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Structural and Optical Studies of Vacuum Evaporated Cadmium Lead Telluride Thin Films

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ABSTRACT

The ternary compounds cadmium lead telluride have been prepared by oxalic acid method. Thin films were coated on glass substrates by vacuum evaporation method (Hindhivac 12A4). The structural properties of the material have been studied using X-ray diffraction technique. The result shows that material is crystalline in nature and the peaks in the XRD graph of CdPbTe corresponds to cubic structure. The lattice parameter and grain size have been calculated. The surface morphology of the thin film is studied using Scanning Electron Microscope (SEM). The SEM analysis shows that surface of the film is uniform and crystalline in nature. Thicknesses of the films have been determined by gravimetric method. The optical absorbance and transmittance have been studied by using UV spectrophotometer in the range of wavelength 300-1100 nm. The optical band gap of this material is found to be 1.24 ev.

Key words: Vacuum evaporated, cadmium, lead, thin films

INTRODUCTION

Thin film science and technology plays an important role in the high tech industries. The PbTe-CdTe system constitutes an attractive material for development of certain electronic or optoelectronic devices (Bukala *et al*., 2012; Scheidt *et al*., 2005; Rusu, 2001). The PbTe belongs to the group of IV-VI narrow gap (0.23 eV) semiconductor compounds and crystallizes in the six fold coordinated lattice of rock salt type structure while the CdTe belongs to the group of II-VI middle gap (1.45 eV) semiconductor compounds and crystallizes in the four fold coordinate zinc blend type structure (Sakthivel *et al*., 2009).

From the chalcogenide, semiconductors have been motivated by their importance in infrared devices, photovoltaic, solar cells fabrication and high temperature thermoelectric. CdTe is an important semiconductor with potential application in solar cell technology (El-Mongy *et al*., 1997; El-Kadry *et al*., 1995; Enriquez *et al*., 2004). CdTe can exhibit both types of conductivity; N and P which makes diode technology and field effect transistors possible and it can exhibit a semi-conducting state. PbTe attracts a lot of interest due to its thermoelectric properties. PbTe have been used for many years as infrared photoconductive detectors (Zemel *et al*., 1965; Mousa and Ponpon, 2007). PbTe in particular is the end-compound of several ternary and quaternary high performance high temperature thermoelectric materials. Thermoelectric devices have been used in broad areas such as refrigerators and in cooling units for fiber junctions in optical fiber communication technology. Recently, also ternary system based on lead telluride increases monotonically when alloyed with cadmium telluride.

In this study, CdPbTe ternary powder has been synthesized by oxalic acid method. CdPbTe material is coated on glass substrates by vacuum evaporation method (Chandramohan *et al*., 2006). The structural, optical and electrical properties are studied by X-ray diffraction analysis, Scanning Electron Microscopy (SEM) and UV-Vis spectrophotometer, respectively.

METHODOLOGY

In preparing the powder, cadmium oxide, lead oxide and tellurium powder were weighed according to their atomic percentage. The proportion of mixture is responsible for the conductivity and other properties of the film. Lead oxide and cadmium oxide were dissolved in the solution prepared by mixing oxalic acid and triple distilled water. Tellurium powder was added to the solution. The complete mixture was heated at 95°C for 8-10 h with refluxing technique. The purity of the powder depends on the method of the heating process and refluxing technique. After 10 h of heating, the entire solution was allowed for ageing (around 20 h). The continuous heating process allows the tellurium metal powder to react with the PbO, CdO and oxalic acid. The undissolved Te residue should be removed from the mixture and it was done through filtration process. The filtration process plays a vital role in the removal of undissolved tellurium from CdPbTe. The ageing process allows the compounds to settle for a certain period of time. Thus the subsequent heating keeps the powder to mix thoroughly with the compounds. The final product of the filtration process was the required powder which will be settled in the 42 whatmann filter paper which is placed in a glass dish and the powder was heated in the oven. The powder on heating turns into a grey colour, it was the CdPbTe powder a ternary compound.

