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Preparation and characterization of cadmium telluride thin films by chemical bath deposition method

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ABSTRACT

Crystalline cadmium telluride thin film has been deposited using appropriate precursor solution containing cadmium sulphate, triethanolamine, sodium hydroxide, Ammonia and Sodium telluro sulphate in aqueous alkaline medium at 335K. The films were characterized by X-ray diffraction(XRD), scanning electron microscopy, 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 1.45eV. 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

CdTe thin films;
Chemical bath deposition (CBD);
XRD;
SEM.

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, morphological and electrical properties are presented.

EXPERIMENTAL

Deposition of CdTe thin film

The AR grade chemicals such as cadmium sulphate octahydrate, tellurium, triethanolamine, sodium hydroxide, ammonia solution and anhydrous sodium sulfite were used. The substrates(glass plates) cleaning was done by washing successively with chromic acid, fol-

lowed by rinsing in alcohol and distilled water.

Cadmium telluride thin films were deposited onto glass substrates by using chemical bath deposition method. 5mL 1M cadmium sulphate octahydrate complexed with triethanolamine, ammonia and 1M sodium hydroxide solution were used to maintain the pH at 10.5. Whole solution was diluted to 150mL with distilled water. The reaction solution was kept in oil bath and temperature of oil bath increased to 335K. The glass substrates were mounted vertically on a specially designed substrate holder and rotated in thee reaction mixture with a speed of 60±2 rpm. Then 5ml 1M sodium telluro sulphate was added from the outside.

Sodium telluro sulphate was obtained by refluxing 1g of metallic tellurium powder and anhydrous sodium sulphite(2.4g) in distilled water at 373K for 24hrs. The resulting concentration of tellurium sulphate was 1M[22]. After about 120mins. The glass substrates were removed, washed with distilled water, dried naturally and kept in dessicator. The colour of the formed film found to be light grey.

Characterization of thin film

The weight difference method was used to determined the thickness of CdTe thin film. The structural properties of the deposited CdTe thin film were studied by a Philips PW-1710 XRD with Cu k_α radiation in the 2θ range from 10^0C-100^0C. Scanning electron microscope(SEM) was used for the surface morphology study. The optical absorption spectra were recorded in the wavelength range from 300-900nm 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 300-500K. A quick drying silver paste was applied for better ohmic contact purposes.

RESULTS AND DISCUSSION

Growth of thin film

The deposition of CdTe thin film was made using reactive precursor solution containing sodium tellurosulphate as a source of telluride ions and TEA complex as the source of cadmium ion 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.

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

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

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

$$Cd^{2+} + nTEA \longrightarrow [Cd\,(TEA)\,n]^{2+} \ldots \quad (3)$$

$$[Cd\,(TEA)n]^{2+} + Te^{2-} \longrightarrow CdTe + (nTEA)\ldots \quad (4)$$

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

Thin film deposition temperature

At room temperature, the film was not formed because all the ions are in a complex bound state. Hence the temperature of reaction container was increased from room temperature to 335K to get homogenous and adherent CdTe thin film. The terminal layer thickness of the deposited film was measured with respect to different temperatures. The observed layer thickness increased almost linearly with increasing temperature upto 335K. Which was decreased at higher temperature 355K.

Above 335K temperature, the reaction gives precipitation rather than film formation. This was indicated by the presence of precipitate in the reaction container as a result layer thickness of CdTe thin film was found to be decreased as shown in figure 1(a).

