www.amlett.org, www.amlett.com, DOI: 10.5185/amlett.2013.icnano.118
"ICNANO 2011" Special Issue Published online by the VBRI press in 2013

Preparation and characterization of the chromium doped ZnTe thin films

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ABSTRACT

The chromium doped zinc telluride (ZnTe:Cr) as well as ZnTe thin films and their sandwich structures were prepared onto glass substrate by thermal evaporation method under the vacuum of 10^{-5} Torr. We have studied the structural, optical and electrical properties of thermally evaporated Cr-doped ZnTe thin films as a function of Cr concentration. XRD measurements show that Cr-doped ZnTe films possess the mix phase of cubical and hexagonal structure of ZnTe thin film. The optical energy band gap (E_g) calculated from the optical absorption spectra which was observed around 2.57 eV for undoped ZnTe, and reduced to 1.47 eV for the Cr-doped thin films. The result of I-V characteristics is also presented in this paper. Copyright © 2013 VBRI press.

Keywords: ZnTe:Cr thin films; XRD; UV-Vis spectrophotometer; I-V characteristics.

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Introduction

Zinc telluride (ZnTe) is an important semiconducting material for the development of various modern solid state devices (blue light emitting diodes, laser diodes, solar cells, microwave devices, etc.) **[1-3]**. This compound does not contain expensive rare metals such as In and Ga, leading to the fabrication of LED with low cost **[4]**. It is a direct band gap semiconductor having band gap 2.26 eV at 300 K and usually a p-type semiconductor. Some methods have been developed for the preparation of ZnTe thin films such as thermal vapor deposition under vacuum, molecular beam epitaxy, organo-metallic chemical vapor deposition, solution growth; spray pyrolysis, etc. **[3, 5–7]**. The choice of the deposition method may be based on quality of the films required for specific applications.

A well-defined composition of Zn–Te can be obtained in thin film form by thermal evaporation method under the vacuum of 10^{-5} Torr. This method has been used for CdTe by Curz and de Avillez **[8]** and copper indium diselenide thin film by Carter et al. **[9]**. It is particularly suitable for deposition of compound semiconductor thin films, as it provides good control of composition. This method has been used as a promising method for producing highly efficient CdTe/CdS solar cells as reported by Ohshita **[10]**.It is also reported in the literature **[11, 12]** that ZnTe exhibits improved photorefractive response when it is doped with vanadium. Vanadium is believed to be a suitable impurity in ZnTe and it has attractive use in a variety of applications including optical power limiting, optical computing and optical communication **[13]**. Since optical response is of great importance for many device applications, many efforts have been made to obtain optical response. Although there have been a number of investigations on the ZnTe films by a number of researchers, no systematic study appears on the structural and optical properties of ZnTe thin films using chromium as a dopant. We therefore have undertaken a systematic study on structural, electrical and optical properties of chromium doped zinc telluride (ZnTe/Cr) thin films. In this paper, we present the results obtained by XRD, electrical and optical properties.

