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Composition and Thickness Dependent Hall Coefficient, mobility and Carrier Concentration of Vacuum Evaporated Ag-Te Thin Films

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Abstract: ***Thin films of Ag-Te compound of varying composition and thicknesses have been formed on glass substrates employing three temperature method. The Hall voltage at different magnetic fields of various thin films was measured for different compositions and thicknesses of films. The Hall coefficient, mobility and carrier concentration of Ag-Te thin films of varying compositions and thicknesses were calculated. The phase change of Ag-Te thin films found composition dependent at room temperature and independent on thickness.***

Keywords: Ag-Te, glass substrate, room temperature, thin films, composition, thickness.

1. Introduction

The Silver–Telluride is a I-VI narrow band gap compound semiconductor. Electrical resistance measurements of Ag_2Te of different thicknesses , vacuum deposited on clean glass substrates held at room temperature in a vacuum of 5x 10^{-5} torr have been carried out from about 300 to 450 ^{0}K. A semiconducting to metallic phase transition takes place during heating. The phase transition temperature is also the function of thickness [1].The Hall coefficient, resistivity and Seebeck coefficient of n-and p-type specimens of Ag_2Te have been measured over the temperature range from 55 to 300 ^{O}K. These results indicated that the compound was highly degenerative over the temperature range studied [2]. Dalven and Gill [3] proposed the measurement of Hall coefficient and energy gap of β-Ag_2Te samples at temperature from 80 to 373 ^{O}K. using standard dc method.

The low temperature n-type specimens of silver telluride were studied for Hall coefficient and Hall mobility measurement [4]. The electrical properties of both n- and p-type samples [5] of β-Ag_2Te have been measured from 4.2 ^{O}K to 300 ^{O}K. The Hall coefficient was negative over the entire temperature range. Similarly Ag-doped CdTe thin films were grown by thermal evaporation onto glass substrates kept at temperature (473 ^{O}K) under vacuum (~2 x 10^{-5}Torr) . The film structures and Hall effect was carried out by using D.C. power supply (0-40) Volt and applied constant transverse magnetic field of B=0.257Tasla [6]. Silver telluride thin films of thickness between 45 nm and 145 nm were thermally evaporated on well cleaned glass substrates at high vacuum better than 10^{-5} mbar. Silver telluride thin films are polycrystalline with monoclinic structure was confirmed by X-ray diffractogram studies [7]. Thickness dependent transition temperature and electrical resistivity of co-evaporated Ag-Te thin films was studied [8]

However these compounds are less investigated in the form of thin films of different composition and thicknesses. From this point of view and considering application in electronic devices the effect of thickness and composition of Ag-Te films are discussed. I report the measurement of thickness and composition dependent Hall coefficient (R_H), Hall mobility (μH) and carrier concentration (n_H) of Ag-Te thin films at room temperature.

2. Experimental Details

2.1 Thin film Preparation

The constituent elements of Ag (99.999% pure) and Te (99.99% pure) were used for the formation of thin films of Ag-Te compound of varying composition and thicknesses on glass substrates. The vacuum deposited thin films of Ag-Te, for the measurement of Hall voltage were prepared by three temperature method [8] – [11]. Silver metal and tellurium powder were evaporated from two different preheated conical mica baskets which in turn heated externally by nichrome wire. The films were prepared at room temperature in a vacuum of the order of 10^{-5} torr with an IBP TORR-120 vacuum unit.

After adjusting the flux rates from two sources by varying the source current, films of varying thicknesses and compositions were obtained by overcoming the experimental difficulties in adjusting and maintaining evaporation rates of the individual components. The films obtained were annealed at ~ 453 ^{0}K for 6 to 8 hours for the purpose of uniform distribution of the components of the deposits. The method employed to determine the composition of the film were similar to those reported earlier [9], [10]. The composition of Ag from Ag-Te films was determined by employing absorption spectroscopy [9] at 350 nm.

