The II-VI polycrystalline semiconducting materials have come under increased scrutiny because of their wide use in the cost reduction of devices for photovoltaic applications. Cd$_{1-X}$Zn$_X$Te is one of the II-VI ternary semiconductor materials whose bandgap can be tailored to any value between 1.48–2.26 eV as $X$ varies from 0 to 1. It is promising material for high-efficiency solar cells, switching, and other optoelectronic devices. Polycrystalline thin film of Cd$_{1-X}$Zn$_X$Te with variable composition (0 ≤ $X$ ≤ 1) has been deposited on ultraclean glass substrates by screen printing method followed by sintering process. The optical and structural properties of Cd$_{1-X}$Zn$_X$Te thin films have been examined. The optical bandgap of these films is studied using reflection spectra in wavelength range of 350–900 nm by using double beam spectrophotometer. The structure of sample was determined from X-ray diffraction patterns. The films were polycrystalline in nature having wurtzite (Hexagonal) structure over the whole range studied. The lattice parameters vary almost linearly with the composition parameter $X$, following Vegard’s law. Sintering is a very simple and viable method compared to other cost-intensive methods. The results of the present investigation will be useful in characterizing the material CdZnTe for its applications in photovoltaics.

1. INTRODUCTION

In recent years, II-VI compound semiconductors are attracting a great deal of attention because of their potential abilities in a wide spectrum of optoelectronic devices [1–6]. Ternary materials provide a possibility of tailoring their properties as per requirements and hence project themselves, as important semiconducting material, for future advancements in the field of device fabrication. The Cd$_{1-X}$Zn$_X$Te (0 < $X$ < 1) ternary semiconductor with Zinc blende-type structure has many applications for its various desirable properties such as the tunability of bandgap and lattice parameter with alloy composition, high optical absorption coefficient above the bandgap energy, and high value of optical transmittance below the bandgap. These favourable properties have attracted many people to work with this material [7–15].

A Cd$_{1-X}$Zn$_X$Te thin film is very useful in high-efficiency tandem solar cell fabrication [7] because of the ease in tuning its bandgap in visible region (between 1.48–2.26 eV) [16]. Cd$_{1-X}$Zn$_X$Te is also used as the most suitable substrate material for epitaxial growth of Hg$_{1-X}$Cd$_X$Te which is the leading infrared detector material [8, 9].

It is generally recognized that any large-scale applications must rely on cheap polycrystalline materials. The use of thin-film polycrystalline semiconductors has attracted much interest in an expanding variety of applications in various electronic and optoelectronic devices. The technological interest in polycrystalline-based devices is mainly caused by their very low production costs. Thin film of Cd$_{1-X}$Zn$_X$Te was prepared by variety of techniques, such as two-source vacuum evaporation [16, 17], molecular beam epitaxy [18], chemical vapour deposition [19], metal organic chemical vapour deposition [20], two-stage process [21], and thermal evaporation [22].

In the present investigation, we have prepared Cd$_{1-X}$Zn$_X$Te thin films by screen printing method followed by sintering process. The optical and structural properties of these polycrystalline-sintered films were studied in relation to the composition ($X$) of the films.
Sintering is one of the best techniques allowing the preparation of polycrystalline semiconducting films with ease, low costs, and large-area applications. It is extremely simple and viable compared to other cost-intensive methods [23–26].

2. EXPERIMENTAL DETAILS

In the present investigation, the films of Cd\(_{1-X}\)Zn\(_X\)Te (\(X = 0, 0.2, 0.4, 0.6, 0.8, 1\)) were prepared by screen printing followed by sintering process. To make different compositions of Cd\(_{1-X}\)Zn\(_X\)Te, we used CdTe and ZnTe of high purity (99.999\%). In fact, Cd\(_{1-X}\)Zn\(_X\)Te alloy was prepared by taking the stoichiometric ratio of CdTe and ZnTe compounds.

