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Thermoelectric Properties of $Zn_xPb_{(1-x)}Te$ Thin Films By Thermal Evaporation.

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ABSTRACT

Thin films of Zinc lead telluride ($Zn_xPb_{(1-x)}Te$) of solid solution with x = 0.1, 0.2, 0.3, 0.4, and 0.5 were synthesized, from the resulting ZnTe and PbTe composition used in preparation of thin films. The deposited samples were annealed and annealed samples were used for characterization. The semiconducting and thermoelectric properties of the samples were investigated by measuring electrical resistivity and Seeback coefficient in the temperature range from 300 to 473 K for annealing samples. Activation energy for charge transport have been evaluated and found in the range of 0.269 to 0.396 eV. Thermoelectric power has been measured and found to be positive indicating that the samples are p-type semiconducting material. The X-ray diffraction analysis and EDAX confirmed that films are polycrystalline in nature.

Keywords: Thermal Evaporation, EDAX, XRD, Activation energy, TEP.

INTRODUCTION

Solid solution formation in semiconductors has been of interest for a number of years. This interest has been generated because solid solution between two or more semiconductors immediately gives rise to a completely new series of semiconductors, thus enormously broadening the scope of the scientific investigation, which can be made and technological advances, which might be possible. Among the II-IV compounds, the lead chalcogenides with narrow energy gap have been extensively studied due to their device applications in many fields like IR detectors, photoconductors, thin film transistor etc. [1-5]. Ternary solid solutions are of great technological interest in electronic and photo-electronic devices. Such alloys systems are known to have well-defined band structures in which the energy gap and other band parameters vary continuously with composition between the values of the constituent binary compounds. This allows them to be tailored to meet specific requirements. $Cd_xZn_{(1-x)}Te$ solid solution is one of many such alloys which has been found to have several applications, such as solar cells, photoconductors and light emitting diodes [6]. Several authors have studied its properties under different conditions of evaporation [7-8], since CdTe and ZnTe display as unlimited solubility in

each other. Many workers have been reported on the transport properties of these chalcogenides in the bulk state but very little is known about their properties in the thin film state. Taking into consideration of the above fact in the present work it is plane to prepare new semiconducting material from solid solution of ZnTe, and PbTe i. e. a ternary semiconductor of the p-type $Zn_xPb_{(1-x)}Te$.

MATERIALS AND METHODS

For the preparation of ternary semiconductors, $Zn_xPb_{(1-x)}Te$ the constituent compounds ZnTe and PbTe have been taken in molecular stiochoimetry proportional weights and crushed and mixed homogenously. The different sets of samples of varying compositions (x = 0.1, 0.2, 0.3, 0.4 and 0.5) were deposited via sublimation of the compound in vacuum higher than 10^{-5} mbar under controlled growth conditions of various compositions onto the amorphous precleaned glass substrates at the temperature of 373 K. The thicknesses of films were controlled by using quartz crystal thickness monitor model No.DTM-101 provided by Hind-High Vac. The deposition rate was maintained 10-15 Å/sec constant throughout sample preparations. These samples were annealed at reduced pressure of 10^{-5} mbar for the duration of 3 hours at the temperature of 573 K and maintain carefully. These samples were then used for various characterizations. The structural characteristics have been studied by X-ray diffractograms (Rigaku, Miniflex Japan) with Cukα radiation (1.5418Å). Scanning electron microscopy (SEM) has been studied by model 501, Philips, Holland with EDAX attachment. Resistivity of the samples was measured by four-probe technique using model No. DEP-02. "Scientific Equipment Roorkee", as a function of thickness and temperature. The thermoelectric power has been measured by the integral method; the set up is used for this measurement provided by "Puspha Scientific Co., Hydrabad".

RESULTS AND DISCUSSIONS

It is seen from X-ray diffraction patterns of all film compositions they are polycrystalline in nature (Fig.1). The d-values of all peaks are comparing with standard ASTM cards of PbTe and ZnTe are in close agreement with observed d-values of respective reflections.

