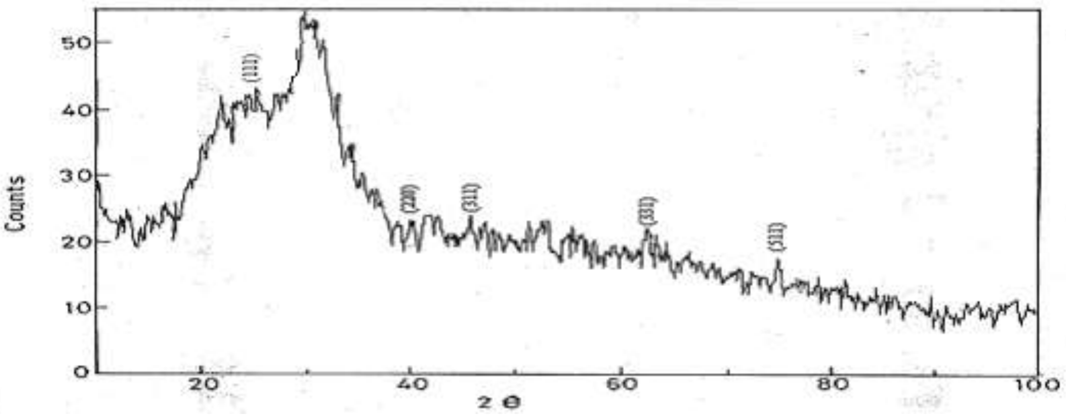

Fig. 2b: XRD pattern of ‘as annealed’ cadmium telluride thin film.

A Comparison of observed d- value with standard d- value confirms that chemically deposited film shows cubic structure (JCPDS-150770). The XRD pattern shows the highest intensity reflection peak at d=-3.7048 Ǻ (111).the diffused background is due to amorphous glass substrate and also some amorphous phase present in the CdTe thin films. Along with (111), plane, (220), (311), (331). (511) peaks also observed. The significant improvement in crystallinity is due to increased in grain size into effectively crystals after annealing. The crystalline phases dominate over the mixture of amorphous phase. The lattice parameters of cubic phase were calculated by using following equation.

$$a = d\,(h^2 + l^2 + k^{2)1/2-}\ldots\ldots\ldots \quad (5)$$

The lattice parameter ‘a’ of annealed films is found to be 6.1120 Ǻ. The crystallite size of CdTe films was calculated by using Scherrers formula

$$D = k\lambda / \beta \cos\theta\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where, D is crystallite size, λ is the X-Ray wavelength used, β is the angular quantum line width of half maximum intensity, θ is Bragg’s diffraction angle and k is constant, 0.94 for CdTe.

3.2 Scanning electron microscopy:

Scanning electron microscopy is an excellent method to study morphology of the sample .The SEM micrograph of as deposited and those annealed at 100^0 C are shown in fig 3(a) and 3(b) respectively at 1000X magnification as deposited CdTe thin film is homogeneous, with cracks or holes and well cover to the glass substrate from the micrographs, it is clearly seen that the films composed of minute grains was uniformly that may correspond to amorphous phase of CdTe thin film.

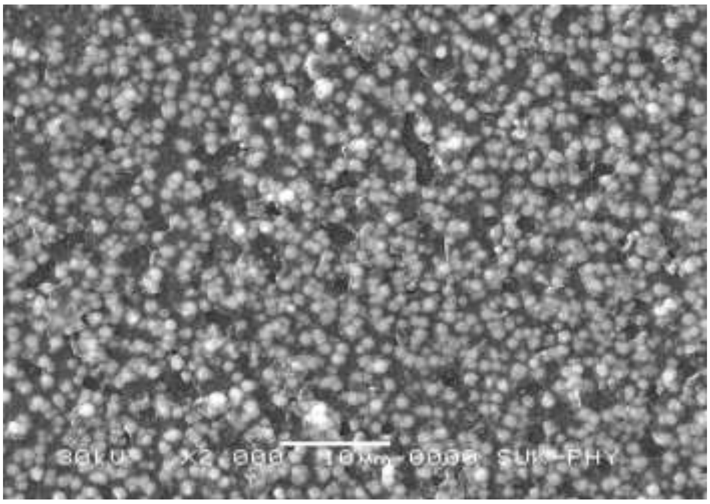

Fig. 3a: SEM micrograph of cadmium telluride 'as deposited' thin film.