2.2 Measurement Procedure

The Hall Effect measurement for Ag-Te deposits of varying composition and thickness at room temperature by the conventional d.c. method. The electric and magnetic fields varied between 100 μA to 1 mA and 3.0 to 9.5 K Gauss respectively. The Hall voltage is found to be independent of electric and magnetic fields, the Hall coefficient (R_H) is found to be dependent on composition and thickness of the

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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. Exact position of the sample was then fixed by further adjusting its position so that maximum Hall voltage was obtained. Hall voltage was measured the manner described before by knowing the voltage drop across terminals before and after applying magnetic field. 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

$$R_H = [(V_H \times d) / (I \times H)] , cm^3 / Coulomb \quad --- (1)$$

Where
V_H = average Hall voltage in volts.
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

$$\mu_H = \sigma \times R_H , cm^2 / V. Sec \quad ---------- (2)$$

$$n_H = (+/-) (1/ R_H \times e), cm^{-3} \quad ---------- (3)$$

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

The film thickness (d) was measured by multiple beam interferrometry [13] and gravimetric method [8] – [11] using the relation,

$$d = \frac{M}{g \times A} cm \quad ----------- (4)$$

Where
A = surface area of the film
M = Mass of the film
g = the density of the film material = $x_1 g_1 + x_2 g_2$

where g_1, g_2 and x_1, x_2 are densities and atomic fractions of Ag and Te elements respectively.

3. Results and Discussion

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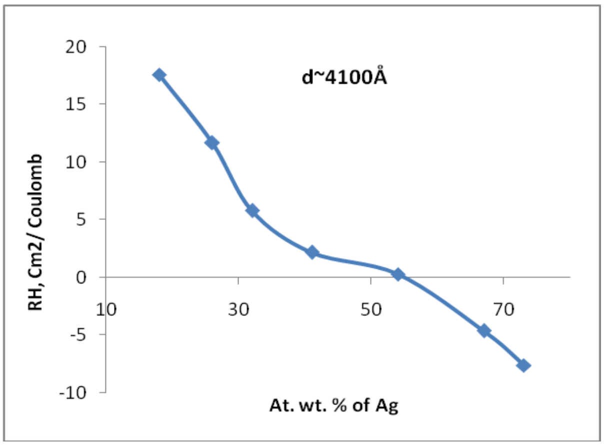

Figure 1: Plot of Hall coefficient (R_H) verses at.wt.% of Ag in Ag-Te films at room temperature.

The variation of Hall coefficient (R_H) with at.wt. % of Ag for Ag-Te thin films at room temperature is shown in fig 1. The Hall coefficient (R_H) was calculated from eq.1. It is found that the transformation of P-type Ag-Te deposit to n-type with change of film composition. The Hall coefficient (R_H) is positive for films containing [Ag] < 54 at.wt. % and negative for films having [Ag] > 54 at.wt. %. Therefore Ag-Te deposits exhibit p-type behavior up to 54 at.wt. % of Ag and n-type behavior beyond 54 at.wt.% of Ag. This is probably due to addition of metallic Ag in Ag-Te thin films.

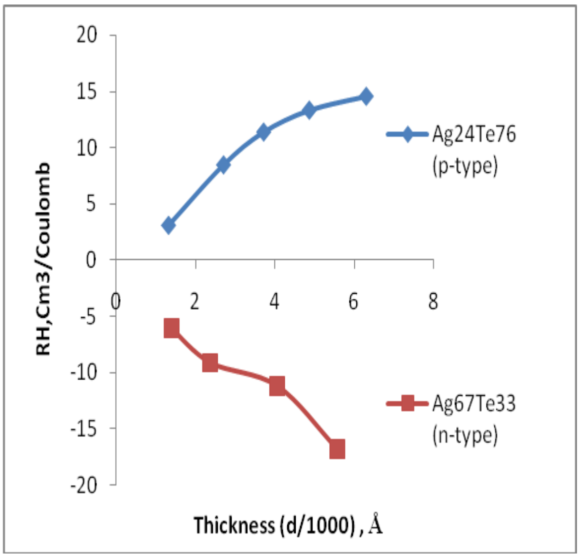

Figure 2: Plot of Hall coefficient (R_H) verses thickness (d) of Ag-Te films for two different concentrations at room temperature.

