Investigation of optical and electrical properties of multilayer thin films of ZnTe/CdSe

P. Ansari[1]*, R. A. Dar[2]* and Y. C. Sharma[1]
[1]*Department of Physics, Vivekananda Global University, Jaipur, Rajasthan*
[2]*Department of Chemistry, Maharashtra College of Arts, Science and Commerce-Mumbai, Maharashtra*

Abstract

Zinc Telluride (ZnTe) and Cadmium Selenide (CdSe) are II-VI semiconductors having bandgap of 2.27eV and 1.74eV. In this work multilayers of ZnTe/CdSe thin films have been prepared by e-beam evaporation, having thickness 50nm/50nm i.e. (100nm) to 100nm/100nm i.e. (200nm); optical bandgap and absorbance were studied by UV-VIS spectrophotometer in the wavelength range 200nm-1000nm. The bandgap result showed that the films have semiconducting nature. Electrical properties of the films have been studied by I-V characteristics and Hall measurement technique.

Keywords: ZnTe/CdSe, UV-VIS, I-V, Hall measurement, Bandgap.

1. INTRODUCTION

Zinc Telluride (ZnTe) and Cadmium Selenide (CdSe) are II-VI semiconductors having bandgap energy of around 2.27eV and 1.74eV, respectively. ZnTe/CdSe thin films were prepared and investigated by using *n*-CdSe in conjunction with *p*-ZnTe by Pal and co-workers by Pal A.K et al [1]. Both the layers were deposited by e-beam evaporation method under vacuum without breaking vacuum by using a mask rotating system [2]. ZnTe/CdSe heterojunctions were made by successive deposition of component films investigated by Heather Dowd et al [3]. In ZnTe/CdSe transmission and absorption spectra were studied and also studied the I-V characteristics. Optical transmission and reflection spectra were recorded [4]. In ZnTe/CdSe heterojunctions, ZnTe play a role of window layer while CdSe is the absorber compound studied by Antohe S et al [5]. ZnTe-CdSe heterojunctions, prepared for photovoltaic tandem systems [6], the photovoltaic performance of ZnTe/CdSe thin film solar cells fabricated by depositing CdSe on ZnTe film deposited at different substrate temperatures and on different thicknesses respectively [2] thus the photovoltaic performances of the cells critically depend on the evaporation conditions of both the layer [7]. The Hall measurements show that ZnTe film has p-type electrical conduction and CdSe film has n-type electrical conduction [8]. CdSe is a well-known semiconducting material having high absorption coefficient in the visible range and often contains n-type conductivity [9]. The CdSe thin film plays an important role for photovoltaic applications because it is used as absorber layer on the top of the tandem solar cells [10]. The ZnTe thin films have recorded very high transmittance in the UV–visible region using optical measurement reported by Hossain M. I [11]. The heterojunctions ZnTe/CdSe are widely used in some important applications in modern technologies because of its wide band gap of ZnTe as window layer and CdSe as an absorber [7]. The thin films having more attention in the field of optoelectronics like photo-detectors [12], gas sensors [13], light emitting diodes [14], solar cells, transistors, photodetectors, etc. [15]. The characteristics and basic fundamental parameters of ZnTe/CdSe thin films are characterized by a very sensitive and complex dependence on the microstructure, deposition conditions, preparation method and the component films [4]. The polycrystalline based devices lies on their very low cost production are the biggest advantage [16]. In this study thin films of ZnTe/CdSe have been prepared by e-beam method, films were further characterized to study the optical and electrical properties.

2. MATERIALS AND METHODS

ZnTe/CdSe were bought from Alfa Aesar, having 99.999% purity. Glass substrate was cleaned by acetone and heated in a vacuum chamber at …..?. The electron beam method is used for deposition of ZnTe/CdSe on glass substrate in a vacuum of 3.75x10-2 Torr. The ZnTe/CdSe thin films were annealed at 100°C & 200°C in a muffle furnace. The optical properties were studied by UV-VIS spectro photo meter and the electrical properties of thin films have also been done by Current-Voltage (I-V) characteristic and Hall measurement technique. HMS 5000, Ecopia corp, Korea: having Hall Effect measurement system property and Agilent

Technology, B1500A Semiconductor Device Analyzer, Malaysia: is all in one analyzer supporting IV, CV, pulse/dynamic IV and more were used.