It is seen from X-ray diffraction patterns of all film compositions they are polycrystalline in nature. For composition x = 0.1 maximum intensity of prime diffraction peak is of the order of 600 cps and minimum peak intensities 230 cps(around 40%). The d-values of all peaks are comparing with standard ASTM cards of PbTe (8-28) and ZnTe (15-746). From this comparison all the reflection intensities varies from 40 to 100 percent indicating growth charactertics randomly. Similarly for the composition x = 0.3 the prime peak intensity is 1000 cps and for all other peak intensity is varying 32% to 45%, again indicating random growth charactertics. Whereas for composition x = 0.2, 0.4 and 0.5 prime maximum reflection intensities are 2816, 3178 and 1304 cps respectively. For all other peak reflection intensities below 20% (for samples x = 0.2 and x = 0.4) while between 20% and 25% for x = 0.5 indicating preferred oriented growth characteristics along (111) direction [For ZnTe (c)], (200) direction [For PbTe(c)] and along (200) direction [For PbTe(c)] respectively. All d-values are in close agreement with standard d-values of respective reflections. For these compositions films are of good quality crystallinity as compare to samples of composition x = 0.1 and x = 0.3.

From the above discussion it may be concluded that $Zn_xPb_{(1-x)}Te$ films for all compositions have cubic structure with mixed phases of ZnTe(c) and PbTe(c), as for different compositions have preferred orientation characteristics growth along (111) and (200) directions. Similar results were

reported by L.P. Deshmukh et. al. [9] for corresponding $Cd_{(1-x)}Pb_xSe$ and Holiman et. al. [10] reported cubic structure for $Cd_xZn_{(1-x)}Te$ thin films.