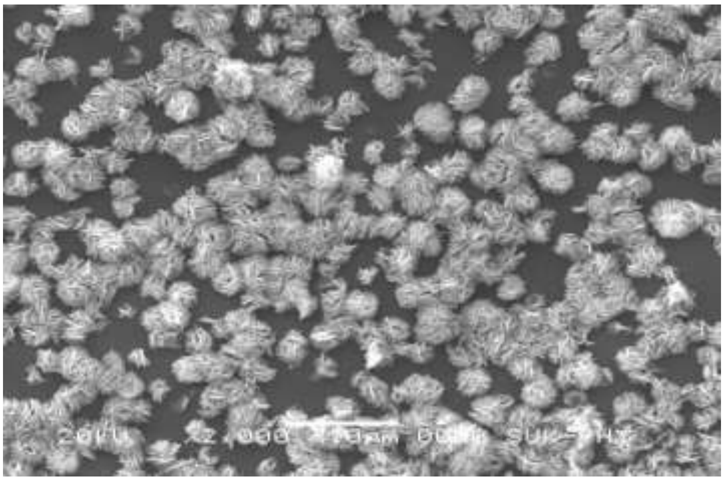

Fig. 3b: SEM micrograph of cadmium telluride 'as annealed' thin film.

In annealed films, the grain are more distinct and of bigger size. The increase in grain size leads to decrease in grain boundaries .The presence of the fine background is an indication of one step growth by multiple nucleation. The crystallographic parameter and average grain size of samples are reported in table no 1 .The Compositional analysis of CdTe thin films was done by using atomic absorption spectroscopy. The compositional stoichometry of CdTe sample are given in table no. 2. The results obtained by these techniques are in good agreement.

Table 1: Crystallographic parameter of CdTe thin film.

Film	d values (Å)		hkl planes	Grain size(SEM) (Å)	cell parameter a (Å)	Activation energy(eV)	
	ASTM	Observed				H.T.	L.T.
CdTe	3.7420	3.7048	111	214	6.1120	0.24	0.15
	2.2900	2.2794	220				
	1.9540	1.9718	311				
	1.4880	1.4848	331				
	1.2470	1.2653	511				

Table No.2: Compositional analysis of CdTe thin film.

Film	Bath content (ppm)		Film content in AAS (ppm)	
	(Cd)	(Te)	(Cd)	(Te)
CdTe	1215	810	808	465

3.3 Optical properties:

The optical absorption spectra of as deposited CdTe film on to non- conducting glass substrate was studied at the room temperature in the wavelength of 400- 850 nm without considering transmission and reflection. The plot of $(\alpha h\nu)^2$ vs. hν is shown in fig. 4

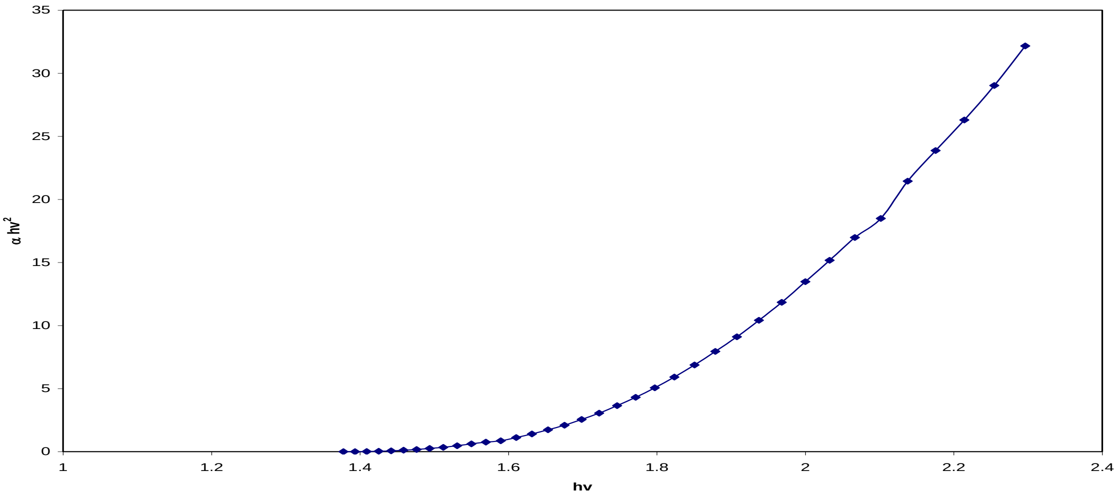

Fig. 4: Plot of (□ hυ^{2}) vs. hυ to determine the optical band gap of cadmium Telluride thin film.