3. RESULTS AND DISCUSION

3.1. Optical properties of ZnTe/CdSe

Optical properties have been studied using UV-VIS spectro photometer (make Perkin Elmer Lambda 750) at MRC, MNIT Jaipur. Variation of absorbance of the films w.r.t to variation in wavelength of incident radiations has been plotted in fig 1 & 2. By using optical properties of ZnTe/CdSe films, very valuable information can be obtained about energy band-gap, characteristics of optical transitions, etc. The optical behaviour of ZnTe/CdSe samples was determined through UV–VIS spectroscopy. Fig1 presents transmittance spectra in the wavelength range of 400–1000nm [17].

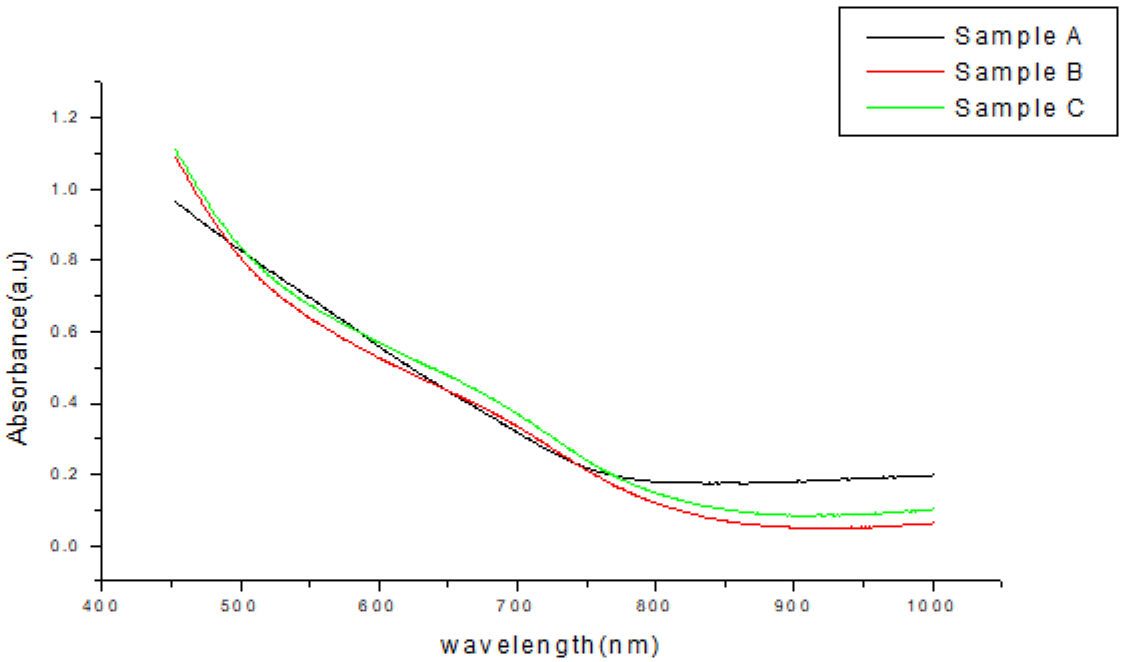

Fig1: Plot of absorbance (a.u) vs. wavelength (nm) for ZnTe/CdSe thin films of 100nm. (A): ZnTe (50nm) / CdSe (50nm) film of 100nm at RT. (B): ZnTe (50nm) / CdSe (50nm) film of 100nm at 100°C. (C): ZnTe (50nm) / CdSe (50nm) film of 100nm at 200°C.

