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ROOM TEMPERATUE STUDY ON SOME SEMICONDUCTING PROPERTIES OF VACUUM DEPOSITED TELLURIUM FILMS

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Abstract:

The Hall coefficient R_H, the Hall Mobility μ_H the hole concentration P in thin Te films were investigated at room temperature as a function of both the applied field intensity (0-0.78 Tesla) and the film thickness (810-8965 Å). It was found that both R_H, μ_H and P are field independent, whilst they show quantum size effect with the film thickness.

In addition, some semiconducting properties as the Fermi energy, the Fermi velocity, the Fermi wave vector and the relaxation time were calculated.

Introduction

Recently, many studies were performed on the semiconducting behaviour of vacuum-deposited tellurium films because of their possible applications in thin film transistors (1,2), strain-sensitive devices (3), infrared detectors (4) and thin film circuits (5). Even though much literature (1-11) is available with regard to the temperature dependence of the electrical properties of Te films, there is no intensive work concerning Hall measurements carried out at room temperature.

In the present work, the primary emphasis was to investigate the following:

(i) The Hall coefficient dependence of the applied field intensity.
(ii) The Hall coefficient dependence of the film thickness.
(iii) The Hall mobility dependence of the applied field intensity.
(iv) The hole concentration dependence of both the applied field intensity and the film thickness.
(v) Magnetoresitance in thin tellurium films.

The observations of our investigations on vacuum-deposited tellurium films are reported in this paper taking into account that all measurements were performed at room temperature (RT).

Experimental Procedure:

Tellurium films were deposited on glass substrates by thermal evaporation in a vacuum of 10^{-5} Torr. The rate of deposition (5 Å s^{-1}) as well as the substrate temperature (RT) was kept constant during the deposition process. The film thickness was controlled using crystal thickness monitor, then measured applying Tolanskys method (12). The film had the standard Hall shape of dimensions 6 x 0.5 cm with 6 leads for current, Hall voltage and magnetoresistance measurements. Figure (1) shows the general shape of the samples. The Hall coefficient measurements were performed using a d.c. technique. Numerals 1 and 2 indicate the current leads, 3 and 4, the Hall voltage probes 5 and 6 the potential leads for measuring the resistance without and with applying the magnetic field respectively.

To obtain a good contact with the film under test, silver electrodes were printed on the glass substrate before the Te film preparation. Printing these electrodes requires a special technique. This technique is based on painting such electrodes with a special paint composed of very finely powedered silver mixed with a flux of lead borate (ratio 2 to 1). The liquid medium was the oil of lavender to give the paint the required constituency for the painting facilities. After dryness, the substrate was baked in a muffle furnace at 500°C for 3 minutes.

The Hall voltage across the terminals 3 and 4 was measured using a Tinsley potentiometer UJ 33E with accuracy ± 0.5 μV, taking into account the usual precautions i.e., reversing the polarity of the electromagnet and the direction of the current passing through the sample.

Results and Discussion:

(i) The Hall Coefficient Dependence of the Applied Field Intensity:

To investigate the effect of the applied field intensity (0-0.78 Tesla) on the Hall coefficient, six samples of different thicknesses were prepared in the thickness range of 810-8965 Å. The obtained data was illustrated in Fig. 2. As shown, the Hall coefficient of Te thin film is field independent for thicknesses up to 5000 Å, but for higher thicknesses R_H behaves as if it is field dependent. This behaviour, indicates that, the measurements, in general, were performed in the low field regime at which $\omega_c \tau \ll 1$, where ω_c is the cycletron orbit and τ is the relaxation time.