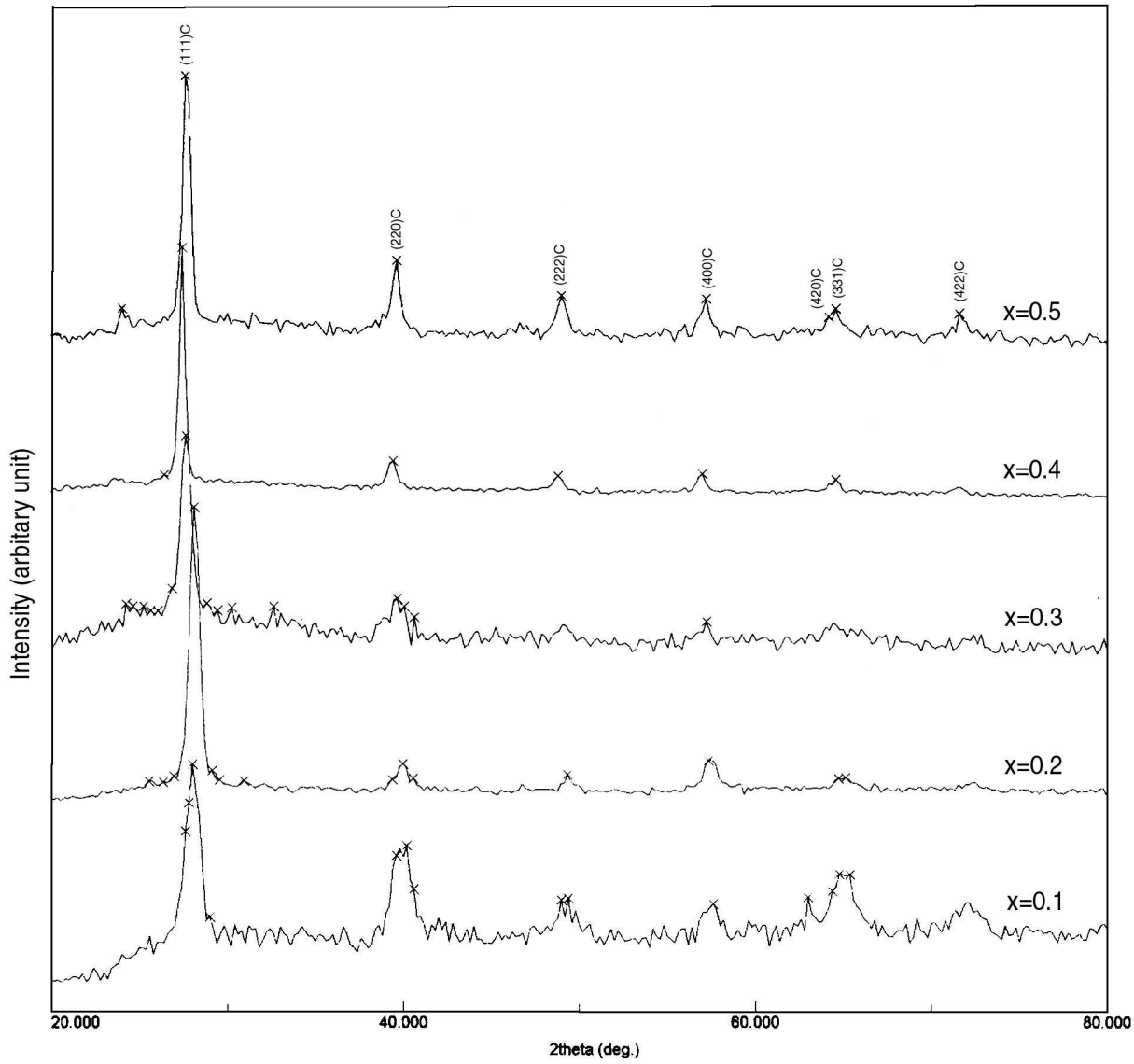

Fig. 1 X-ray diffractogram of various $Zn_xPb_{(1-x)}Te$ structures.

It is seen from scanning electron micrographs films surfaces are very smooth (Fig. 2). The film surfaces were minutely observed the reflectivity was found to be slowly increasing with the composition of Zn. The film also shows development of straitions. The straitions were initiated at the Zn composition (x = 0.1) and successively reduce at the composition x = 0.2 and x = 0.3. From the above discussion it may be conformed that films for all compositions with the straitions, which is the indicating of oscillatory growth [11-12]. From the analysis of EDAX the film composition (atomic% of Zn, Pb and Te) and source compositions are matching closely as seen from the comparative study presented in table 1.

