Journal of New Materials for Electrochemical Systems 10, 39-42 (2007)

Photoconductive Properties of Hot Wall Deposited $CdSe_{0.7}Te_{0.3}$ Thin Films

N. Muthukumarasamy[1], R. Balasundaraprabhu[2], S. Jayakumar[2], M. D. Kannan[2],
P. J. Sebastian[3,4] and *S. Velumani[5]

[1]Department of Physics, Coimbatore Institute of Technology, Coimbatore-641014,India
[2]Thin Film Centre, P.S.G. College of Technology, Coimbatore-641004, India
[3]Centro de Investigación en Energía,-UNAM, Temixco, Morelos, C.P.62580, México
[4]Universidad Politécnica de Chiapas, 29010 Tuxtla Gutiérrez, Chiapas, Mexico
[5]Department of Physics, TEC de Monterrey – Campus Monterrey, Nuevo Leon C.P.64849, Mexico

Received: August 28, 2005, Accepted: December 14, 2005

Abstract: *II–VI semiconductor compounds, especially CdSe, CdTe and $CdSe_xTe_{1-x}$ are of great practical interest owing to their unique properties including high photosensitivity to electromagnetic radiation and its extensive application in solar cells. In the present work, $CdSe_{0.7}Te_{0.3}$ compound has been synthesized using high purity elemental cadmium, tellurium and selenium. Stoichiometric amounts of the elements are placed in a quartz ampoule, which is evacuated to a vacuum of 10^{-4} Torr and then sealed. The sealed ampoule is placed in a rotating furnace and then heated at a rate of 100 K per hour in steps up to 1200 K. The ampoule is maintained at this temperature for about four hours and then allowed to cool slowly to room temperature. Then, thin films of $CdSe_{0.7}Te_{0.3}$ have been deposited on glass substrates by hot wall deposition technique. The hot wall set up used in the present study consists of a quartz tube of 6.5 cm length and 1cm diameter with one end open and the other end closed. The structural studies carried out on the deposited $CdSe_{0.7}Te_{0.3}$ films revealed that the films are polycrystalline in nature with single phase exhibiting hexagonal structure. The composition of the films has been determined using energy dispersive X-ray analysis. The photoconductive properties of the films have been studied as a function of light intensity and wavelength. Using the spectral dependence of photocurrent the band gap of the $CdSe_{0.7}Te_{0.3}$ films has been determined and is found to be 1.55 eV. The variation of photosensitivity with light intensity has been studied.*

Keywords: hot wall deposition, structural, CdSeTe, photoconductive, synthesis

1. INTRODUCTION

$CdSe_xTe_{1-x}$ ternary thin films, alloys of the binary compound semiconductors CdSe and CdTe are being investigated largely in recent years due to their unique properties including high photosensitivity to electromagnetic radiation, almost 100% quantum yield to radiative recombination and their ability to form solid solutions. $CdSe_xTe_{1-x}$ finds extensive application in solar cells [1], photoconductors [2], solar control applications [3], etc. The main advantage of the $CdSe_xTe_{1-x}$ thin films is its crystal structure and tailoring of band gap by changing the concentration of selenium and tellurium, so that solar energy can be effectively harnessed for maximum conversion to electrical energy. $CdSe_xTe_{1-x}$ thin films have been deposited by several workers by different techniques such as thermal evaporation [4], electron beam evaporation [5], hot wall deposition [6-8] etc. Among the different techniques; hot wall deposition technique has gained importance because it is a simple technique in which device quality thin films can be prepared under conditions very close to thermodynamical equilibrium. Schikora et al [9] have claimed that hot wall deposited CdTe on GaAs substrates show superior luminescence properties when compared to molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD) films. In this paper we report the preparation of $CdSe_{0.7}Te_{0.3}$ thin films by hot wall deposition technique and the structural and photoconductive properties of the deposited films.