(ii) The Hall Coefficient Dependence of the Film Thickness:

One of the interesting results of Hall effect measurements carried out at RT using Te thin films is the variation of R_H with the film thickness t. Figure 3 represents R_H = f(t). This figure indicates the existence of quantum size effect which can be attributed to the quantum nature of the charge carriers which becomes obvious when the thickness of the sample is commensurate with its de Broglie wavelength, and when the film thickness is much less than the mean free path of the

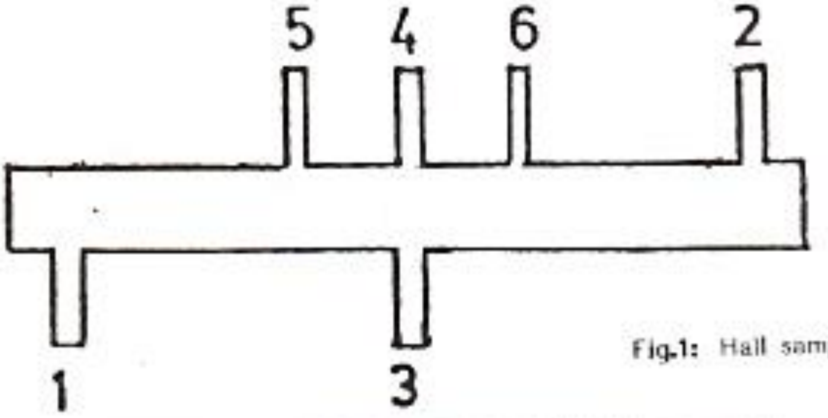

Fig.1: Hall sample shape.

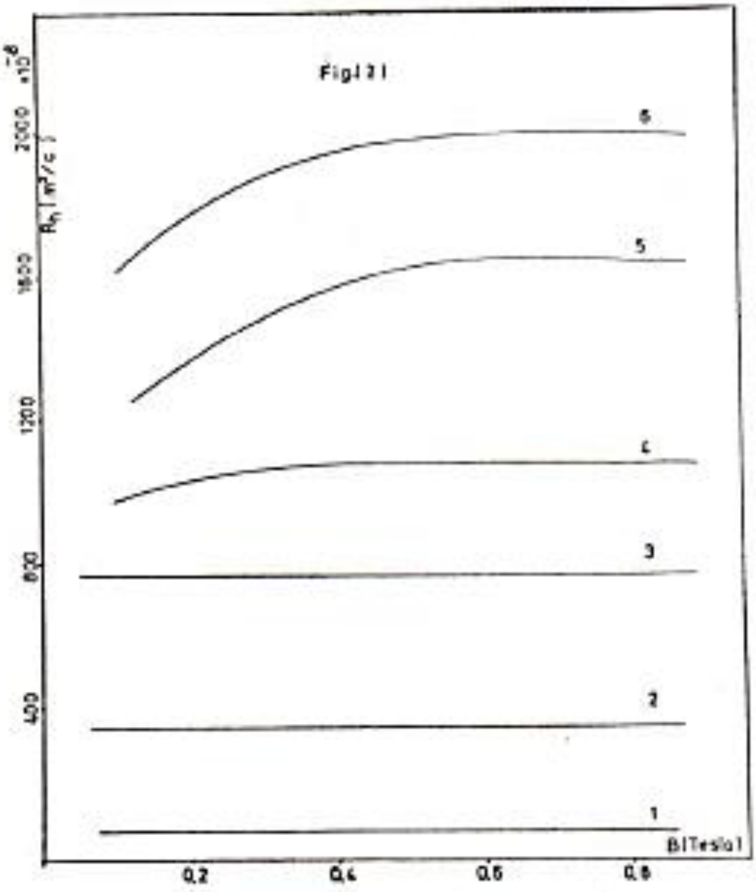

Fig.2: Plots the relation between Hall coefficient R_H and intensity of magnetic field B for different thicknesses of thin Te films:

