

Thickness Dependent Temperature Coefficient of Resistance (T.C.R) for various Ag-Te thin films.

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Abstract: Thin films of Ag-Te compound of varying thicknesses have been deposited on glass substrate employing three temperature method. The temperature coefficient of resistance (TCR) was studied as a function of thickness for Ag-Te thin films at [Ag] >50 at. wt. % and < 50 at. wt. %. The temperature dependent phase change from semiconducting to metallic for the composition of [Ag] > 50 at. wt. % in Ag-Te thin films. The T.C.R. is negative for semiconducting Ag-Te films with [Ag] < 54 at. wt. %, irrespective of thickness and temperature. For [Ag] > 54 at. wt. % is negative in low temperature region ($T < 413$ K) and positive in high temperature region ($T > 413$ K).

Keywords: Ag-Te, substrate, thin films, thickness, temperature, TCR.

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I. Introduction

The phase transition temperatures, as observed during the above semiconductor to metal transition of Ag_2Te reported [1]. The electrical and structural properties of silver telluride films having stoichiometric composition have been measured as a function of temperature [2, 3]. Sharma [4] has studied in detail the structural transformations in Ag_2Te thin films by electron diffraction technique. These studies indicated that transformation temperatures during heating and cooling were 430 and 388 K respectively in case of Ag_2Te thin films. The X-ray diffraction carried out by Mamedov et al [5] for the synthesis of bulk samples of Ag_2Te revealed that the transition takes place during heating at 420 K and during cooling at 411 K.

So, I report the temperature dependent phase transition from semiconducting to metallic with [Ag] > 50 at. wt. % in Ag-Te thin films and the thickness dependent TCR was calculated.

II. Materials and Methods

The Ag-Te thin films of different thicknesses for 'Ag' >50 at. wt. % and < 50 at. wt. % were prepared by vacuum deposition technique of the constituent elements 'Ag' (99.999% pure) and 'Te' (99.99% pure) by three temperature method [6-10]. 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 on glass substrate kept at room temperature in a vacuum of the order of 10^{-5} torr.

The films obtained were annealed at ~ 423 K upto 8 hours for the purpose of uniform distribution of components of the deposits. The films thickness (d) was measured by gravimetric method as reported earlier [8-10]. The composition of 'Ag' in Ag-Te films was determined by employing absorption spectroscopy [11] at 620 nm.

III. Results and discussion

The temperature coefficient of resistance (T.C.R.) of Ag-Te thin films at different temperatures, from the resistance versus temperature graph was calculated by using the relation

$$\text{T.C.R.} = (1/R) (\Delta R/\Delta T), \text{K}^{-1} \text{-----(1)}$$

It is found that the T.C.R. is negative for semiconducting Ag-Te thin films with [Ag] < 54 at. wt. %, irrespective of thickness and temperature. For [Ag] > 54 at. wt. % is negative in low temperature region ($T < 413$ K) and positive in high temperature region ($T > 413$ K).

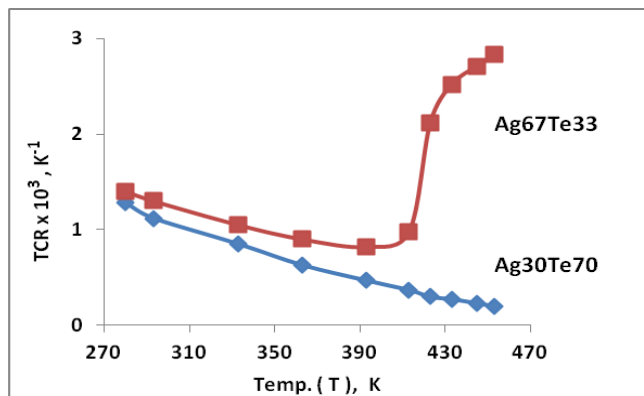


Fig.1: Plot of T.C.R versus temperature of Ag-Te thin films.

Fig.1 shows the variation of TCR with temperature, from fig. it is concluded that TCR of semiconducting films decreases with increase of temperature, while that for metallic films TCR rapidly increases with increase of temperature.