Usage of certain instruments in good and cleaned form also had important part in the yield of the powder. The method adopted for this study is the vacuum evaporation technique on clean glass substrates (Khan *et al*., 2012). The vacuum coating unit employed was HINDIVAC, model 12A4. DC 704 was the silicon fluid used in the diffusion pump. The material in the powder form is taken in the molybdenum boat and placed inside the chamber and made it air tight. Water circulation was opened and backing, roughing and baffle valves were used to get 1×10^{-5} Torr pressure for coating.

The powder x-ray diffraction studies on the synthesized nanoparticles were performed using Seifert JSO-2002 using CuK_{α} (1.5406ε) radiation. Structural properties were studied using gravimetric method. Absorbance, transmittance and band gap were studied using UV-visible spectrophotometer in 300-1100 nm range.

RESULTS AND DISCUSSION

X-ray diffraction analysis: The XRD pattern for CdPbTe is shown in Fig. 1.

As the 2θ value increases the intensity of absorption also varies and the maximum value was found to be 2θ = 23.734°. Crystal structure of the CdPbTe material was cubic for the (111) plane. The crystalline size (D) is calculated using the Scherrer's formula from the full width at half maximum (β) using the relation, β = 0.314:

$$D = \frac{0.94\gamma}{\beta\cos\theta}$$

The strain (ε) is calculated by the equation:

$$\varepsilon = \frac{\beta\cos\theta}{4}$$

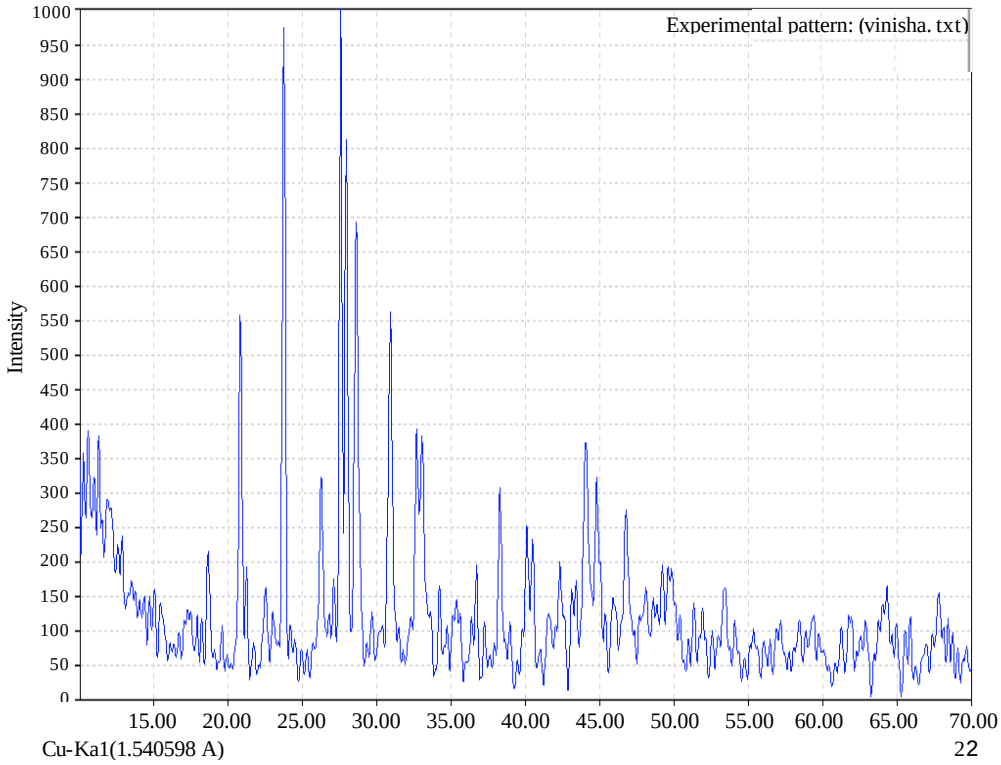

Fig. 1: XRD pattern of CdPbTe powder

Table 1: Grain size, strain, dislocation density and lattice constaxt of CdPbT (III) cubic phase

(D) (nm)	Strain ($\varepsilon\times10^{-4}$) (line^{-2} m^{-4})	Dislocation density ($\delta\times10^{13}$) (line m^{-2})	Lattice constant (a) Å
26	13.69	147.92	6.4879

The dislocation density (δ) is evaluated from the relation:

$$\delta = \frac{1}{D^2}$$

The lattice parameter 'a' is calculated from the Laue Method and is found to be:

$$d = \frac{a}{\sqrt{\left(h^2 + k^2 + l^2\right)}}$$

(hkl) is the miller indices of the peaks. The Grain size (D), Strain (ε), Dislocation Density (δ), Lattice Constant (a) for the sample CdPbTe (111) cubic phase have been calculated and the values are shown in Table 1.