1) 3448 Å
2) 810 Å
3) 5034 Å
4) 4655 Å
5) 8965 Å
6) 7069 Å

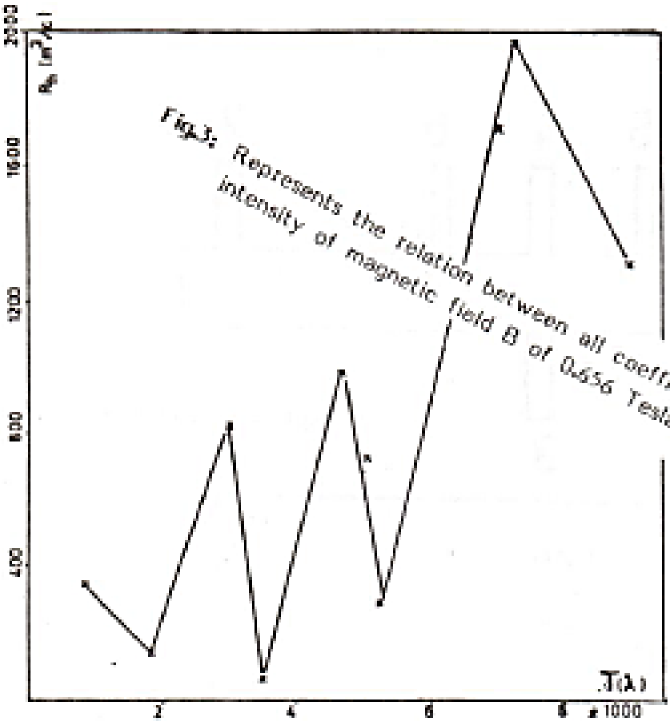

Fig.3: Represents the relation between all coefficient R_H against film thickness t for intensity of magnetic field B of 0.656 Tesla.

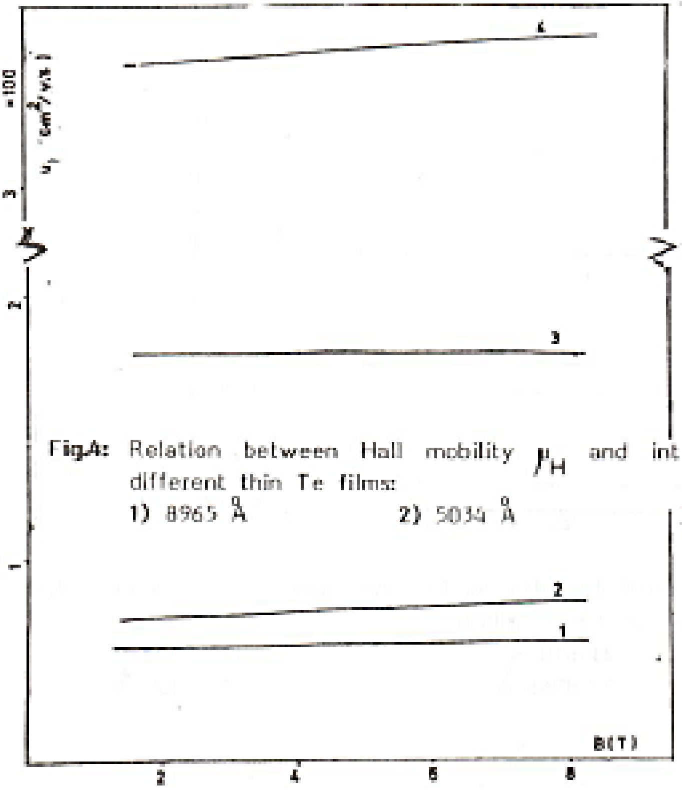

Fig.4: Relation between Hall mobility μ_H and intensity of magnetic field B for different thin Te films:
1) 8965 Å 2) 5034 Å 3) 4655 Å 4) 810 Å

