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Preparation and Optical Properties of ZnTe/ZnTe:Cr Bilayer Thin Films

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Abstract - ZnTe/ $Zn_{0.9}Cr_{0.1}Te$ and ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ bilayer thin films alongwith pure ZnTe thin film were prepared onto glass substrate by thermal evaporation method under the vacuum of 10^{-5} Torr. Thickness of these thin films is determined by ellipsometric measurements. The optical band gap of 2.4 eV for ZnTe thin film decreased to 1.6 eV for ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ bilayer thin film by analyzing the optical absorbance spectra observed using Uv-Vis spectroscopy . Surface topography of these films done by optical microscopy is also reported here.

Keywords - ZnTe:Cr thin films, Uv-Vis spectroscopy, Surface topography.

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I. INTRODUCTION

In recent years, the II–VI family of compound semiconductors, including cadmium selenide (CdSe), zinc selenide (ZnSe), cadmium telluride (CdTe) and zinc telluride (ZnTe), have been studied due to their low cost and high absorption coefficients for applications to photovoltaic and photoelectrochemical cells [1]. ZnTe possess a cubic, zinc blende type structure with lattice constant a = 6.1034 Å. Usually, it is a material of high absorption coefficient [2] and shows p-type [3] nature. For ZnTe band gap of 1.7 to 2.4 eV has been reported from the measured absorption [4]. It is a promising compound for development of various solid state devices including the blue light emitting diodes [5], laser diodes, solar cells , microwave devices and various optoelectronic devices [6,7]. It is also reported [8] that the ZnTe exhibits improved photorefractive response when it is doped with vanadium. Large magneto refractive effect (MRE) is found for Fe/ZnTe Bilayers [12,13]. Cr 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 [9]. There have been a number of investigations on the electrical, optical and electro-optical properties of ZnTe and ZnTe:V [8] materials by a number of researchers. Nanowire of $Zn_{1-x}Mn_xTe$ (x=0.6) have been made by MBE method [10]. Enhanced light output as LED's made from ZnTe thin film have been reported [11]. The synthesized ZnTe thin films were nanocrystalline with densely aggregated particles in nanometer scale and were free from the voids or cracks. The optical band gap energy of the film was found to be thickness dependent. The elemental chemical compositional stoichiometric analysis revealed good Zn:Te elemental ratio of 53:47 [14]. ZnTe is one of the promising materials for pure green light emitting diodes (LEDs) because of its direct transition band gap of 2.26 eV at room temperature (RT). This compound does not contain expensive rare metals such as In and Ga, leading to the fabrication of LED with low cost [15]. In recent years, owing to a number of practical applications in the field of micro-electronics and opto-electronics a great deal of interest has been shown in the study of the dielectric and conduction behaviour of various semiconducting materials such as ZnTe[16]. The various deposition techniques have been used to grow thin films such as flash evaporation, R.F. sputtering, molecular beam epitaxy, spray pyrolysis, co-evaporation and stacking elemental layer deposition technique [17–26]. Among these techniques, thin film deposition processes have higher cost and need sophisticated instrumentations. The stacked elemental layer (SEL) deposition technique is a most and appropriate technique suitable for large area production of solar cell. This is due to its low cost, easiness, high efficiency and stability of the product [27,28]. The advantage of SEL technique is the ability to adjust and control the elemental fluxes and substrate temperatures throughout the film deposition process. Currently, one-dimensional nanoscale materials have attracted much attention due to their interesting physical properties and potential device applications. There does not exist any systematic study on the electrical and optical properties, in particular for bilayer ZnTe/ ZnTe:Cr films, at varying deposition conditions.