2. EXPERIMENTAL TECHNIQUES

$CdSe_xTe_{1-x}$ compound has been synthesized by direct reaction of

*To whom correspondence should be addressed: Email: velu@itesm.mx
or vels64@yahoo.com Tel: 052 81 83582000 ex.4630

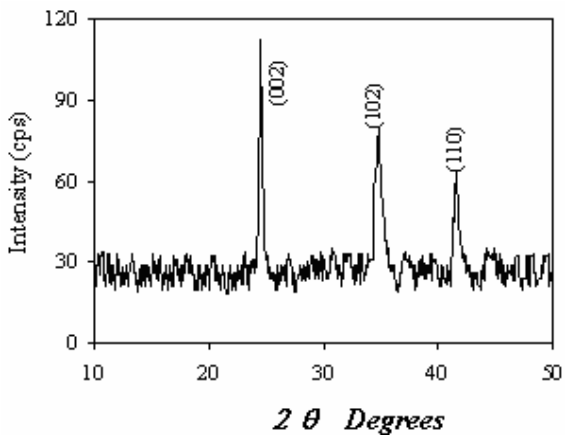

Figure 1. X-ray diffractogram of bulk $CdSe_{0.7}Te_{0.3}$

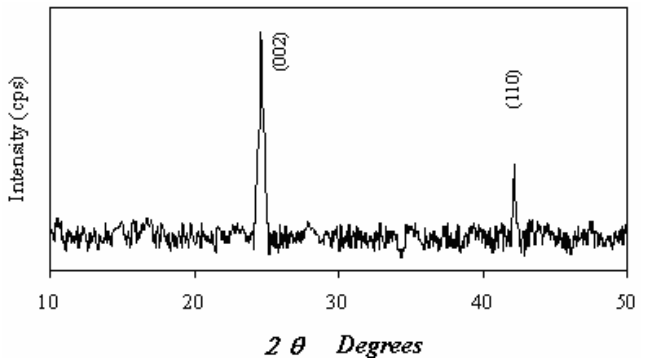

Figure 2. X-ray diffractogram of $CdSe_{0.7}Te_{0.3}$ thin film of thickness 2985 Å

