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Hall coefficient, mobility and carrier concentration as a function of composition and thickness of Zn-Te thin films

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ABSTRACT

The Hall Effect studies on Zn-Te thin films of different composition and thicknesses have been made at room temperature for different magnetic fields between 3 to 9.5 K Gauss at different electric field currents between 1 to 50 µA. Hall voltages was measured for varying magnetic and electric fields. The Hall coefficient (R_H) and mobility (μ_H) are independent of magnetic and electric fields, however they changes with film thickness and composition of the film. The films showed P-type behavior irrespective of thickness and composition. The variation of carrier concentration (n_H) depends on thickness and composition of Zn-Te films, observations show the carrier concentration decreases with increase of thickness while that increases with increase of at. wt.% of Zn in the film. Thin films of Zn-Te compound of varying composition and thicknesses have been formed on glass substrates employing three temperature method.

Keywords: Hall coefficient, Mobility, Carrier concentration, glass substrate, thin film.

INTRODUCTION

The Zn-Te is a II-VI semi conducting compound has a direct band gap of 2.26 eV at room temperature. Thin films of Zn-Te have been made by several workers from the crystallization point of view and application considerations [1- 2]. Patel and Patel [3] reported that the vacuum deposited films of ZnTe having thickness about 100 nm onto the silver stimulator substrate were used for the measurements of the electrical resistivity, the Hall effect, the photosensitivity and the field effect. The crystalline size of film increased as the stimulator thickness increased with decrease in electrical resistivity, the increase in the Hall mobility and decrease in the carrier concentration.

Hall effect measurements on Zn-Te deposits are carried out at room temperature. Hall voltage (V_H) developed from Zn-Te deposits over entire composition range revealed that holes are majority current carriers in these films, irrespective of composition and thickness of the film. Similar results have been reported by Crowder and Hammer [4], Larsen and Stevenson [5] on bulk ZnTe crystals. Tubota et al [6] reported Hall effect measurements on Zn-Te thin films. They also confirmed the p-type conductivity in these films. The p-type nature of ZnTe in its bulk form is explained by Bottom [7]. Accordingly the doping of elements in Te always yields p-type materials. The positive carriers contributing to the electrical conduction in ZnTe films comes presumably from the Zn vacancies, because the vapor pressure of Zn is much higher than that of Te and then Zn may escape in the process of crystallization [8].

Fischer et al [9] reported that ZnTe is normally p-type, which is amongst other reasons, due to the fact that Te vapor, is largely mono atomic at 1000^0C, thus comparable to Zn vapor in its effectiveness to fill vacancies. The experiments of Aven and Segall [10] have indicated that the stoichiometric defects in ZnTe is doubly ionisable centre (probably a Zn vacancy) with acceptor levels 0.05 and 0.13 eV above the valence band. Similar results are obtained by Shiozawa and Jost [11] who analyzed Hall data from shallow levels observed in nominally undoped ZnTe grown from the vapor phase. They concluded that the shallow acceptor exhibited a decrease in effective ionization energy with increase in acceptor concentration.

MATERIALS AND METHODS

1. **Preparation of Zn-Te thin films**

For the measurement of Hall voltage, Zn-Te thin films were prepared by three temperature method [12-15]. Zn-Te films of different compositions and different thicknesses were prepared by thermal evaporation technique of the constituent elements Zn (99.999 % pure) and Te (99.99 pure) in a vacuum of 10^{-5} torr. The films were prepared mostly on glass substrate kept at room temperature in a vacuum, after adjusting the flux rates from two heating sources by varying the source current, films of varying compositions were obtained. Overcoming the experimental difficulties in adjusting and maintaining evaporation rates of the individual components to obtain films of different compositions having nearly same thickness and films of different thicknesses and nearly same composition, films of the required compositions and thicknesses were obtained. The films deposited were annealed at ~ 150 ^{0}C for the purpose of uniform distribution of the components in the deposits.

2. Measurement Procedure

Determination of composition, thickness and uniformity of the film were similar to those reported earlier [12-15]. The composition of the film was determined by employing absorption spectroscopy [16] at a wavelength of 550 mμ with an accuracy of ±1 at.wt. %. The film thickness (d) was measured by using multiple beam interferrometry [17] and also by gravimetric method [1-4] (±100Å) using the relation

$$d = \frac{M}{g \times A} cm \qquad (1)$$

Where,
A - Surface area of the film
M - Mass of the film material
g - Density of the film material = $\mathbf{g_1 x_1 + g_2 x_2}$
where g_1, g_2 and x_1, x_2 are densities and atomic fractions of Zn and Te elements of the film material respectively.