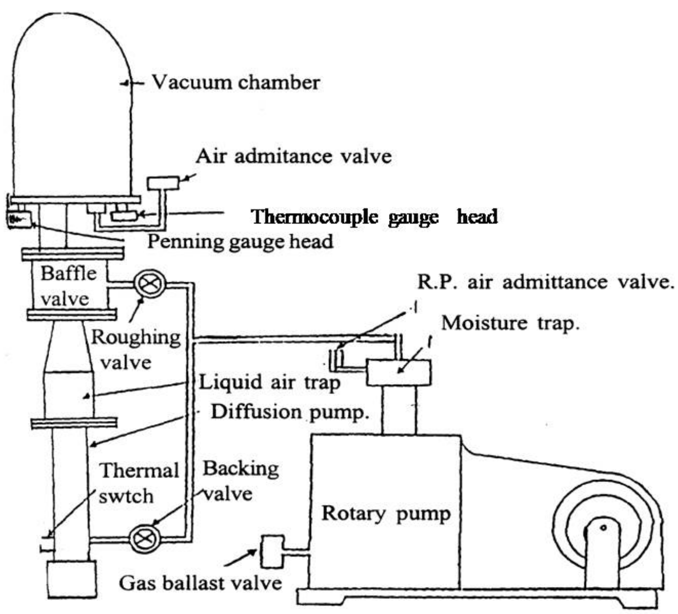

Fig.1 (a): Schematic diagram of vacuum thermal evaporation

We have therefore undertaken a systematic study how varying deposition conditions affect the optical properties of ZnTe, In the ealier communication [29], it is found that the optical band gap decreased upon Cr-doping in ZnTe single layer thin films. In this paper, the optical properties of ZnTe/$Zn_{0.9}Cr_{0.1}Te$ and ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ bilayer thin films observed by the Uv-Vis spectroscopic measurements will be described.

II. Deposition Of Thin Films

A. Substrate Cleaning

An important influence exerted by the substrate on film growth is through its cleanliness. Substrate cleaning is performed before inserting the substrate inside the evaporation chamber. The substrate serves as a mechanical support for the film. For long term stability of thin film, it is imperative that no chemical reactions occur which could change the properties of the film. The substrate must fulfill certain requirements like its mechanical strength and there must be adequate adhesion of the film to the substrate not only at normal temperature but also during relatively large temperature change. It should also fulfill the practical requirements, such as the possibility of vacuum processing and the availability and cost of the material. The most widely used substrates for thin films are glass, fused silicon and ceramics.

An integral part of cleaning is the procedure employed for drying the substrate after final washing. If drying agents like acetone are utilized recontamination can occur unless extremely pure agents are employed. Even wiping with a clean cloth may leave a residue. Therefore drying is frequently accomplished in a vapour degreaser followed by blowing off the remaining moisture with compressed, filtered air or nitrogen.

B. Evaporation of Thin Films

The ZnTe/ZnTe:Cr bilayer thin films were prepared using a vacuum coating unit (Hind High Vacuum Company, Bangalore) Model 12A4D. High purity Zn (99.99%), Te (99.99%) and Cr (99.99%) metal powder were taken in the stoichiometric proportion for the preparation of ZnTe/$Zn_{1-x}Cr_xTe$ alloys with varying Cr composition with x =0, 0.1 and 0.2. Each material of ZnTe:Cr was weighed by an electronic balance which has a resolution of ±0.0001 g, according to percentage of composition to be used. Then the materials were mixed and ground together using an agate mortar and pestle. The material (~ 100 mg) was placed into molybdenum boat and it was heated indirectly by passing current through the electrodes. Initially we have deposited ZnTe layer then $Zn_{1-x}Cr_xTe$ alloys with varying Cr composition with x =0, 0.1 and 0.2 layers respectively to obtain as-grown ZnTe/ZnTe:Cr stacked layers. The schematic diagram of vacuum thermal evaporation is shown in Fig. 1. Cleaned glass slides were used as a substrate. The deposition has been done at vacuum of 10^{-5} torr.

Fig.1(b): Vacuum Thermal Evaporation Unit

III. Thickness Measurement

Thickness of as-grown ZnTe, ZnTe/ $Zn_{0.9}Cr_{0.1}Te$ and ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ films was estimated using ellipsometery. The calculated thicknesses are 146 nm, 247 nm and 249 nm respectively for these three films.

IV. Result & Discussion

A. Optical Absorbance Spectra

Optical absorbance studies were carried out in the wavelength range of 200 – 900 nm to investigate the optical absorbance properties of the as-grown ZnTe/$Zn_{1-x}Cr_xTe$ (x = 0, 0.1 and 0.2) films. ZnTe and ZnTe/ZnTe:Cr films exhibit a remarkable difference in the optical absorbance. This difference may be attributed to structural and compositional changes in the films taking place when Cr is heavily doped into the ZnTe lattice.