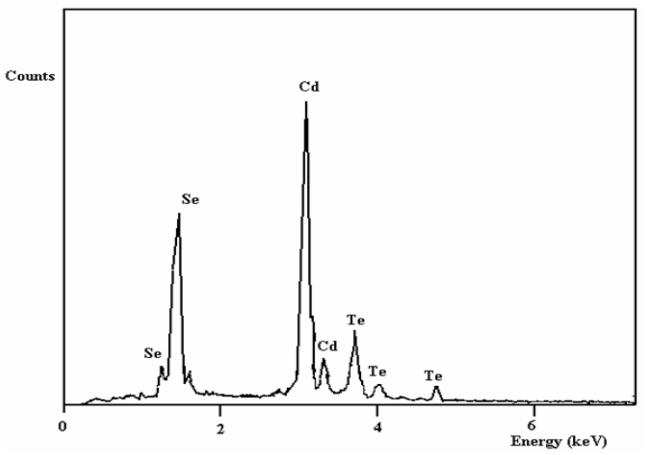

Figure 3. EDAX pattern of bulk $CdSe_{0.7}Te_{0.3}$

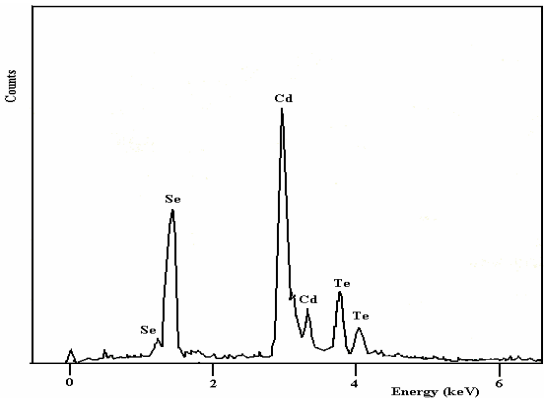

Figure 4. EDAX pattern of $CdSe_{0.7}Te_{0.3}$ thin film of thickness 2985 Å

high purity elemental cadmium, selenium and tellurium. Stoichiometric amounts of the elements are placed in a quartz ampoule in which a vacuum of 10^{-4} Torr is achieved, and then sealed. The sealed ampoule is placed in a rotating furnace and then heated up to 1200 K at a rate of 100 K/hr. The ampoule is maintained at 1200 K for about four hours and then allowed to cool slowly to room temperature. The quartz ampoule is rotated continuously during the course of heating and cooling to ensure homogeneity in the molten mixture. $CdSe_{0.7}Te_{0.3}$ thin films have been prepared by hot wall deposition technique using the $CdSe_{0.7}Te_{0.3}$ compound.

One of the techniques that have contributed significantly to the preparation of epitaxial films of congruently evaporating compound semiconductors with bulk like properties is the hot wall epitaxy technique [10]. The main feature of the hot wall system is the heated linear quartz tube, which serves to enclose and direct the vapor from source to substrate. The hot wall set up used in the present study consists of a quartz tube of 6.5 cm length and 1cm diameter with one end open and the other end closed. Kanthal wire wound closely along the length of the quartz tube heats the wall of the quartz tube. Two independent heater coils are used to heat the source and wall of the tube. The source material is taken in the quartz tube and the substrate is positioned at a distance of less than 1mm exactly above the open end of the quartz tube acting almost as a lid closing the tube. The hot wall arrangement is placed inside the vacuum chamber in which a pressure of 10^{-5} Torr is achieved. $CdSe_{0.7}Te_{0.3}$ thin films have been deposited on to well-cleaned glass substrates with wall temperature around 770 K. Due to radiation from the hot wall of the quartz tube the substrate temperature automatically raised to 350 K during deposition.

The structure of the deposited films has been studied using X-ray diffractometer (model JEOL 8030 Japan) fitted with monochromatic $CuK_{\square}$ radiation. Thickness of the deposited films has been measured by multiple beam interferometric technique. The composition of the chemical constituents present in the prepared $CdSe_{0.7}Te_{0.3}$ bulk and hot wall deposited $CdSe_{0.7}Te_{0.3}$ thin films has been determined using energy dispersive X-ray analysis (EDAX Leica.S 440i). The photoconductive studies have been carried out by illuminating the film using tungsten lamp. A series of Oriel VIS-NIR interference filters were used for obtaining monochromatic light. The photocurrent was measured using a multifunctional optical power meter (Oriel – model 70310).

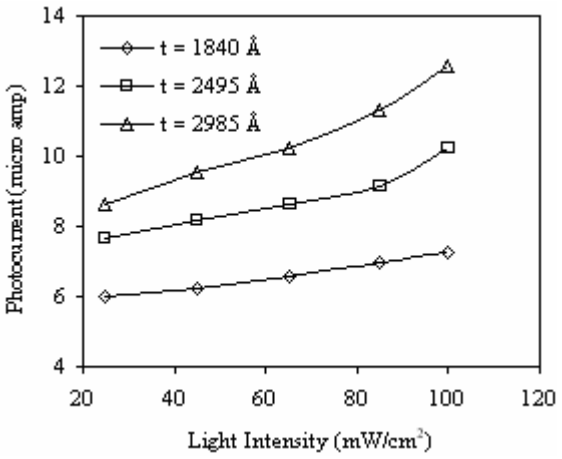

Figure 5. Variation of photocurrent with light intensity of $CdSe_{0.7}Te_{0.3}$ thin films