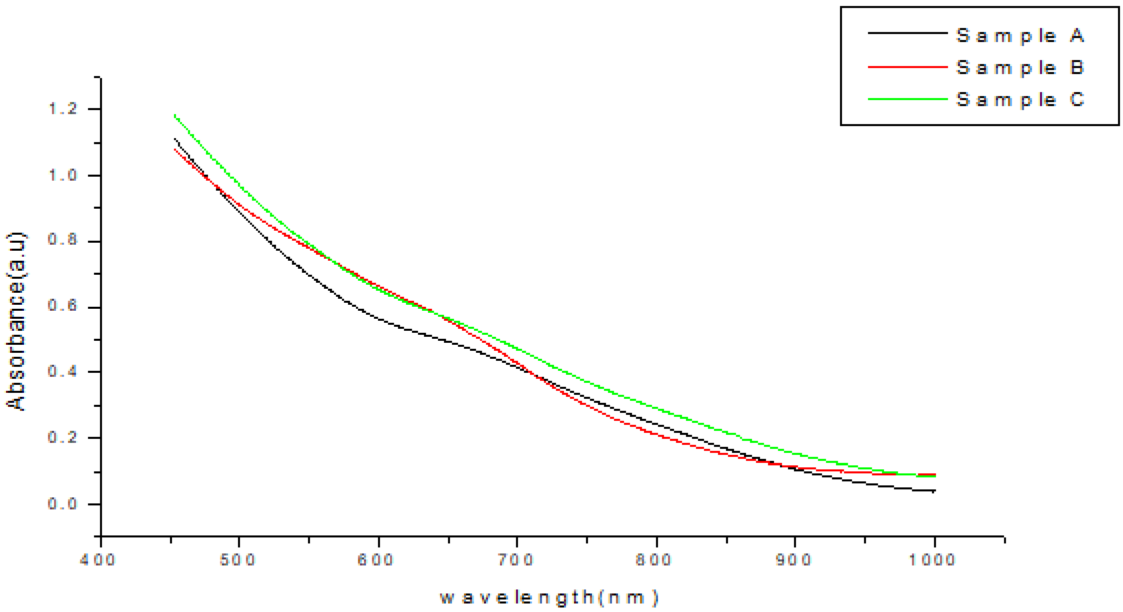

Fig2: Plot of absorbance (a.u) vs. wavelength (nm) for ZnTe/CdSe thin films of 200nm. (A): ZnTe (100nm) / CdSe (100nm) film of 200nm at RT. (B): ZnTe (100nm) / CdSe (100nm) film of 200nm at 100°C. (C): ZnTe (100nm) / CdSe (100nm) film of 200nm at 200°C.

The energy bandgap was determined by using the following relation.

$\alpha hv = C(hv\text{-}E_g)^{1/2}$

here E_g is the energy band gap, C is constant which is dependent on the structure of sample, α is the absorption coefficient and h is a plank's constant [18].

The energy bandgap from plot of $(ahv)^2$ vs E(eV) are shown in fig 3 & 4. The linear nature indicates direct nature of transition.

Our results have been shown in fig 3 & 4, which show the same trend.