The variation of Hall coefficient (R_H) verses thickness (d) of Ag-Te thin films for two different concentrations at room temperature is shown in fig. 2. It is seen that the Hall coefficient (R_H) increases positively and negatively (for p-type and n-type regions) with the increase of film thickness. This is due to transformation of P-type Ag-Te deposit to n-type with change of film composition for [Ag] ~54 at.wt. %.

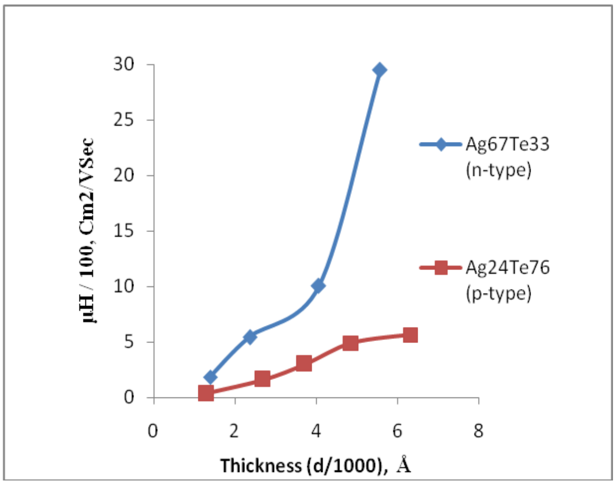

Figure 3: Plot of Hall mobility (μ_H) verses thickness (d) of Ag-Te films for two different concentrations at. room temperature.

The Hall mobility (μ_H) verses thickness (d) of Ag-Te films for two different concentrations at. room temperature shown in fig. 3. Hall mobility (μ_H) was calculated from eq.2. It is found that the Hall mobility (μH) values are found to increase with increase of thickness (d) for p-type as well as n-type deposits, probably due to removal of defects and ordering of stoichiometry in thicker films.

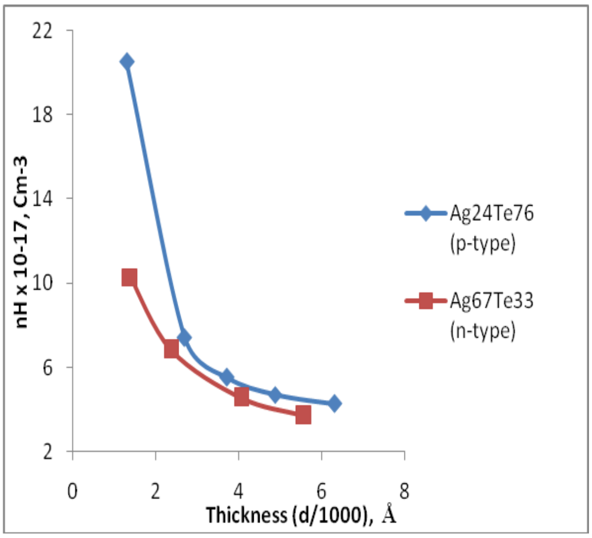

Figure 4: Plot of carrier concentration (n_H) verses thickness (d) of Ag-Te films for two different concentrations at. room temperature.

Plot of carrier concentration (n_H) verses thickness (d) of Ag-Te films for two different concentrations at. room temperature shown in fig.4. The carrier concentration (n_H) obtained from eq.3. It is found that the carrier concentration (n_H) to be dependent on composition as well as thickness of the films. The value of carrier concentration lies between 10^{17} to 10^{18} cm^{-3}, depending upon composition and thickness.

The carrier concentration decreases with increase of thickness irrespective of p or n type behaviors; this decrease of 'n_H ' with thickness in both types of samples is attributed to decreased rate release of free carriers from trap centers in thicker films. Since the thicker films are less defective, the scattering of carriers by defects will be also less.