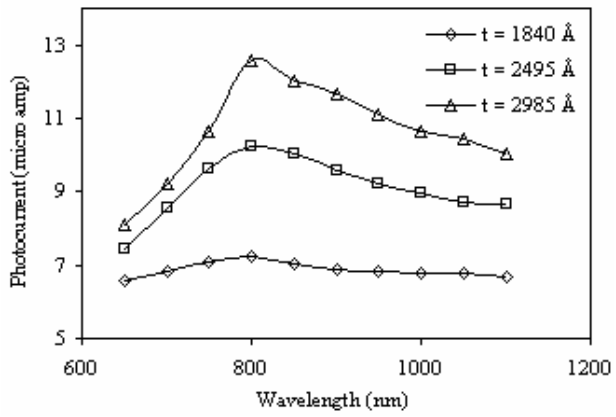

Figure 6. Spectral response characteristics of photocurrent of $CdSe_{0.7}Te_{0.3}$ thin films

3. RESULTS AND DISCUSSION

The X-ray diffraction patterns of the prepared $CdSe_{0.7}Te_{0.3}$ compound and thin film are shown in figs.1 and 2. The presence of sharp peaks in the X-ray diffractogram indicate that both the prepared $CdSe_{0.7}Te_{0.3}$ compound and thin film are polycrystalline in nature. They are found to be single-phase exhibiting hexagonal wurtzite structure. The crystallites are found to have a preferred orientation along (002) and (110) direction. The lattice parameter values of the prepared $CdSe_{0.7}Te_{0.3}$ compound and thin film have been determined and are a = 4.316 Å, c = 7.263 Å and a = 4.296 Å, c = 7.258 Å respectively. The results indicate that there is no appreciable difference among the lattice constants of bulk and thin film. These values are in good agreement with the values reported by earlier workers [11-13]. Using the X-ray diffractogram of the $CdSe_{0.7}Te_{0.3}$ thin film the grain size, strain and dislocation density have been evaluated. The grain size has been calculated using Scherer's formula and the methodology is well explained in our previous article [6 and references there in]. The grain size, dislocation density and strain were found to be 708 Å, 1.989×10^{14} lines/m^2 and 6.248×10^{-4} respectively. Figs. 3 and 4 show the EDAX pattern of the prepared $CdSe_{0.7}Te_{0.3}$ compound and thin film respectively. The bulk and the thin film are found to have a composition of Cd – 50.85 at%, Se – 36.12 at%, Te – 13.03 at % and Cd – 51.10 at%, Se – 35.56 at%, Te – 13.34 at% respectively which is found to correlate very well with the calculated composition. This clearly shows that excellent composition control can be easily achieved using hot wall deposition technique without sacrificing the simplicity of the vacuum technique.

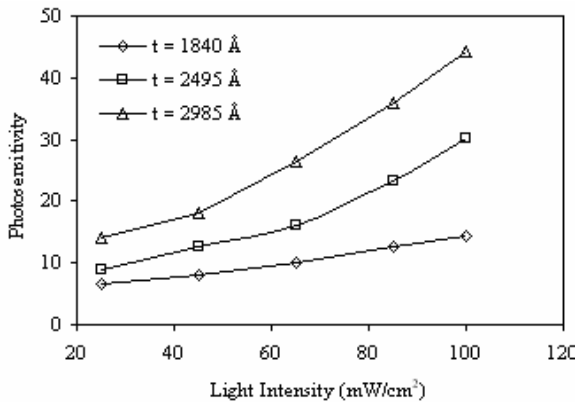

Figure 7. Variation of photosensitivity with light intensity of $CdSe_{0.7}Te_{0.3}$ thin films