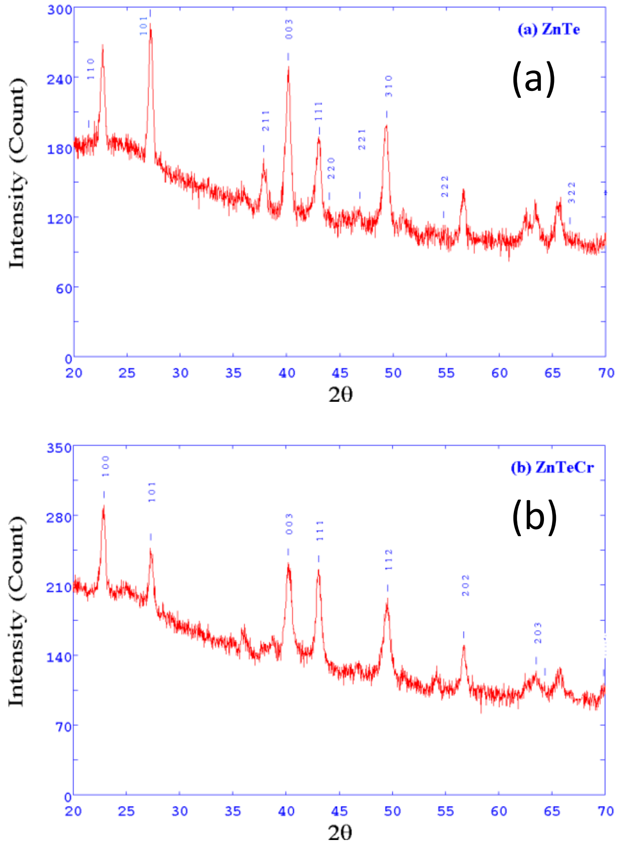

Fig. 1. X-ray diffraction patterns of (a) as-deposited ZnTe and (b) Cr doped ZnTe thin films.

Experimental

Sample preparation

The ZnTe thin films were prepared using a vacuum coating unit (Hind High Vacuum Company, Bangalore, India). High purity of metal powder Zn (99.99%), Te (99.99%) and Cr (99.99%) were taken in the stoichiometric proportion for the preparation of $Zn_{1-x}Cr_xTe$ alloys films with varying Cr composition with x = 0.0, 0.1 and 0.2. Each element of $Zn_{1-x}Cr_xTe$ composition was weighed by an electronic balance (which has a resolution of ±0.0001 g) with x = 0.0, 0.1 and 0.2. Then the elemental quantities were mixed and ground together using an agate mortar and pestle. This mixture (~ 100 mg) was placed into Molybdenum boat and it was heated indirectly by passing current through the electrodes. Cleaned glass slides were used as a substrate for the thin film deposition under vacuum of 10^{-5}Torr. The films prepared in such a way were subjected to different experimental characterization techniques.

X-ray diffraction

X-ray diffraction measurements have been taken by using Panalytical System having CuK_α, as a radiation source of wavelength λ = 1.54 Å with 2θ = 20°-70° at the scan speed 0.5°/min for the determination of structure of the films. The analysis has been performed using Powder X program **[14]**.

I-V characteristics

I-V characteristics of as-grown samples have been recorded using Keithley-238 high current source measuring unit. I-V characteristics of thin films have been monitored with the help of SMU Sweep computer software. All the measurements have been performed at room temperature.

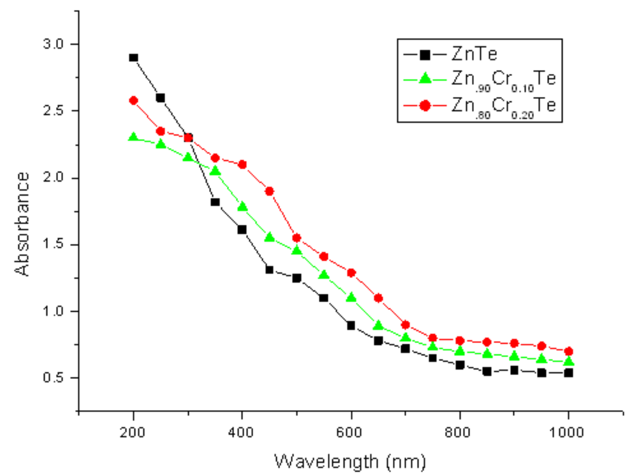

Fig. 2. Optical Absorbance spectra of $Zn_{1-x}Cr_xTe$ thin films.