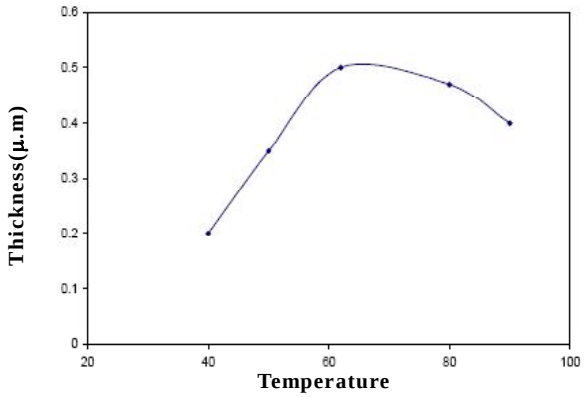

Figure 1a: Variation of the film thickness with deposition temperature

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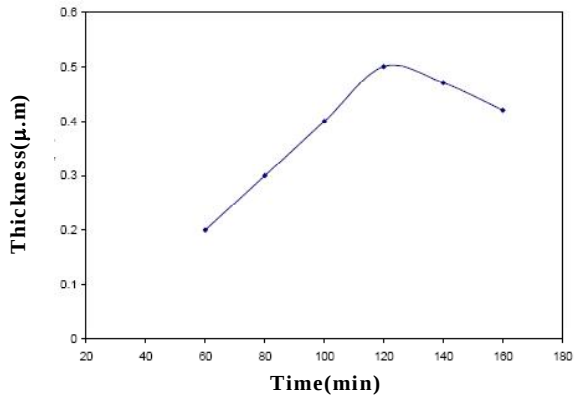

Figure 1b: Variation of the film thickness with deposition time

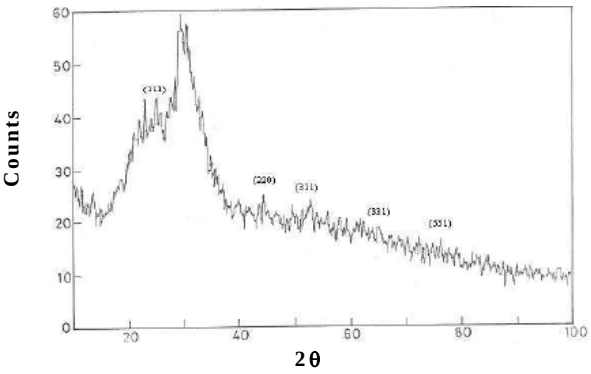

Figure 2a: XRD pattern of 'as deposited' cadmium telluride thin film

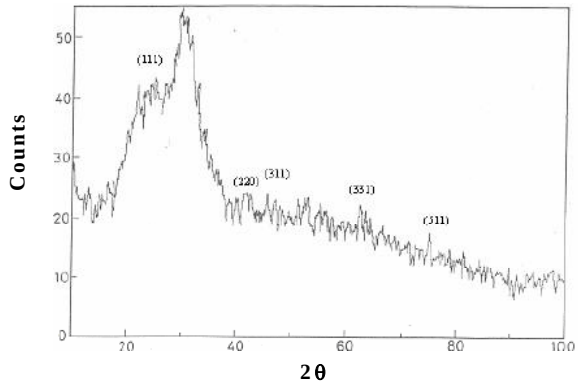

Figure 2b: XRD pattern of 'as annealed' cadmium telluride thin film

TABLE 1: Crystallographic parameter of CdTe thin film

Film	d values (A°)		hkl	Grain	cell parameter,
	ASTM	Observed	planes	size(Å)	a (Å)
	3.7420	3.7048	111		
	2.2900	2.2794	220		
CdTe	1.9540	1.9718	311	214	6.1120
	1.4880	1.4848	331		
	1.2470	1.2653	511		

Thin film deposition time

The duration of the thin film formation was studied. For this, the film deposition time was increased upto 180 min. The substrates were subsequently removed from the reaction solution at different times, (80,100,120,140,160 and 180min). In the present study, CdTe thin films have been deposited at 120min. The layer of thickness was measured after every 20min and plotted against time which is shown in figure 1(b).

It is seen that film growth is time dependent and was initially linear, which showed saturation after end.

X-ray and morphological studies

The crystallographic properties of CdTe thin film was investigated with X-ray diffraction. The reflections were compared with JCPDS(15-0770), diffraction pattern[23]. The observed 'd' values correspond to cubic phase of CdTe and therefore are indexed according to cubic structure. The prominent peaks showed by the sample corresponds to the reflections from (111), (220),(311),(331) and (511) planes as shown in TABLE 1.

The XRD pattern of the annealed sample showed higher peak intensity, due to the high crystallinity than that of 'as deposited' CdTe thin film. The diffused background is due to the amorphous glass substrate and also may be due to the presence of same amorphous CdTe thin film. The (hkl) indices are shown above the reflection in figure 2.

The lattice parameter of cubic phase was determined by using the relation

$$1/d^2=(h^2 + k^2 + l^2)/ a^2$$

The lattice constant was calculated by taking an average of all the observed diffraction peaks. The average grain size of CdTe thin film was calculated by using the Scherrer formula

$$D = k \lambda/B \cos \theta$$

Where D is average crystalline size, λ is wavelength in Å, B is half maximum line width and k is constant

The average grain size of the CdTe thin film was found to be 214Å.