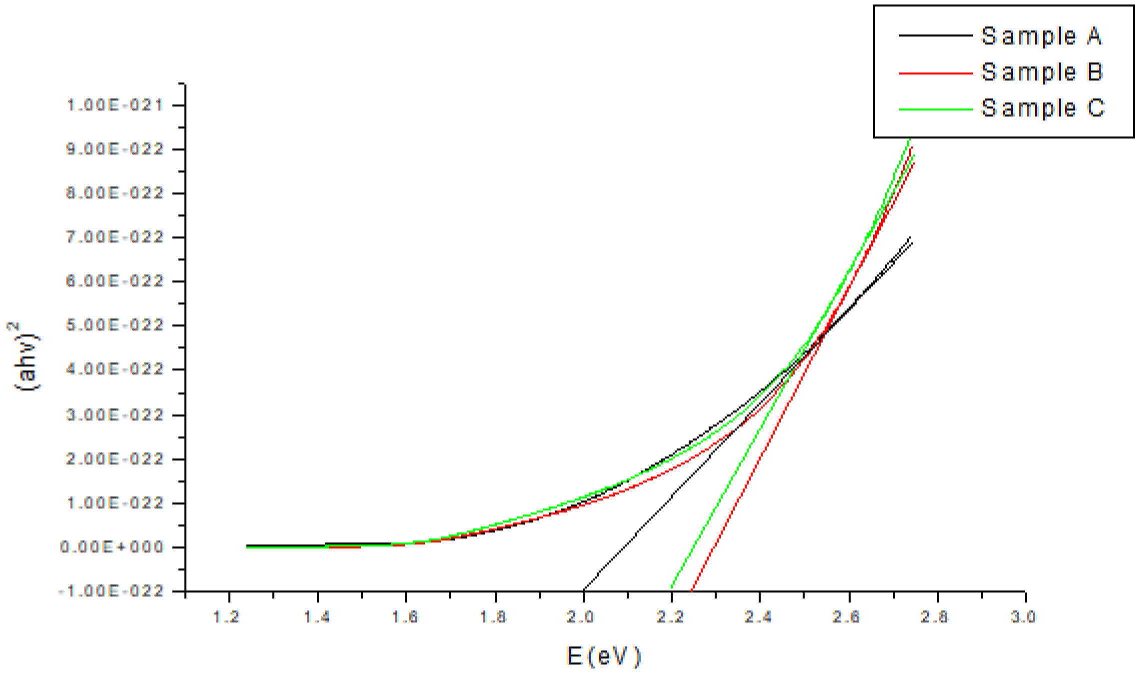

Fig3: Plot of $(ahv)^2$ vs. E(eV) for ZnTe/CdSe thin films of 100nm. (A): ZnTe (50nm) / CdSe (50nm) film of 100nm at RT. (B): ZnTe (50nm) / CdSe (50nm) film of 100nm at 100°C. (C): ZnTe (50nm) / CdSe (50nm) film of 100nm at 200°C.

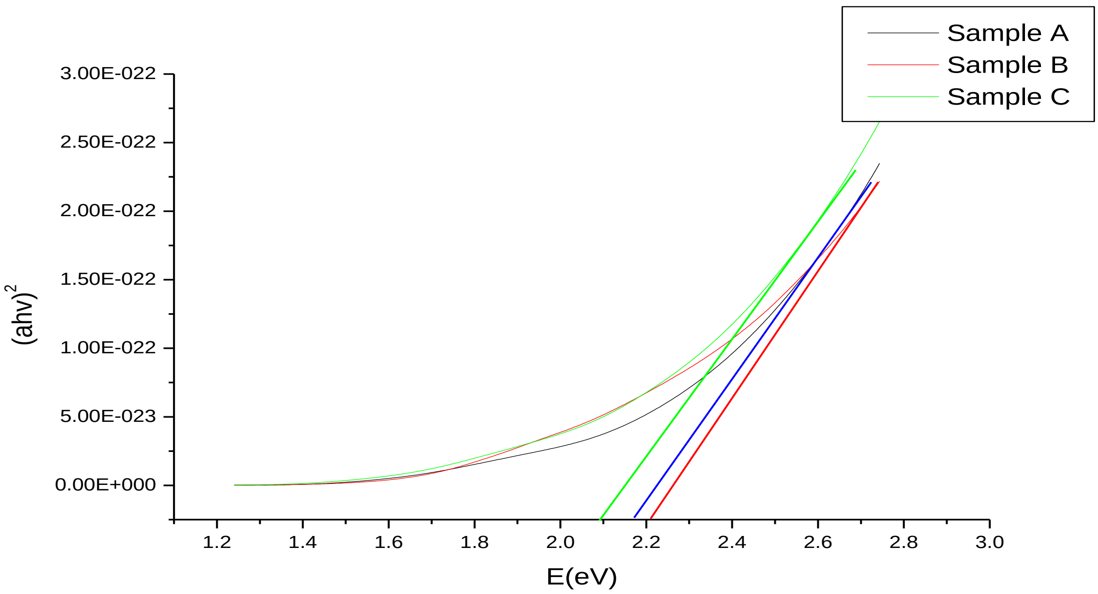

Fig4: Plot of $(ahv)^2$ vs. E(eV) for ZnTe/CdSe thin films of 200nm. (A) : ZnTe (100nm) / CdSe (100nm) film of 200nm at RT. (B): ZnTe (100nm) / CdSe (100nm) film of 200nm at 100°C. (C): ZnTe (100nm) / CdSe (100nm) film of 200nm at 200°C.