Results and discussion

Structural characteristics

Fig. 1 (a) and (b) shows the X-ray diffraction pattern for as-deposited ZnTe and ZnTe/Cr thin film respectivly. It was found that the diffraction peaks at 2θ angles of 22.88°, 27.44°, 37.58°, 40.30°, 43.30°, 49.38°, 56.74°, and 62.51°, 66.80° correspond to (110), (101), (211), (003), (111), (310), (222), (203) and (322) planes of the mix cubical and hexagonal structure of ZnTe. This shows that ZnTe formed in mix phase. No additional diffraction peaks associate with metallic Cr, Zn and Te indicating that respective thin films possess major phase corresponding to ZnTe. The ZnTeCr sample crystallizes in hexagonal with lattice parameters a=4.34(4) Å, c=6.79(5) Å. The fundamental reflection (211) of the cubic phase is suppressed in Cr doped sample.

Optical absorbance spectra

The absorbance spectra of the ZnTe and $Zn_{1-x}Cr_xTe$ for x= 0.1 & 0.2 thin films are shown in **Fig. 2**. The spectra reveal that all the films show more absorbance in ultraviolet region corresponding to 200-500 nm spectral regions.

There is a slight decrease in the absorbance for the doped films due to incorporation of Cr atoms into the ZnTe films. It may be concluded from above studies that optical absorbance decrease below 300 nm but for higher spectral region it is increased in Cr doped ZnTe compared to ZnTe. From the absorbance data, we have estimated the absorption coefficient using Lambert law:

$$Log\left(\frac{I_0}{I}\right) = 2.303; \qquad Abs = \alpha\, d \qquad (1)$$

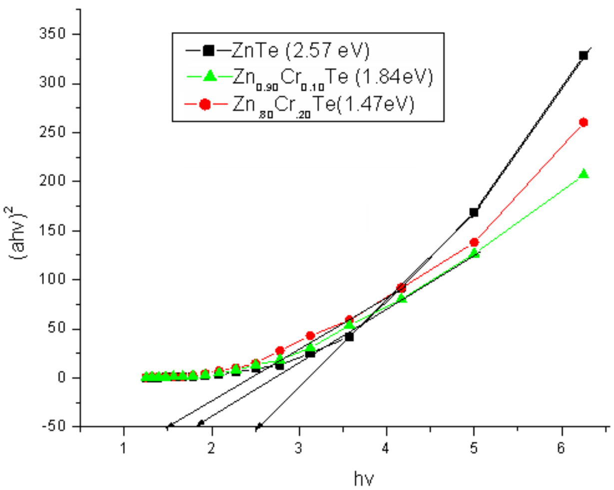

Fig. 3. Plots of $(\alpha h\nu)^2$ versus Energy for band gap calculation.

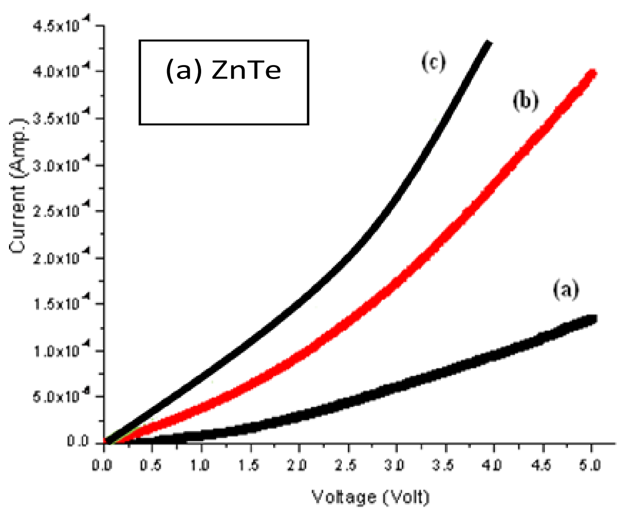

Fig. 4. I-V characteristics of ZnTe films before and after doping.