The SEM micrograph of as deposited film and those annealed CdTe thin films at 423 K are shown in figure 3(a) and figure 3(b) at 10000 x magnification. The surface morphology clearly shows that film was uniformly

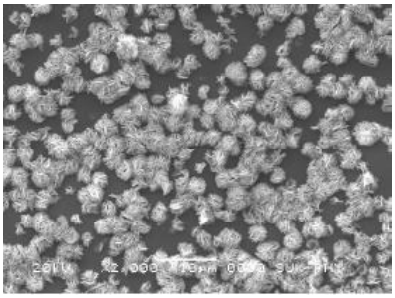

Figure 3a: SEM micrograph of cadmium telluride 'as deposited' thin film

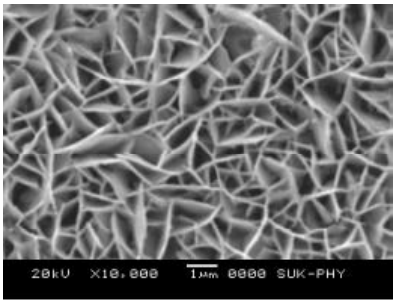

Figure 3b: SEM micrograph of cadmium telluride 'as annealed' thin film

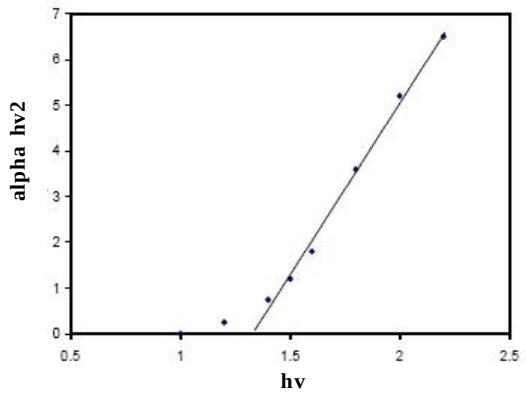

Figure 4: Plot of ($\alpha h\nu^2$) vs. hv to determine the optical band gap of cadmium telluride thin film

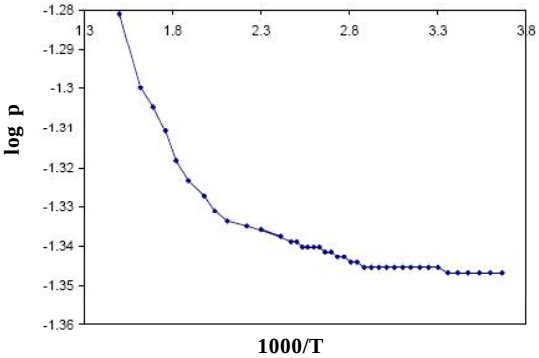

Figure 5: The variations of log (conductivity) with inverse temperature

deposited and has compact structure. In annealed film figure 3(b) the grains are more distinct and of size. The increasing grain size leads to the decrease in the grain boundaries, while in unannealed film (figure 3a), the grains are of smaller size, more compact with cracks.

Optical properties

The plot of $(\alpha h\nu)^2$ vs. hν is shown in figure 4 These results are in good agreement with those already reported[21,24,25,27]. The annealed sample gave better results due to the fact that heating helps grain growth and restructuring of the films, leading to better properties. The observed straight-line behaviour established that the film has direct band gap is 1.45eV.

Electrical and transport properties

The electrical conductivity was measured in the temperature range 303-500K. It is observed that the resistivity decreases with increases in temperature indicating semiconducting nature. At room temperature resistance of film was found to be order of $10^6\Omega$.cm. The plot of log σ vs. inverse absolute temperature for the film is shown in figure 5 The nature of the plot is nonlinear type indicating the presence of two types conduction mechanisms. The temperature dependence of electrical conductivity can be calculated Arrhenius equation

$$\sigma = \sigma_o \exp(-Ea / kT)$$

where, Ea is a activation energy, σ_o is a constant, k is a Boltzmann constant, T is a absolute temperature, σ is a conductivity.

The activation energies of CdTe film were found to be 0.24eV at higher temperature and 0.15eV at low temperature. The thermoelectric power measurement for CdTe film showed n-type electrical conduction mechanism.

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) 1.45 eV. The Electrical conductivity of CdTe sample was found to be in the order of $10^6\Omega$.cm. TEP measurements showed n-type electrical conduction mechanism.

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