The Hall effect measurement for Zn-Te deposits of varying composition and thickness at room temperature by the conventional d.c. method. The electric and magnetic fields varied between 1 to 50 μA and 3.0 to 9.5 K Gauss respectively. The Hall voltage was found to be independent of electric and magnetic fields, the Hall coefficient (R_H) were calculated to be dependent on composition and thickness of the film. The magnetic field was calibrated as a function of current and pole gap. After carefully fixing the contacts, the sample was placed between the pole gap of the magnet, appropriate amount of current was passed through the sample so that the Hall voltage was sufficient, to be accurately measured by potentiometer. At the same time, avoiding Joule heating due to excessive current. The position of the sample was adjusted, so that plane of the film was exactly parallel to the pole faces then position of sample was fixed so that maximum Hall voltage was obtained. Hall voltage was also noted by reversing the magnetic field and current to eliminate errors due to the misalignment of Hall electrodes. Hall coefficient was calculated by using the relation

$$R_H = [(V_H \times d) / (I \times H)] , \quad cm^3 / Coulomb \qquad (2)$$

Where
V_H = average Hall voltage in volts. Hall effect measurement give information
d = Thickness of thin film.
I = current flowing through the film.
H = applied magnetic field in Gauss.

Hall mobility (μ_H) and carrier concentration (n_H) of charge carriers for each film was calculated using Hall coefficient (R_H) as

$$\mu_H = \sigma \times R_H, \quad cm^2 / V. Sec \tag{3}$$
$$n_H = (+/-) (1/ R_H \times e), \quad cm^{-3} \tag{4}$$

Where
σ = Electrical conductivity of film material.
e = charge of an electron.

RESULTS AND DISCUSSION

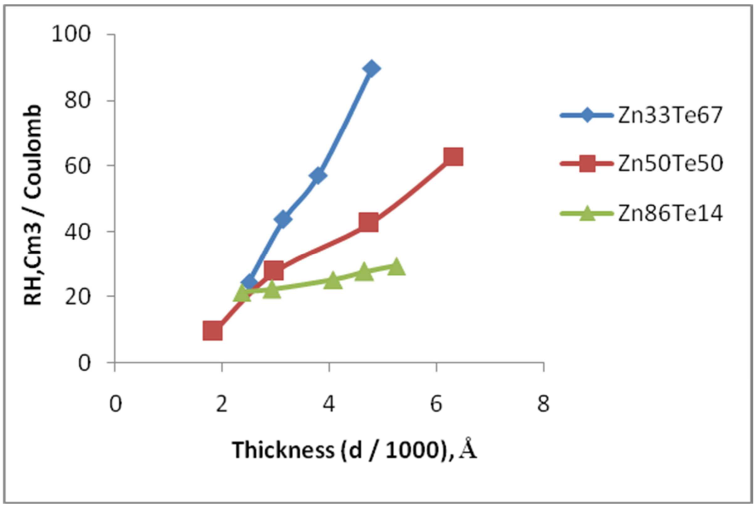

Fig.1: Plot of Hall coefficient (R_H) verses thickness (d) of Zn-Te films for different concentrations at room temperature

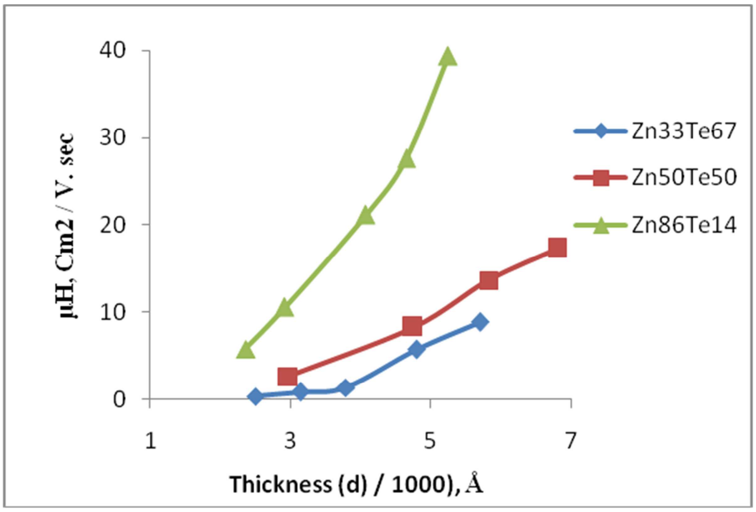

Fig.2: Plot of Hall mobility (μ_H) verses thickness (d) of Zn-Te films for different concentrations at room temperature