Abs. is optical absorbance, I_0 & I are intensities of the incident & transmitted radiation respectively, α is absorption coefficient and *d* is thickness of the films (cm). Optical band gap *(Eg)* was determined by analyzing the optical data with the expression for the optical absorption coefficient α and the photon energy $h\nu$ using the relation

$$\alpha = k\,(h\nu - Eg)^{n/2} / h\nu \qquad (2)$$

where *k* is a constant, the value of *n* is equal to one for a direct-gap material, and four for an indirect-gap material. Plots of $(\alpha h\nu)^2$ versus $h\nu$ were drawn using the above equation. Extrapolation of the linear portion of the plot to the energy axis yielded the direct band gap value as shown in **Fig. 3**. Shift of optical band gap with chromium doped ZnTe was observed and band gap decreases for chromium doped thin films.

I-V characteristics

I-V characteristics of the ZnTe and $Zn_{1-x}Cr_xTe$ for x=0.1 & 0.2 thin films is shown in **Fig. 4**. It was observed that the remarkably larger (5-10 times) forward current at all voltages has been obtained for Cr doped thin films, which means the higher conductivity of these films. The remarkably increased conductivity may be helpful in obtaining higher efficiency in the solar cell. The more definitive experiments (like Hall coefficient measurement) are being planned for this purpose in near future and results will be reported in near future.

Conclusion

ZnTe and $Zn_{1-x}Cr_xTe$ for x= 0.1 & 0.2 thin films could be prepared using thermal evaporation method. XRD of the $Zn_{0.90}Cr_{0.10}Te$ thin film reveal mix phase of ZnTe having cubical and hexagonal structure. Optical absorption data revealed that decrease in band gap for Cr doped ZnTe films. There is an order of magnitude enhancement in the conductivity of the Cr doped ZnTe films compared to ZnTe.

Acknowledgements

The authors are thankful to Dr. Sudhish Kumar, Department of Physics, MLS University, Udaipur for critical discussion and helping us in analyzing the XRD data. A special thanks from one of the author (Dinesh C. Sharma) to Dr. Kuldeep Singh Rathore, Amity University, Rajasthan, India.

Reference

1. Bhahada, K. C.; Tripathi, B.; Acharya, N. K.; Kulriya, P. K.; Vijay, Y. K. *Applied Surface Science* **2008**, 255, 2143–2148.
2. Rusu, G. I.; Prepelita, P.; Rusu, R. S.; Apetroaie, N.; Oniciuc, G.; Amariei, A. J. *Optoelectronics and Advanced Materials* **2006**, 8(3), 922 – 926.
3. Bhargava, R. (Ed.) *Properties of Wide Band gap II–VI Semiconductors;* INSPEC publication: London, **1997**.
4. Tanaka, T.; Katsuhiko, S.; Mitsuhiro, N.; Qixin, G.; Hiroshi, O. *Applied Physics Express* **2009**, 2, 122101. **DOI:** 10.1143/APEX.2.122101
5. Georgobiani, A. N. *Physics of A_2B_6 Compounds*; M.K. Sheinkman (Eds.); Nauka: Moscow, **1986.**
6. Chopra, K. L. *Thin Film Phenomena*; McGraw-Hill:New York, **1969**.
7. Massel, L. I. R. *Handbook of Thin Film Technology*; Glang (Eds.); McGraw-Hill:New York, **1980**.
8. Curz, L. R.; de Avillez, R. R. *Thin Solid Films* **2000**, 15,373.
9. Carter, M.J.; Amson, I.; Knowles, A.; Hill, R. Proceedings of the 19th IEEE Conference of Photovoltaic Specialists, New Orlence, New York, **1987**, p. 1275 .
10. Ohshita, M. J. *Appl. Phys*. **1971**, 10, 1365.
11. Ziari, M , Steier, W.H.; Ranon, P. M. *Appl. Phys. Letts*. **1992**, 60, 1052.
12. Kreissl, J.; Irmscher, K. *Phys. Rev. B*, **1996**, 53, 1917.
13. Hossain, M. S.; Islam, R.; Khan, K. A. *Chalcogenide Letters* **2010**, 7, (1), 21 – 29.
14. Dong, C. J. *Appl. Cryst.* **1999**, 32, 838.