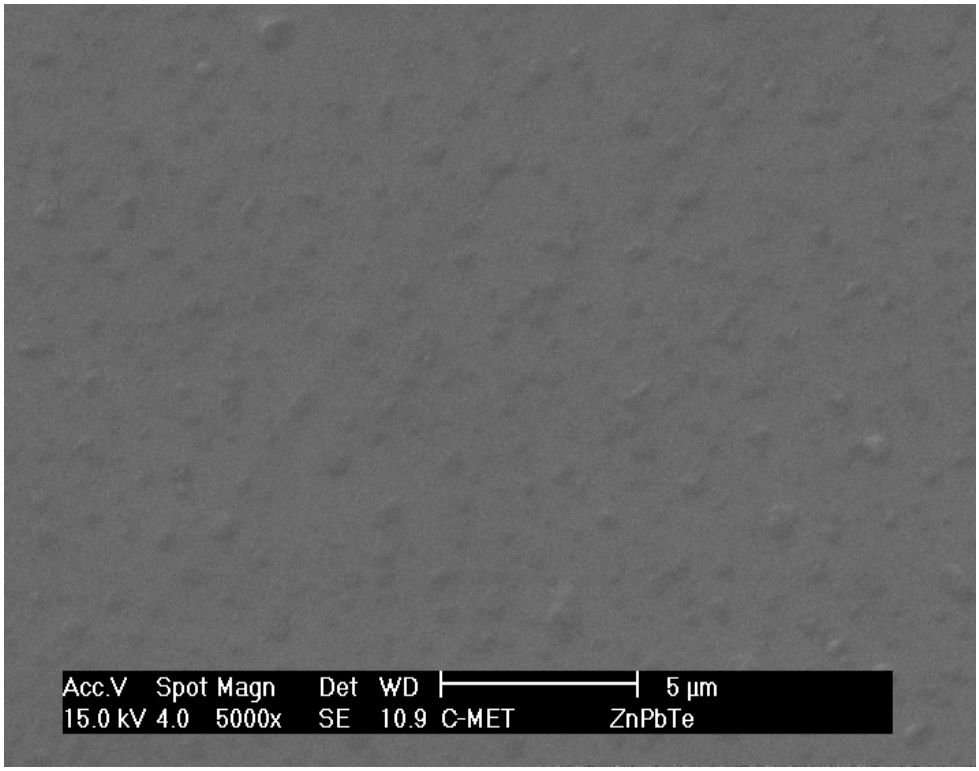

Fig. 2 Scanning Electron Micrograph of $Zn_xPb_{(1-x)}Te$ for (x = 0.2) thin film.

Table 1. EDAX data for $Zn_xPb_{(1-x)}Te$ thin films

Basic Ingredient Taken				EDAX Composition		
Composition 'x'	At% Zn	At% Pb	At% Te	At% Zn	At% Pb	At% Te
0.1	5	45	50	7.83	43.86	48.31
0.2	10	40	50	11.24	39.91	48.85
0.3	15	35	50	15.57	35.09	49.33

The resistivity increases almost linearly with increasing composition parameter 'x'. From approximately 0.2 Ω-cm (x = 0.1) to about 1.6 Ω-cm (x = 0.5). This suggests the formation of solid solution of ZnTe and PbTe. The nature of variation of resistivity as a function of reciprocal of temperature is similar for all compositions with $x \geq 0.2$ and is almost linear for these compositions resistivity increases with decreasing temperature suggesting film material is semiconductor with negative temperature coefficient of resistivity. From this study of resistivity as a function of temperature activation energies of transport of free charge carriers have been evaluated using Arrehenius relations.[13] and are presented in table 2.

Table 2. Estimated values of activations energies of $Zn_xPb_{(1-x)}Te$ thin films.

Composition (x)	Activation energy gap in (eV)
0.1	0.269
0.2	0.291
0.3	0.290
0.4	0.322
0.5	0.396

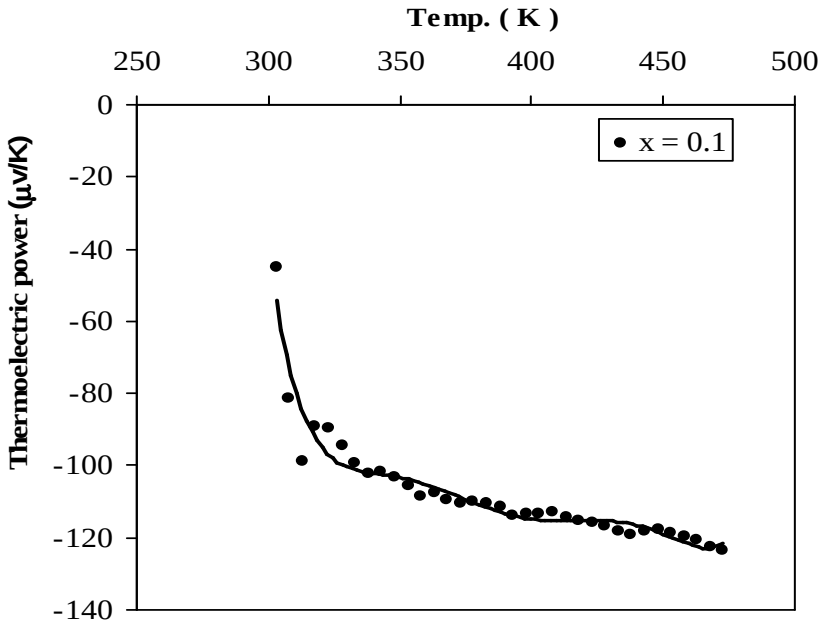

Fig. 3 Temperature varition of the TEP for $Zn_xPb_{(1-x)}Te$ thin films .