Fig.1 and fig. 2 shows variation of 'R_H' and 'μ_H' with thickness (d) is explained on defect density and inhomogeneity in films. These are being higher in thinner films, yielding lower values of R_H and μ_H. The Hall coefficient and mobility increases with thickness could be related to the shortening of effective mean free path of conduction carriers by scattering from the surface of the film when the thickness is of the order of bulk free path.

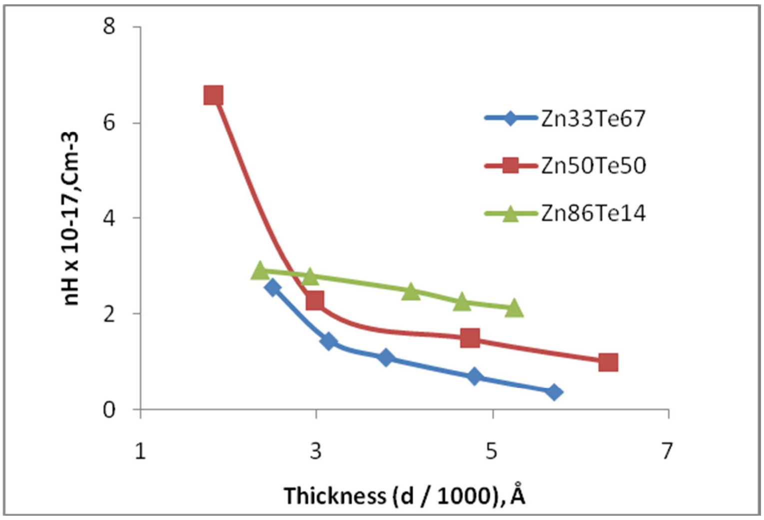

Fig.3: Plot of carrier concentration (n_H) verses thickness (d) of Zn-Te films for different concentrations at room temperature

Fig 3 shows Plot of carrier concentration (n_H) verses thickness (d) of Zn-Te deposits of various compositions. It is seen that the carrier concentration decreases with increase of thickness for all compositions, higher values of (n_H) for thinner films are attributed to higher defect density and higher grain boundary scattering.

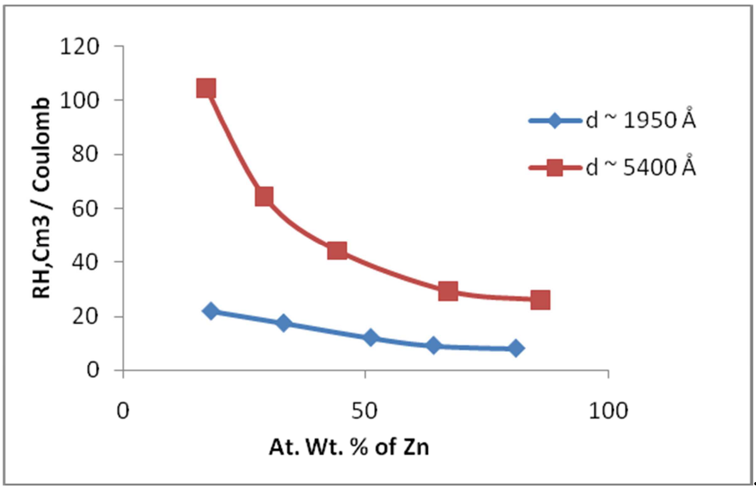

Fig.4: Plot of Hall coefficient (R_H) verses at.wt.% of Zn in Zn-Te films at room temperature

Fig.4 shows variation of Hall coefficient (R_H) with at.wt. % of Zn in Zn -Te thin films at room temperature. The decrease of R_H with increase of Zn concentration in Zn-Te films irrespective of its thickness. This decrease of 'R_H' is explained on the basis that addition of Zn to Te causes local inhomoginities in the structure produced by the difference in the sizes of the Zn and Te atoms. These inhomoginities along with other imperfections probably stoichiometric defects are responsible for decrease in 'R_H' with increase in Zn content.