The different compounds have been taken as follows:

\[
\begin{align*}
\text{weight of CdTe} & = 240(1 - X) \text{ g}, \\
\text{weight of ZnTe} & = 192.97 X \text{ g}, \\
\text{weight of ZnCl}_2 \cdot \text{H}_2\text{O} & = 10\% \text{ wt. of (CdTe + ZnTe) g}.
\end{align*}
\]

(1)

As these weights were very large, we reduce them in the same proportion. All the three compounds are mixed thoroughly and few drops of ethylene glycol are added to make it a paste. Zinc chloride was used as an adhesive (cadmium chloride was used as adhesive when \(X = 0\), i.e., in case of CdTe film) and ethylene glycol as a binder. The paste thus prepared was screen printed on ultraclean glass substrates, which has been cleaned by embryo powder and acetone, and finally washed with distilled water. The samples thus prepared were dried in air atmosphere; but in nitrogen, this problem does not exist. All the films were synthesized under the same experimental conditions [27].

3. TECHNIQUES OF CHARACTERIZATION

The thicknesses of films were determined by an optical interference technique. The thickness of various films was found of the order of 1 \(\mu\)m. The optical reflectance versus wavelength traces of all the films was recorded from 350–900 nm wavelength range using a double beam spectrophotometer (Hitachi U-3400). The XRD traces were obtained using a Philips PW 1140/09 X-ray diffractometer with CuK\(_a\) (\(\lambda = 1.5405\)) radiation.

4. RESULT AND DISCUSSION

4.1. Optical studies

The optical reflectance measurements of Cd\(_{1-X}\)Zn\(_X\)Te- (\(X = 0, 0.2, 0.4, 0.6, 0.8, 1\)) sintered films were recorded at room temperature from 350 to 900 nm wavelength range using a Hitachi U-3400 UV-VIS-NIR double beam spectrophotometer. The optical bandgap of these films was determined with the help of reflection spectra. Almost all the II-VI compounds are direct bandgap semiconductors. According to Tauc relation [28], the absorption coefficient for direct bandgap material is given by

\[
\alpha h\nu = A(h\nu - E_g)^n,
\]

(2)

where \(h\nu\) is photon energy, \(A\) is constant which is different for different transitions, \(E_g\) is the bandgap, and \(n = 1/2\) for direct bandgap material. The absorption coefficient may be written in terms of reflectance as [29]

\[
2\alpha t = \ln \left[\frac{(R_{\text{max}} - R_{\text{min}})}{(R - R_{\text{min}})}\right],
\]

(3)

where \(t\) is the thickness of the film and \(R\) is reflectance for any intermediate photon energy, where reflectance falls from \(R_{\text{max}}\) to \(R_{\text{min}}\) due to absorption of light by the material.

We plot a graph between \((\alpha h\nu)^2\) or the square of \(h\nu\ln([R_{\text{max}} - R_{\text{min}}]/(R - R_{\text{min}}))\) (as ordinate) and \(h\nu\) (as abscissa) a straight line is obtained. The extrapolation of straight line to \((\alpha h\nu)^2 = 0\) axis gives the value of energy bandgap of film material. Figure 1 represents the reflection spectra of Cd\(_{1-X}\)Zn\(_X\)Te-sintered films. In Figure 2 we plotted a graph between the square of \(h\nu\ln([R_{\text{max}} - R_{\text{min}}]/(R - R_{\text{min}}))\) and \(h\nu\) for the determination of bandgap. The bandgap of Cd\(_{1-X}\)Zn\(_X\)Te-sintered films varies between 1.48–2.26 eV as composition \(X\) varies from 0 to 1. The decrease in
Figure 2: Energy bandgap determination of Cd$_{1-X}$Zn$_X$Te-sintered films from reflectance measurement. (A plot of $[\hbar \nu \ln ([R_{\text{max}} - R_{\text{min}}]/[R - R_{\text{min}}])]^2$ vs. $\hbar \nu$.)

Figure 3: The compositional dependence of bandgap of Cd$_{1-X}$Zn$_X$Te-sintered films.

Figure 4: X-ray diffraction pattern of CdTe-sintered film.

Figure 5: X-ray diffraction pattern of Cd$_{0.4}$Zn$_{0.6}$Te-sintered film.