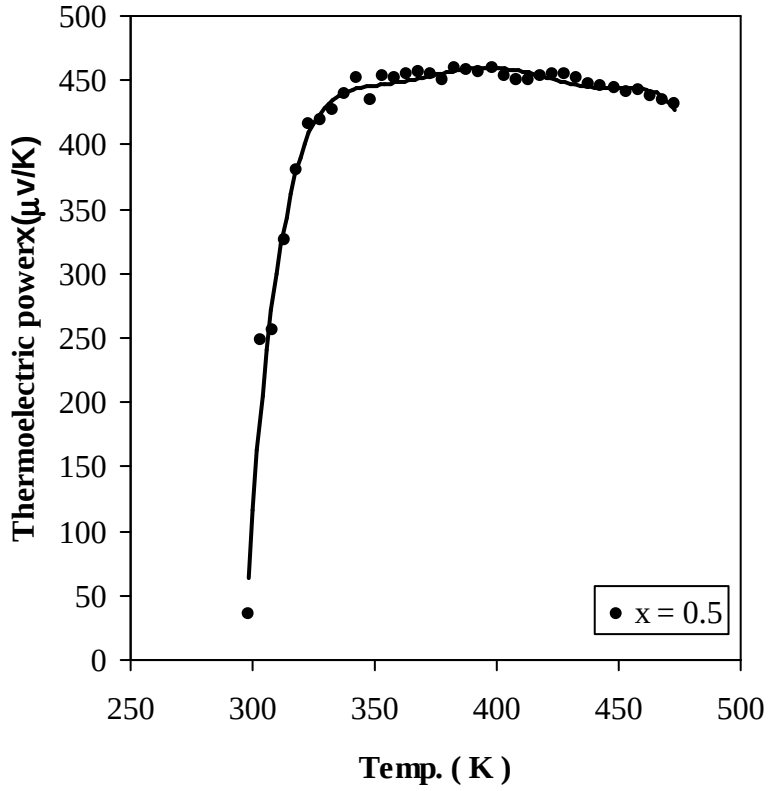

Fig. 4 Temperature varition of the TEP for $Zn_xPb_{(1-x)}Te$ thin films .

The study of thermo emf and thermoelectric power for all films of different compositions indicate that the film material (for composition x = 0.1) is n-type semiconducting shown in (Fig 3) and for all other compositions x = 0.2 - 0.5 (Fig 4) film material is p-type semiconducting. Reported values [14] have been of the thermoelectric power variation (thickness dependent) in

the range of 100-200 μV/K. For the composition x = 0.1 in a low temperature range the change in magnitude of thermoelectric power is large and in high temperature range the change in thermoelectric power is small, which can be explained phonon drag effect [15-17]. While for other compositions in low temperature range thermoelectric power increases rapidly and remains constant over the wide range of temperature. For the sample (x = 0.1) the magnitude of thermoelectric power range is 40 to 120 μV/K over the entire temperature range. This is relatively very small compared to the magnitudes of thermoelectric power range from 50 to 450 μV/K over the same temperature range. This may be attributed to corresponding to structural changes and electrical resistivity behavior of film materials for x = 0.1 and all other compositions.

V Damodara Das et. al. [14] reported the thermoelectric power variation (thickness dependent) in the range of 100-200 μV/K. He also reported thermoelectric power figure of merit increases with thickness of films for the material $Pb_{0.5}Sn_{0.5}Te$.

Compare with thermoelectric power of pure and co-evaporated PbTe films [18]; the film material of composition x =0.1 is poor thermoelectric material, while film materials of all other compositions (x = 0.2, 0.3, 0.4 and 0.5) are better thermoelectric materials.

CONCLUSION

In conclusion, homogeneous cubic structure of mixed-phase thin films of $Zn_xPb_{(1-x)}Te$ have been successfully deposited by thermal evaporation technique using basic ZnTe and PbTe elemental starting materials. The composition of starting basic ingredients and film composition comparison seems to be in agreement with that obtaining from EDAX analysis. Resistivity study shows films are of negative temperature coefficient of resistivity indicating that film material is semiconducting in nature while thermoelectric power measurement shows p-type conduction.

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