The decrease of negative TCR with increase of temperature can be explained on the basis of the island structure concept proposed by Neugebauer and Webb [12] and later developed by Neugebauer [13] to explain semiconducting behavior of very thin films. The expression for negative TCR is given by,

$$\text{Negative TCR} = (-d(t)/dt) \left[\left\{ 4\pi (2m\phi)^{1/2} / h^2 \right\} - 1/t \right] + C/T^2 \text{ -----(2)}$$

$$\text{Where } C = [(2e^2 / \epsilon\nu) + \Delta E_g] / 2K$$

‘t’ is the average distance between islands , ‘e’ electronic charge

‘m’ mass of electron. ‘K’ Boltzmann constant.

‘Γ’ the average radius of islands

‘Φ’ the potential barrier between islands.

‘h’ Planks constant

‘ε’ dielectric constant of the substrate,

‘ΔE_g’ Energy band gap.

In the present investigation, negative TCR continuously decreases. It can be said that the contribution towards TCR due to first term in above expression is more predominant compared to the second factor. At higher temperatures, it may be possible that contribution from second term may increases, thus changing the nature of the curve. Similar observations have been made by Nikam and Mankar [14], Goswami and Jog [15].

The increase of positive TCR with increase of temperature for metallic films (fig.1) may be attributed to continuous increase of dR/dT coefficient of equation (1), with increase of temperature.

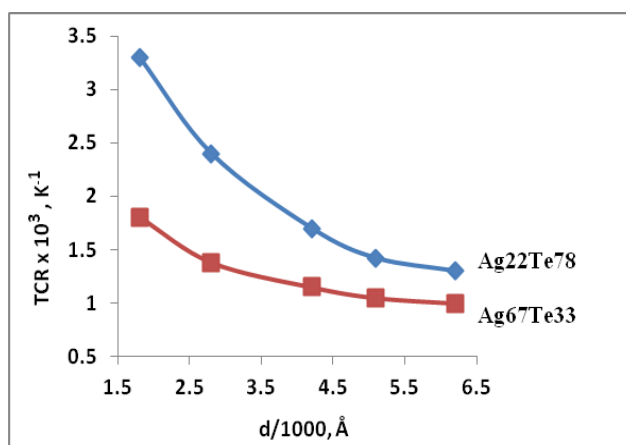


Fig. 2 shows the variation of T.C.R. with thickness of Ag-Te deposits.

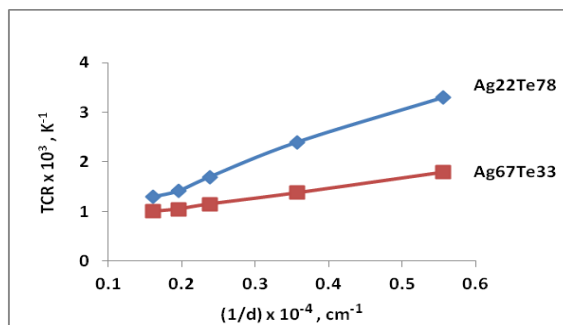
It is found that T.C.R. decreases with increase of film thickness. The dependence of T.C.R. on film thickness can be attributed to Fuch-Sondheimer theory [16,17]. T.C.R. equations under Fuch-Sondheimer and grain boundary scattering model can be written as [18, 19].

$$B_F = B_O [1 - (3/8) (l_o/d) (1-p)] \quad \text{-----(3)}$$

and

$$B_F = B_g [1 - (3/8) (l_g/d) (1-P)] \quad \text{-----(4)}$$

Where B_F is T.C.R. of the film, B_O and B_g are T.C.R. in bulk state, 'd' is the thickness of the film, ' l_o ' the mean free path and 'p' the specularly constant.



It is seen from above equations (3 & 4) that B_F is a linear function of reciprocal thickness. In the present work the variation of T.C.R. (B_F) on reciprocal of thickness is linear as shown in fig.3.

IV. Conclusions

It is concluded that the size effect theory, surface and grain boundary scattering effects are predominant in our studies. The intercept on y-axis of the plot of T.C.R. versus 1/d for Ag-Te thin films gives B_O or $B_g \sim 0.7 \times 10^{-4} \text{ K}^{-1}$ for Ag₂₂Te₇₈ thin films and $\sim 0.9 \times 10^{-4} \text{ K}^{-1}$ for Ag₆₇Te₃₃ films respectively in the semiconducting phase.

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