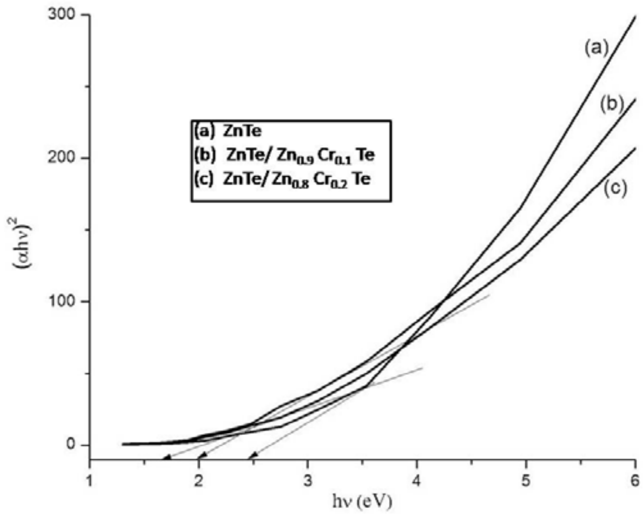

Fig-2: Plots of $(\alpha h\nu)^2$ versus hν for ZnTe, ZnTe/ $Zn_{0.9}Cr_{0.1}Te$ and ZnTe/ $Zn_{0.8}Cr_{0.2}Te$

From the absorbance data, the absorption coefficient was calculated using Lambert law:

$$Ln\ (I_o/I) = 2.303\ , \qquad Abs = \alpha d \quad \ldots\ldots\ldots (1)$$

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.

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

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.1.Theoretical band gap determined from this analysis for pure ZnTe , ZnTe/ $Zn_{0.9}Cr_{0.1}Te$ and ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ bilayer thin films were 2.4eV,1.9 eV,1.6 eV respectively.

B. Surface morphology

Surface morphology of the as-deposited ZnTe thin film is shown in Fig. 2(a). It shows a smooth surface. Fig. 2(b) and Fig. 2(c) show the morphology of the ZnTe/$Zn_{0.9}Cr_{0.1}Te$ and ZnTe/$Zn_{0.8}Cr_{0.2}$ thin films. A large number of grains can be seen, which indicates the crystalline nature of the film. More conclusive results will be obtained by carrying out XRD studies of these thin films.

Fig. 3(a)

Fig. 3(b)

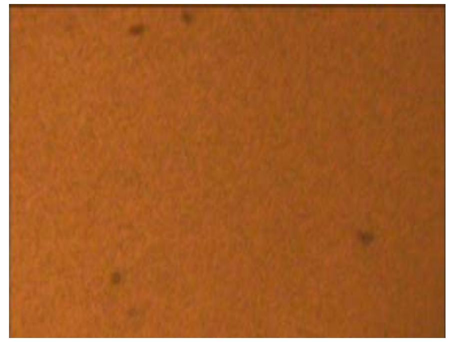

Fig. 3(c)

Fig. 3: Optical micrographs of (a) as-grown ZnTe (b) ZnTe/$Zn_{0.9}Cr_{0.1}Te$ and (c) ZnTe/ $Zn_{0.8}Cr_{0.2}Te$

V. CONCLUSION

ZnTe and ZnTe/ $Zn_{1-x}Cr_xTe$ for x=0.1 & 0.2 thin films could be prepared using thermal evaporation method. It can be concluded from above studies that optical band gap decreases from 2.4 eV to 1.6 eV for pure ZnTe to ZnTe/ $Zn_{0.8}Cr_{0.2}Te$ bilayer thin films.

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VII. REFERENCES

[1] Takahiro Ishizaki, Takeshi Ohtomo and Akio Fuwav, Structural, optical and electrical properties of ZnTe thin films electrochemically deposited from a citric acid aqueous solution J. Phys. D: Appl. Phys. 37 (2004) 255–260.

[2] G. I. Rusu, P. Prepelita, N. Apetroaei, G. Popa , on the electronic transport and optical properties of ZnTe thin films Journal of Optoelectronics and Advanced Materials Vol. 7, No. 2, April 2005, p. 829 – 835.

[3] M. S. Hossain et al. structural, elemental compositions and optical properties of ZnTe:V thin films, Chalcogenide Letters 7, (2010) 21-29.

[4] J. Singh, Physics of Semiconductors and Their Heterostructure 1993), Mc Graw Hill, N.Y (USA).

[5] Jayadev Patter et al., Structural, Optical and Electrical properties of Vacuum Evaporated Indium Doped Zinc Telluride Thin Films, Int. J. Electrochem. Sci., 4 (2009) 369-376.