SEM analysis: Micro structural investigations of thin films on glass substrate are carried out using scanning electron micrograph (Vega 3 series). The SEM micrographs are analyzed

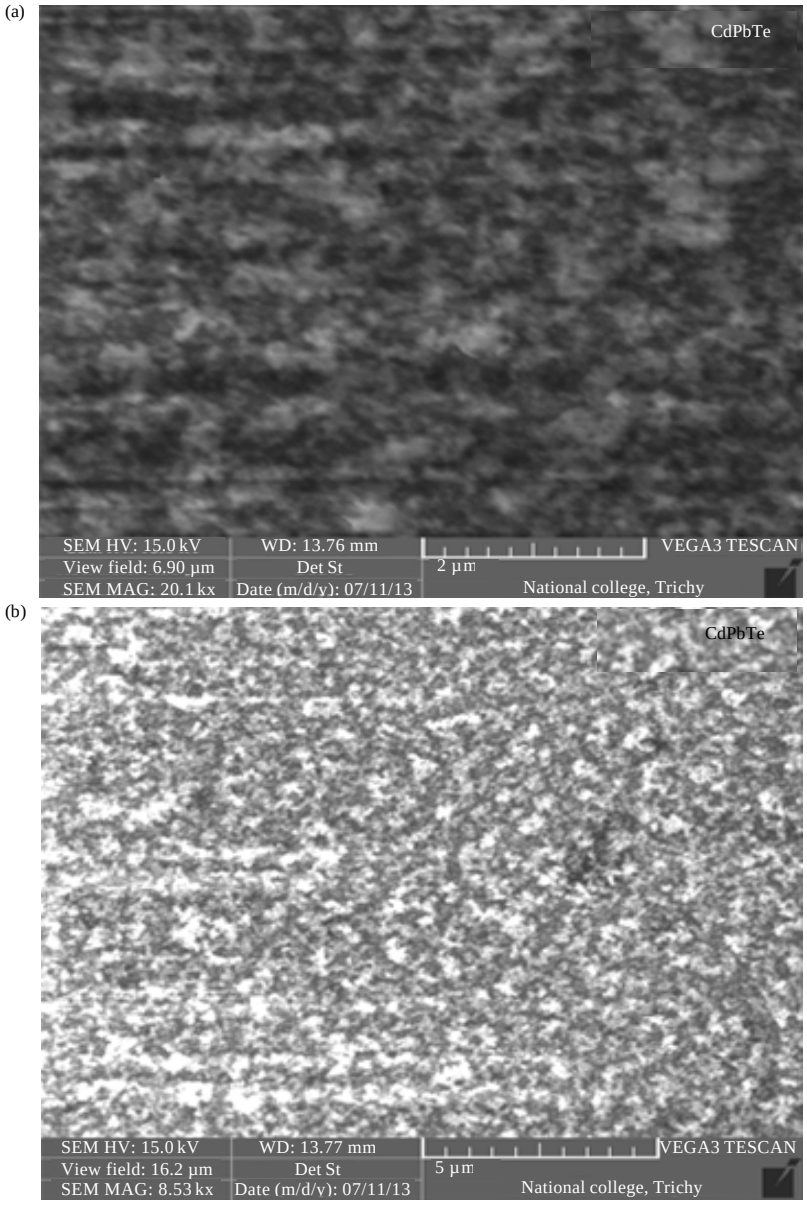

Fig. 2(a-b): SEM images of CdPbTe

at a resolution of 2 and 5 µm, respectively. The SEM micrograph indicates that the orientations of the particles are uniform on the surface of the film. The SEM images are shown in Fig. 2a and b.