3.2. Electrical properties of ZnTe/CdSe

3.2.1. I-V Characteristics of ZnTe/CdSe

I-V Characteristics of various samples have been studied using Semiconductor Device Analyzer (Agilent Technology, B1500A, Malaysia) at MRC, MNIT Jaipur. An I-V Characteristics of ZnTe/CdSe thin film for thickness 200nm at room temperature shows the semiconducting behavior of material. While the annealing of this material at 200°C shows the metallic nature or conducting behavior of films.

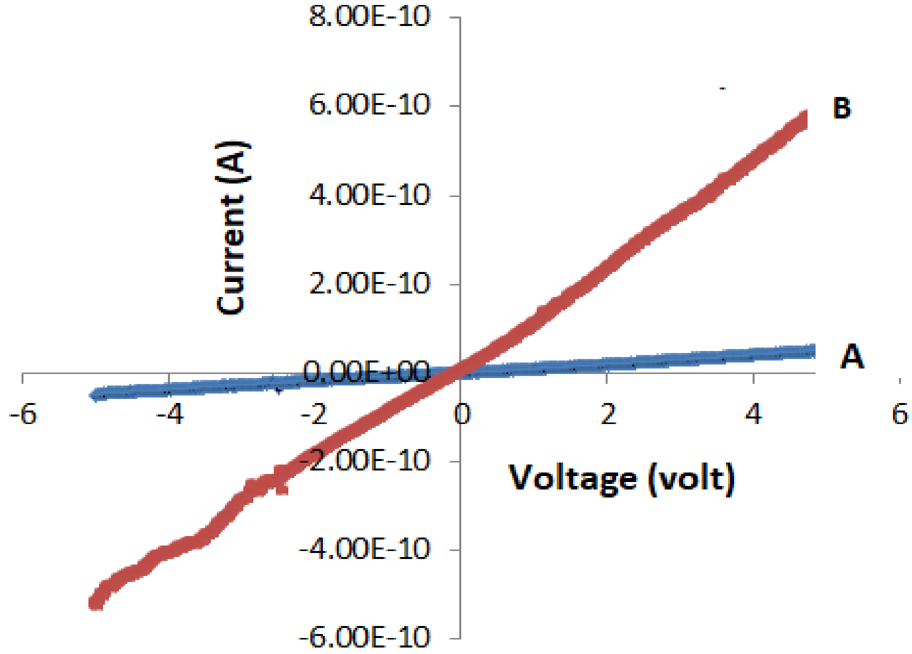

Fig5: I-V characteristics of ZnTe/CdSe films of 200nm at RT & 200°C. (A): ZnTe (100nm) / CdSe (100nm) film of 200nm at RT. (B): ZnTe (100nm) / CdSe (100nm) film of 200nm at 200°C.

3.2.2. Hall measurements of ZnTe/CdSe thin films:

Hall characteristics of various samples have been studied by using (HMS 5000, Ecopia corp, Korea) at MRC, MNIT Jaipur. The ZnTe/CdSe thin films for 200nm at Room temperature show that p-type semiconducting material. While these materials annealed at 200°C the thin film exhibits p-type semiconductor.

Sample name	Resistivity Ωm	Conductivity S/m	Magneto Resistance	Avg Hall m^3/C
ZnTe / CdSe 200nm RT	1.91×10^{-2} 1.98×10^{-2}	5.22×10^{1} 5.03×10^{1}	1.46×10^{3} 1.47×10^{3}	2.60×10^{-1} 4.76×10^{-1}
ZnTe / CdSe 200nm 200°C	1.84×10^{-2} 1.92×10^{-2}	5.42×10^{1} 5.19×10^{1}	1.41×10^{3} 1.44×10^{3}	0.38×10^{0} 1.10×10^{0}

Table1: Hall measurement of ZnTe/CdSe 200nm (RT & 200°C).

4. CONCLUSION

It is concluded that ZnTe/CdSe thin films have been successfully prepared by e-beam evaporation method. The optical bandgap of ZnTe/CdSe thin film at 100°C were about 2.25eV, the relation indicates direct transition of bandgap. I-V characteristics shows ZnTe/CdSe thin film of 200nm at room temperature shows the semiconducting behavior of material while the annealing of ZnTe/CdSe at 200°C shows the metallic nature of behavior of films while Hall measurements of ZnTe/CdSe for 200nm at room temperature and materials annealed at 200°C exhibits p-type semiconductor.