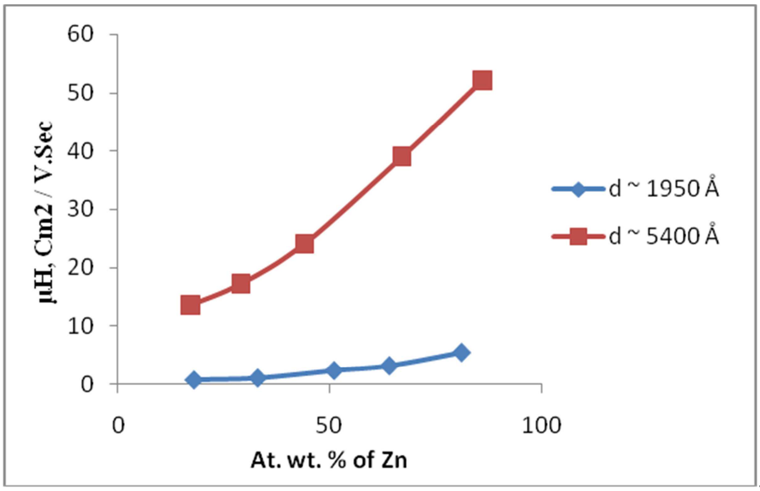

Fig.5: Plot of Hall mobility (μ_H) verses at.wt.% of Zn in Zn-Te films at room temperature

Fig.5 shows Hall mobility (μ_H) verses at.wt.% of Zn for Zn-Te thin films at room temperature. It is seen that Hall mobility (μ_H) increases exponentially with increase of at. wt. % of Zn for higher thickness. It has been suggested that shallow acceptor levels exist in Zn-Te films due to stoichiometric defects.

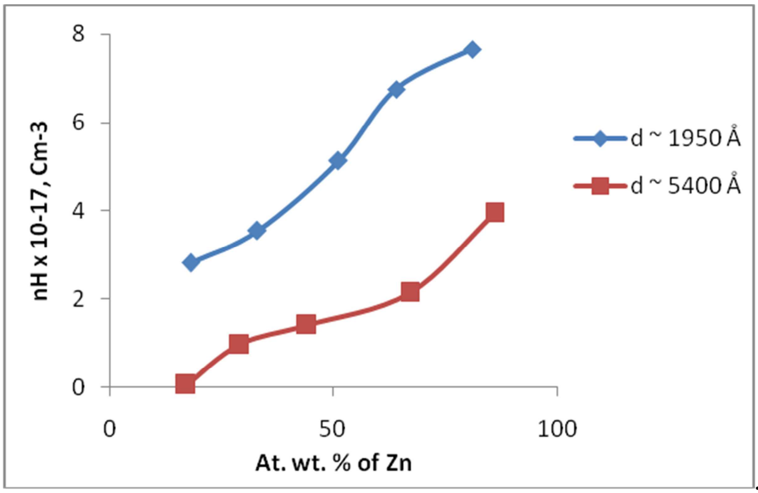

Fig.6: Plot of carrier concentration (n_H) verses at.wt. % of Zn in Zn-Te films at room temperature

Fig 6 shows the variation of carrier concentration (n_H) with at. wt. % of Zn in Zn-Te thin films at room temperature. It is found that increase of carrier concentration with increase of Zn concentration is probably due to creation of more acceptor levels with addition of Zn.

CONCLUSION

The Hall Effect measurement for Zn-Te deposits of varying composition and thickness at room temperature by the conventional d.c. method. The Hall coefficient (R_H), mobility (μ_H) and carrier concentration (n_H) was found to be dependent on composition and thickness of the films. The Hall coefficient (R_H) is positive for all compositions of Zn and Te in Zn-Te thin films show P-type behavior. The increase of film thickness increases Hall coefficient (R_H) and mobility (μ_H) while the carrier concentration (n_H) decreases. The composition dependent study shows increase of Zn content in Zn-Te thin films decreases Hall coefficient while the mobility and carrier concentration increases.

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