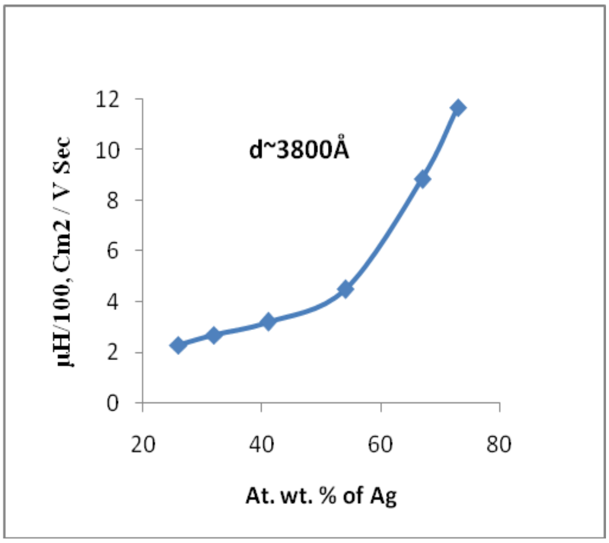

Figure 5: Plot of Hall mobility (μ_H) verses at.wt.% of Ag in Ag-Te films at room temperature.

Hall mobility (μ_H) verses at.wt.% of Ag for Ag-Te thin films at room temperature shown in fig.5. It is found that the Hall mobility (μH) values are found to increase with increase of at.wt.% of Ag irrespective of film thickness . It is interesting to note that carrier mobility in p-type samples is less than that for n-type samples due to easier scattering of light electrons as compared to that of by heavy holes.

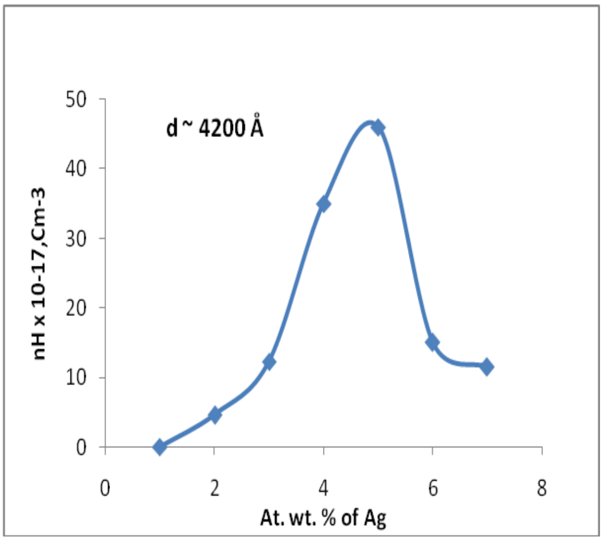

Figure 6: Plot of carrier concentration (n) verses at.wt.% of Ag in Ag-Te films at room temperature

Plot of carrier concentration (n_H) verses at. wt. % of Ag for Ag-Te thin film at room temperature is shown in fig .6. It is observed that the carrier concentration (n_H) is found to maximum at about 54 at. Wt. % of Ag in Ag-Te thin films.

4. Conclusion

The Hall Effect measurement for Ag-Te deposits of varying composition and thickness at room temperature by the conventional d.c. method. The Hall coefficient (R_H) is found to be dependent on composition and thickness of the film. The Hall coefficient (R_H) is positive for films containing [Ag] < 54 at.wt. % and negative for films having [Ag] > 54 at.wt. %. Therefore Ag-Te deposits exhibit p-type

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behavior up to 54 at.wt. % of Ag and n-type behavior beyond 54 at.wt.% of Ag.

The Hall mobility (μH) values are found to increase with increase of thickness (d) for p-type as well as n-type deposits. The carrier concentration (n_H) was composition as well as thickness dependent . It was found to be maximum at about 54 at. wt. % of Ag in Ag-Te thin films.

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