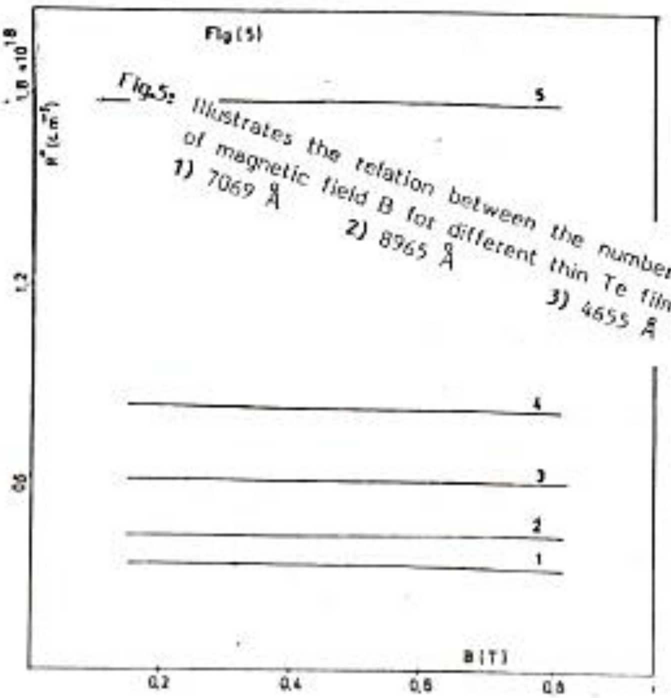

Fig.5: Illustrates the relation between the number of charge carriers p and intensity of magnetic field B for different thin Te films:
1) 7069 Å
2) 8965 Å
3) 4655 Å
4) 5034 Å
5) 810 Å

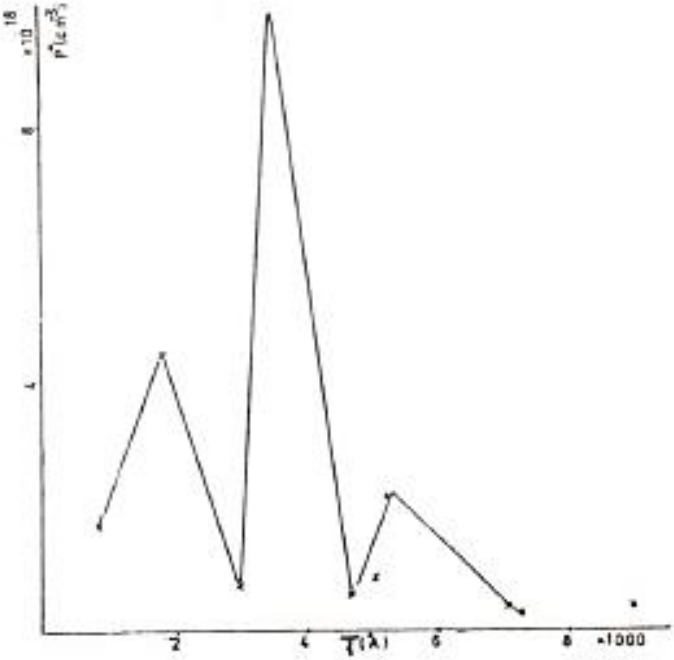

Fig.6: Represents the relation between the number of charge carriers P against the film thickness t at a magnetic field of intensity B = 0.656 Tesla.

tory it was found that ℓ_0 = 18350 Å. Accordingly, as t_{max} = 8965 Å, one can expect under these condition, that the transverse motion of the free carriers in our Te films shows the effect of quantization.

(iii) The Hall Mobility Dependence of the Applied Field Intensity:

Figure 4 shows the Hall mobility in Te films as a function of the applied field intensity. Four samples of different thicknesses were given as a representative example. As observed, it seems that μ_H is field independent up to 0.78 Tesla.

(iv) The Hole Concentration Dependence of Both the Applied Field Intensity and the Film Thickness:

Throughout Hall coefficient measurements, it was found that Te films are p-type semiconductors. The effective number of holes per cm^3 was calculated. The obtained data shows that the hole concentration is field independent, whilst it shows quantum size effect as shown in Figs. 5 and 6 respectively.

From the Hall effect measurements of Te films, the Fermi energy E_f, the Fermi velocity v_f, the Fermi wave vector K_f and the average relaxation time have been calculated. The obtained data is given in Table 1.

Table 1: E_f, v_f, K_f and τ for Te films at RT

t, Å	E_f, eV	v_f, m/sec$\times 10^5$	K_f, $cm^{-1}\times 10^{-7}$	τ, sec$\times 10^{-14}$
810	0.0053	0.433	0.375	5.03
4655	0.0027	0.306	0.266	93.68
5034	0.0033	0.340	0.295	19.90
7068	0.0018	0.255	0.220	42.78
8965	0.0022	0.278	0.242	33.12

(v) Magnetoresistance in Thin Tellurium Films:

Thin tellurium films in the thickness range of 810-8965 Å did not show any significant magnetoresistance when measured at RT. This result is in agreement with that reported by Goswami and Ojha (7) and in disagreement with those reported by Albers and Gertig (11).

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