Optical properties: The optical absorption spectrum was taken in the range of 300-1100 nm wavelength. The Fig. 3 shows the variation of absorbance for the different wave length λ. A linearly varying absorbance graph highlights the good mobility factor in the film which ensures a good band gap value of the semiconductor thin film.

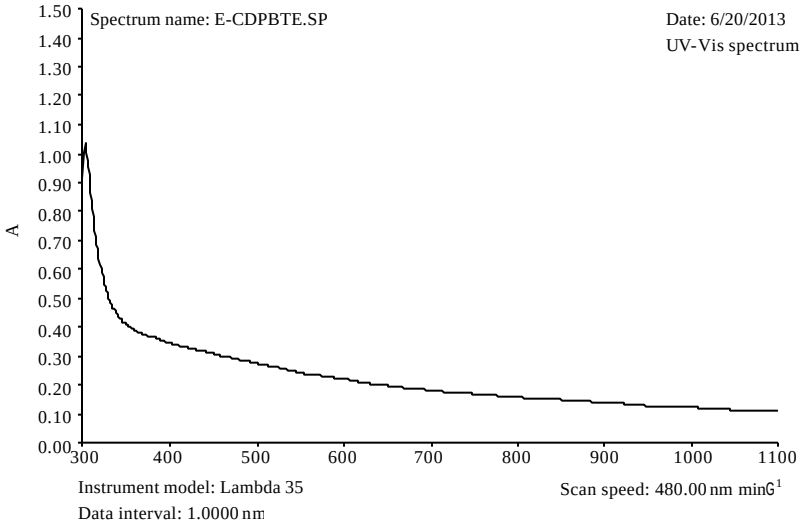

Fig. 3: Absorbance vs. wavelength

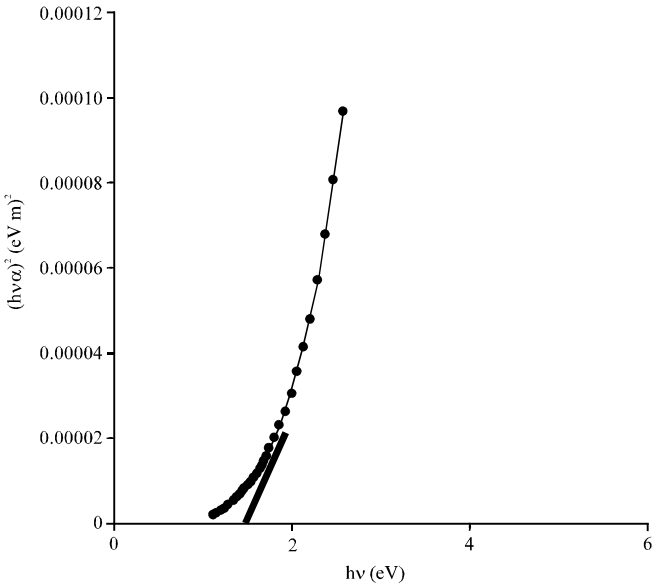

Fig. 4: Band gap estimation plot ($(h\nu\alpha)^2$ vs. photon energy

The optical energy band gap was calculated from the absorption values of the different samples. The absorption coefficient is calculated using the following equation:

$$\alpha = 2.303 \times abs/t$$

and with the photon energy $h\nu$, the values of $h\nu\alpha$ and $(h\nu\alpha)^2$ were also found.

The graphs drawn between the linear dependence of variation in the square of absorption coefficient as a product of incident photon with the photon energy i.e., $(h\nu\alpha)^2$ vs. $h\nu$ have been shown in the Fig. 4. The band gap value is given by 1.24 eV.

CONCLUSION

The ternary compound CdPbTe powder has been prepared by oxalic acid method by the vacuum evaporation method on glass substrates. The XRD studies have revealed that the sample is crystalline in nature and has cubic structure. The structural parameters like grain size, strain, dislocation density and lattice constant have been calculated from the XRD Pattern. The SEM images confirm crystalline nature, particles are found to be uniform on the surface. The thickness of CdPbTe has been found by gravimetric method. From the optical studies, the energy band gap of thin films is found to be in the range of 1.24 eV.

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