ACKNOWLEDGMENTS

Authors are sincerely thankful to the Director and Dr. Jasaram, Defense Laboratory, Jodhpur; the Director, MRC, MNIT, Jaipur; Dr. S. N. Jha, Dr. A. K. Sinha, Dr. M. K. Tiwari, V. Srihari and U.C. Gautam INDUS-II, RRCAT, Indore and BARC Mumbai for their experimental and technical support.

REFERENCES

1. Pal A.K., Mondal A., Chaudhuri S., (1990), Preparation and characterization of ZnTe/CdSe solar cells. Vacuum. 41: 1460-1462.
2. Patel N. G., Panchal C. J., Makhija K. K., Patel P. G., Patel S. S., (1994), Fabrication and characterization of znte/cdse thin film solar cells. Advance Science. 29: 247-252.
3. Zhong Zhi. Xu., Heather Dowd., Shang Fen., (1998), Phonons in ZnTe/CdSe superlattices with interchange of cation layers across interfaces. Journal of Physics: Condensed Matter. 10: 7.
4. Prepelita P., RUSU G.I., Pirghie C., (2007), The structural and optical characterization of thin-film ZnTe/CdSe heterojunctions. Optoelectronics and advanced materials-rapid communications. 9(10):3200-3205.
5. Antohe S., Ion L., Ruxandra V., (2001), Electrical properties of electron irradiated thin polycrystalline CdSe layers. J. Appl. 90: 5928.
6. Fisterer F.P., Schock H.W., (1982), ZnTe-CdS thin film photovoltaic cells. Journal Of Crystal Growth. 59: 432-439.
7. Kyoung Su Lee., Gyujin Oh., Eun Kyu Kim., (2016), Optimization of p+-ZnTe layer for Back Contacts of ZnTe Thin Film Solar Cells. Journal- Korean Physical Society. 3: 69.
8. Milnes A. G., Fehcht D. L., (1972), Heterojonctions and metal-semiconductor junctions. Acadeemic Press. 63: 418.
9. Bakiyaraj G., Dhanasekaran R., (2012), Effect of annealing on the properties of chemical bath deposited nanorods of CdSe thin films. Cryst. Res. Technol. 47: 960.
10. Yang Q., Zhao J., Guan M., Liu C., Cui L., Han D., Zengcc Y., (2011), Growth and annealing of zinc-blende CdSe thin films on GaAs (001) by molecular beam epitaxy. Appl. Surf. Sci. 257: 9038.
11. Hossain M. I., Siddiquee K. A. M. H., Islam O., Gafur M. A., Qadir M. R., Ahmed N. A., (2019), Characterization of electrodeposited ZnTe thin films. Journal of Optics. 48: 295–301.
12. Zhu T., Shanmugasundaram K., Price S.C., Ruzyllo J., Chang F., Xu J., Mohney S.E., Zhang Q., Wang A.Y., (2008), Mist fabrication of light emitting diodes with colloidal nanocrystal quantum dots. Appl. Phys. Lett. 92: 023111.
13. Luo F.C., (1979), High voltage CdSe thin film transistor. J. Vac. Sci. Technol. 16: 1045–1048.
14. Banfi G.P., Degiorgio V., Tan H.M., (1995), Optical nonlinearity of semiconductor-doped glasses at frequencies below the band gap. J. Opt. Soc. Am. B. 12: 621–628.
15. Komin V., Tetali B., Viswanathan V., Yu S., Morel D. L., Ferekides C. S., (2003), The effect of the cdcl2 treatment on cdte/cds thin film solar cells studied using deep level transient spectroscopy. Thin Solid Films. 2: 143-147.
16. Kazmerski L. L., (1980), Polycrystalline and amorphous thin films and devices. Academic Press. 1: 320.
17. Ochoa-Estrella F. J., Vera-MarquinaI A., Mejia I., Leal-Cruz A. L., Pintor-Monroy M. I., Quevedo-López M., (2018), Structural, optical, and electrical properties of ZnTe:Cu thin films by PLD. Journal of Materials Science: Materials in Electronics. 29: 20623–20628.
18. Ghobad N., (2013), Band gap determination using absorption spectrum fitting procedure. Int. Nano Letters. 3: 2.