The variation of photocurrent with light intensity in $CdSe_{0.7}Te_{0.3}$ thin films of different thicknesses are shown in fig. 5. The photocurrent is found to increase with increase in light intensity. This is due to the increase in the concentration of majority charge carriers with light intensity. The dependence is a power function of light intensity and indicates the presence of energy levels with complex distribution in the forbidden band. A similar behavior has been reported by earlier workers [14, 15]. The spectral response of the photocurrent in $CdSe_{0.7}Te_{0.3}$ thin films is shown in fig. 6. The photocurrent is found to increase with increase in wavelength of the incident photons, reach a maximum around 800 nm and then decrease. The maximum observed in the spectral response curve corresponds to the absorption edge, which is related to the energy band gap of the material. The energy band gap of $CdSe_{0.7}Te_{0.3}$ thin films is found to be 1.55 eV that corresponds to the maximum observed in the spectral response characteristics of the photocurrent. This in good agreement with the values reported by Islam et al [5] and Ravichandran et al [15]. In the higher wavelength region the radiation is partially observed giving rise to less photocurrent than the maximum. The presence of defect centers extends the spectral response to longer wavelength region due to direct excitation of carriers from defect levels. The sharpness of the peak in the response curve is found to be thickness dependent. If the photoconductive films are very thin, no maximum is observed in the response curve, as all the photo-excited carriers will recombine by surface recombination kinetics. The variation of photosensitivity with light intensity in $CdSe_{0.7}Te_{0.3}$ thin films is shown in fig. 7. The photosensitivity, which is the ratio of photocurrent to dark current, is found to increase with increase in light intensity. Thicker films are found to exhibit greater photosensitivity.

4. CONCLUSION

$CdSe_{0.7}Te_{0.3}$ compound has been synthesized by direct reaction of high purity elemental cadmium, selenium and tellurium. Using the synthesized alloy, $CdSe_{0.7}Te_{0.3}$ thin films have been prepared by hot wall deposition technique. The composition analysis revealed the maintenance of the stoichiometry in films similar to that of the synthesized bulk poweder. The films are found to be polycrystalline in nature with hexagonal structure. Photo current and photosensitivity were found to increase with film thickness. The band gap of the material has been calculated from the spectral response characteristics of the photocurrent.

5. ACKNOWLEDGEMENT

We like to thank CONACYT for the financial support through the project G 38618U and the India-Mexico project on nanostructured solar cells.

REFERENCES

[1] G. Hodes, Nature, 285, 29 (1980)
[2] M. I. Izakson, N. Ya. Karasik, L. M. Prokator, D. A. Sakreev, G. A. Fedorova and I. N. Yakimenko, Inorganic Materials, 15, 178 (1979)
[3] P. J. Sebastian and V. Sivaramakrisnan, Journal of Physics D, 23, 114 (1990)
[4] P. J. Sebastian and V. Sivaramakrisnan, Journal of Applied Physics, 65, 237 (1989)
[5] R. Islam, H. D. Banerjee, D. R. Rao, Thin Solid Films, 266, 215 (1995)
[6] S. Velumani, Xavier Mathew, P. J. Sebastian, Solar Energy Materials and Solar Cells, 76, 359 (2003)
[7] N. Muthukumarasamy, S. Jayakumar, M. D. Kannan, R. Balasundaraprabhu and P.Ramanathaswamy, Journal of Crystal Growth, 263, 308 (2004)
[8] N. Muthukumarasamy, R. Balasundaraprabhu, S. Jayakumar, M. D. Kannan, and P. Ramanathaswamy, Physica Status Solidi a, 10, 2312 (2004)
[9] D. Schikora, H. Sitter, J. Humenberger and K. Lisekha, Applied Physics Letters, 48, 1276 (1986)
[10]A. Lopez - Otero, Thin Solid Films, 49, 3 (1978)
[11]M. Bouroushian, Z. Loizos, N. Spyrellis and G. Maurin, Thin Solid Films, 229, 101 (1983)
[12]M. Bouroushian, C. Kollia, Z. Loizos, N. Spyrellis and G. Maurin, Applied Surface Science, 102, 112 (1996)
[13]G. Hodes, J. Manassen and D. Cahen, Journal of American Chemical Society, 102, 5962 (1980)
[14]M. I. Izakson, N. Ya. Karasik, L. M. Prokator, D. A. Sakreev, G. A. Fedorova and I. N. Yakimenko, Transalated from Izvestiya Akademii Nauk USSR, Neoorganicheskie Materialy, 15, 227 (1979)
[15]D. Ravichandran, Francis. P. Xavier, S. Sasikala and S. Moorthy Babu, Bulletin of Materials Science, 19, 437 (1996)