[6] R. Bhargava (ed), Properties of Wide Band Gap II-VI Semiconductors (Inspec., London 1997).

[7] Q. Wu, M. Litz, X. C. Zang, Broadband detection capabililty of ZnTe electro-optic field detectors, Appl. Phys. Lett. 68, 2924 (1996).

[8] M. S. Hossain et al, Effect of Various parameters on the DC electrical properties of ZnTe: V thin films J. of Ovonic Research 5 (2009) pp 195-205.

[9] Manoj K. Yadav, Biplab Sanyal and Abhijit Mookerjee , Structural, electronic and magnetic properties of Cr-doped doped $(ZnTe)_{12}$ clusters , Journal of Magnetism and Magnetic Materials, Volume 321, Issue 4, February 2009, Pages 235-240.

[10] Wojciech Zaleszczyk *et al*., Zn1-xMnxTe Diluted Magnetic Semiconductor Nanowires Grown by Molecular Beam Epitaxy, Nano Letters 8 (2008) 4061-4065.

[11] Tooru Tanaka *et al*. Characterization of Al-doped ZnTe layer using scanning capacitance microscopy and Kelvin probe force microscopy, J. Mater Sci. Mater Electron 20 (2009) S505-09.

[12] I. D. Lobov *et al*., Magnetooptical and magnetic properties of Fe/ZnTe/Fe heterostructures, Journal of Magnetism and Magnetic Materials Volume 264, Issues 2-3, August 2003, Pages 164-168.

[13] I.D.Lobov *et al*, Magnetooptical and magnetic properties of Fe/ZnTe/Fe Nanohetrostructures, The physics of metal and Metallography 2006, Volume 102, pp 149-156.

[14] S.S. Kale, R.S. Mane, H.M. Pathan and Sung-HwanHan, Preparation and characterization of ZnTe thin films by SILAR method Applied Surface Science, Volume 253, Issue 9, 28 February 2007, Pages 4335-4337

[15] Tooru Tanaka, Katsuhiko Saito, Mitsuhiro Nishio, Qixin Guo, and Hiroshi Ogawa, Enhanced Light Output from ZnTe Light Emitting Diodes by Utilizing Thin Film Structure, Applied Physics Express 2 (2009) 122101.

[16] R. Amutha, A. Subbarayan, R. athyamoorthy, K. Natarajan1 and S. Velumani, Conduction Studies on ZnTe Thin Films, Journal of New Materials for Electrochemical Systems 10, 27-31 (2007).

[17] A. Bouraiou, M.S. Aida, E. Tomasella, N. Attaf, Journal of Materials Science 44 (2009) 1241.

[18] A. Ashour, Journal of Materials Science: Materials in Electronics 17 (2006) 625.

[19] J.J. Loferski, Journal of Applied Physics 27 (2002) 777.

[20] S.P. Grindly, A.H. Clark, S. Rezaie-serej, E. Falconer, J. Mcneily, Journal of Applied Physics 51 (1980) 544.

[21] S. Prabahar, B. Subramanian, N. Subramanian, N. Muthukumarsamy, Chalcogenide Letters 7 (2010) 49.

[22] R. Scheer, K. Diesner, H.J. Lewerenz, Thin Solid Films 268 (1995) 130.

[23] J. Araujo, R. Ortiz, A. Lopez-Rivera, J.M. Ortega, M. Montilla, D. Alarcon, Journal of Solid State electrochemistry 11 (2007) 407.

[24] T.P. Gujar, V.R. Shinde, J.W. Park, H.K. Lee, K.D. Jung, O.S. Joo, Journal of the Electrochemical Society E131 (2008) 155.

[25] S. Yun, K. Hong, H. Park, Journal of Ceramic Processing Research 9 (2008) 25.

[26] S.P. Nehra, Deepshikha Sharma, M. Singh, Y.K. Vijay, Journal of Alloys and Compounds 502 (2010) 220.

[27] M.E. Calixto, P.J. Sebastian, R.N. Bhattacharya, R. Noufi, Solar Energy Materials and Solar Cells 59 (1999) 75.

[28] D. Lincot, Thin Solid Films 487 (2005) 40.

[29] Dinesh C. Sharma, Garima, Subodh Srivastava, Y.K.Vijay, Y.K.Sharma, AIP Conf. Proceedings of the 55th DAE Solid State Physics Symposium 1349, (2011) 759-760.