The as deposited samples gave better results due to the fact that helps grain growth and restructuring of the films, leading to better properties. The value of absorption coefficient is depends upon radiation energy as well as the composition of films. The simplest forms of the equation obeyed linear and above absorption edge.

$$\alpha = (A/ h\upsilon) \quad (h\upsilon - Eg)^{n} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where hυ is the photon energy, Eg is the band gap, A and n are constant. A is depending upon temperature phonon energies etc.The linear nature of plot shows that the existence of the direct transition. Extrapolation of the linear portion of the curve to $\alpha^{2} = 0$ gives the optical band gap, which is about 1.78eV. The values of band gap obtained agree well with results of previously reported CdTe thin films [23-24]. The observed value is greater than standard band gap values of CdTe material. This is because due to size quantization occurs due to localization of electrons and holes in combined volumes of the semiconductor material.

3.4 Electrical and transport properties:

The electrical conductivity was measured in the temperature range 300 – 525 K. It is observed that the conductivity on the film increases with increasing temperature this indicates semi conducting behavior of the film.   . The plot of log □ (conductivity) □ Vs inverse absolute temperature for the cooling curve is shown in fig.5

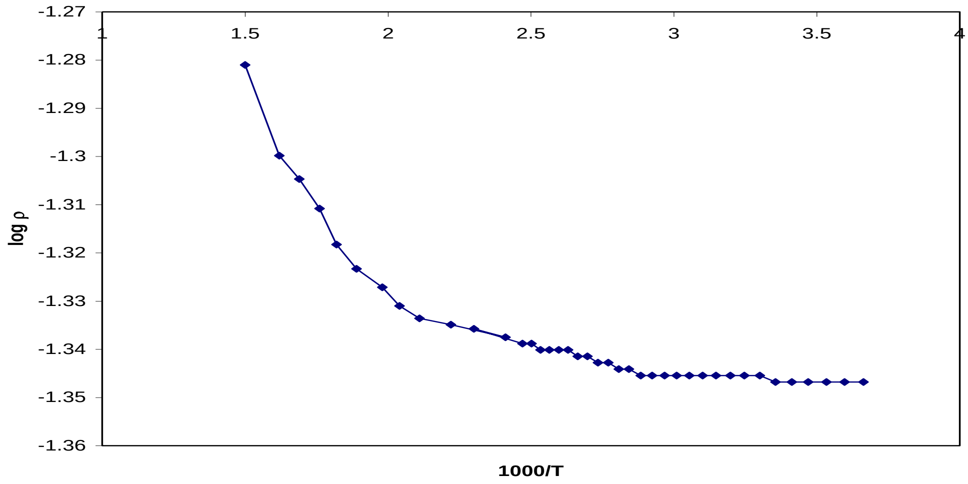

Fig. 5: The variations of log (conductivity) with inverse temperature.

The nature of the plot is nonlinear type indicating the presence of two linear region, as intrinsic region setting at low temperature, characterized by small slope (300- 350). High temperature region is associated with extrinsic conduction due to the presence of donor states. The activation energy is calculated using exponential form of Arrhenius equation.

$$\square = \square_o \exp \quad (- Ea / kT)$$

where, Ea is a activation energy, $\square_o$ is a constant, k is a Boltzmann constant, T is a absolute temperature, □ is a conductivity. The activation energies of CdTe film were found to be 0.24 eV at higher temperature and 0.15 eV at low temperature. The thermoelectric power measurement for CdTe film showed n-type electrical conduction mechanism.

4) Conclusion:

CdTe thin films have been deposited using chemical bath deposition method. The films were found to be polycrystalline with cubic structure. The SEM analysis showed the crystalline nature of the material. The analysis of optical absorption data showed band gap energy Eg 1.78 eV. The Electrical resistivity of CdTe sample was found to be in the order of 10^{-6} (΄Ω.cm)$^{-1}$**.** TEP measurements showed n-type electrical conduction mechanism.

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