4.2. XRD studies

X-ray diffraction (XRD) studies were carried out on these samples and diffractograms were analyzed to obtain information about various crystallographic aspects. XRD traces of all samples were taken at room temperature and found to show almost similar trends. We have shown here the XRD traces of CdTe and Cd$_{0.4}$Zn$_{0.6}$Te in Figures 4 and 5, respectively. These traces confirmed the formation of alloys of Cd$_{1-X}$Zn$_X$Te. The presence of sharp structural peaks in these XRD patterns confirmed the polycrystalline nature of the films. The XRD peaks show no peaks of CdTe or ZnTe Oxidation.

The bandgap is attributed to the basic properties of these compounds. The compositional dependence of the bandgap is shown in Figure 3. The variation of $E_g$ with $X$ is almost linear for this system. These results are in good agreement with the reported values [16, 22].

The mode of optical transitions in these films is of band-to-band direct type. This has also been confirmed by plotting $\ln(\hbar \nu)$ versus $\ln(\hbar \nu - E_g)$ for direct, allowed type transitions [30]. The variation yields a straight line with slope almost 1/2. The electronic transitions between the valence and conduction band start at the absorption edge corresponding to the minimum energy difference between the lowest energy of the conduction band and the highest energy of the valence band in the crystalline materials. In case of cadmium and zinc salts, the plot of electron energy $E$ as a function of electron wave vector $k$ (E–k band diagram) indicates that the top of the valence band has the same $k$ value as the bottom of the conduction band and hence the transitions are of direct type. As given above, the absorption coefficient $\alpha$ of the film material is proportional to $\ln([R_{\text{max}} - R_{\text{min}}]/[R - R_{\text{min}}])$. The absorption coefficient for all the Cd$_{1-X}$Zn$_X$Te composition is high. The absorption coefficient increases sharply with photon energy beyond the fundamental absorption edge. The high absorption coefficient and tunable bandgap of Cd$_{1-X}$Zn$_X$Te-sintered films will be an added advantage in respect of their applications in photovoltaic devices.
5. CONCLUSION

The experimental d-values for different compositions of Cd$_{1-x}$Zn$_x$Te system are calculated from Bragg’s relation

\[ 2d_{hkl} \sin \theta = n\lambda, \]  

by taking \( \theta \) values from the peaks of XRD patterns; these d-values are compared with the standard ASTM data (d*) for the confirmsation of the structure of the film material. The experimental d-values and ASTM (d*) values are in good agreement and show hexagonal (wurtzite) structure of each composition. Various workers [16–22] have prepared the binary-sintered films were investigated. The absorption coefficient of the films of Cd$_{1-x}$Zn$_x$Te system are calculated from Bragg’s relation

\[ 2d_{hkl} \sin \theta = n\lambda, \]  

The lattice parameter “a” as a function of composition x is plotted in Figure 6. The lattice parameter varies almost linearly with composition parameter x, following Vegard’s law. A decrease in lattice parameter was observed with the increase of zinc content in the films.

5. CONCLUSION

The optical, structural properties of Cd$_{1-x}$Zn$_x$Te pseudobinary-sintered films were investigated. The absorption coefficient of the films of Cd$_{1-x}$Zn$_x$Te system is high, and varying X from 0 to 1 can engineer their bandgap from 1.48 to 2.26 eV, which are suitable for efficient absorption in the visible region of the solar spectrum. All the films of Cd$_{1-x}$Zn$_x$Te system are found to be polycrystalline in nature and have hexagonal (wurtzite) structure over entire composition range. The lattice parameters vary almost linearly with the composition parameter X, following Vegard’s law.

Due to optimum band gap, large absorption coefficient, polycrystalline nature, and stability, these sintered films may be suitable for use in solar cells, wide band gap window material, and other photovoltaic devices. The sintering technique is simple, inexpensive, viable, and attractive means of obtaining films of II–VI semiconductors and offers a wide flexibility for their use in a variety of applications.

ACKNOWLEDGMENTS

The authors are thankful to the Department of Science and Technology, Government of India, New Delhi, for providing the financial support to carry out this work. Authors are also thankful to Dr. Ajay Sharma (Director General, Krishna Institute of Engineering and Technology, Ghaziabad, India) and Professor C. M. Batra (Head of Department of Basic Science, Krishna Institute of Engineering and Technology, Ghaziabad, India) for their constant support and encouragement to carry out this work.

REFERENCES


Submit your manuscripts at http://www.hindawi.com