Pak J Sci Ind Res 1999 42 (3) 113-116

EFFECTS OF PROBE SHAPES ON THE BARRIER HEIGHT AND SURFACE CONDUCTANCE OF TELLURIUM THIN FILMS

S S Oluyamo

Department of Physics, Ondo State College of Education, P M B 250, Ikere-Ekiti, Nigeria

(Received 1st December 1996; accepted 23 May 1998)

The study centered on the effects of probe shapes on the conductance and barrier height of Tellurium thin films. It was found that the shape of the contacts affected the conducting behaviour of the films. The conductances of each of the sample used changed with the shape of the contacts. This can even be discovered with those of the differential electrodes having relatively lower conductance compared with their counterparts. However, the study revealed that the shape of the contacts had no significant effects on the barrier height of tellurium thin films.

Key words: Probe shape, Barrier height, Conductance, Tellurium, Thin films.

Introduction

Tellurium films have been studied extensively and found to exhibit different behaviours in liquid and solid states (Grochowshi and Brenner 1971; Sze 1985). Tellurium is a group VI element and lies to the right hand side of the periodic table where the metalloids and non-metals are found. It is not a pure metal, although, it is suggested that the density of state at Fermi level may be very high and indicative of metallic behaviour (Ormar 1975; Geiss and Lee 1983; Omar 1997). Studies carried out on the electrical properties of this material at various stages have shown that the shape of the I-V characteristics of Tellurium film is symmetrical in both the forward and reverse directions (Kittel 1985; Iyayi 1989; Rogers and Cale 1993; Oberafo *et al* 1994).

The present work tends to study the effect of probe shapes on the conduction characteristics of Tellurium (Te) films and the barrier heights as most devices for electronic and metallurgical works depend on the shape of the contacts. In the present work, antimony (Sb) metal which has been found to exhibit very good contact characteristics is used as electrodes (Oberafo *et al* 1994). Three shapes of the electrodes, triangular, rectangular and semicircular are used for simplicity. In addition, some of the samples are made up of differential electrodes at opposite ends (see Fig 2b) and (Table 2). Eight different samples (labelled, S_1-S_8) and probe shapes are used altogether. These shapes are investigated using the I-V characteristics and the Norde modified forward I-V plot for schottky diode (Norde 1979).

Experimental

The polished glass slides used as substrates were first boiled in chromic acid and then ultrasonically cleaned successively in deionized water, acetone and ethyl alcohol for twenty minutes each before drying. The mica mask used to generate the required pattern was cleaned thoroughly, first with soap detergent then rinsed in distilled deionized water followed by ultrasonic agitation as described above. After cleaning, the substrates were enclosed in a vacuum chamber (Edward Coating Unit model 306). Tellurium films of thickness 1000A° were evaporated on the substrates from a tungsten filament. Contacts were made on opposite ends of the Tellurium film by depositing antimony metal on to the various electrode widths. Two different electrode widths were used in this work: (1) differential electrode whereby the metal electrode outside the film area is of differential dimension from that within the film region, (ii) uniform electrode whereby the metal electrode is of uniform width within and outside the film. After deposition, the film dimensions were measured with a sensitive microscope. The final configuration, areas and dimensions of films after deposition are shown in Fig 2(a and b).

The I-V measurements of various samples were obtained using I-V circuit diagram (Fig 1) at room temperature.

Results and Discussion

Tellurium films have been shown to be symmetrical in both the forward and reverse directions, however, only the forward characteristics have been used in the study.

The results (Table 1a & b) show the current (I), current density (J) and voltage measurements of the samples. The current in all the samples increases with the increase in voltage. The I-V and J-V plots (Fig 3 and Fig 4) of the samples are shown. In these figures, samples with comparable electrodes are found to overlap. However, no overlap was found for the J-V plot. This could be attributed to the difference in probe areas of the

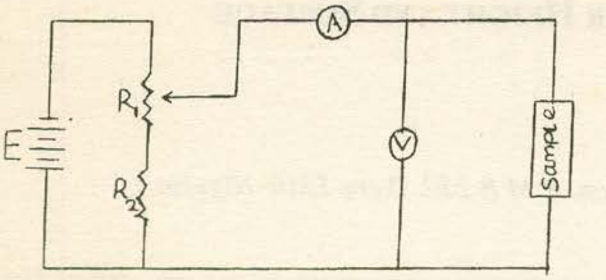

Fig 1. Circuit diagram for current (I) - voltage (V) measurements sample - Enclosed in a croachet maintained at room temperature. V - Voltmeter (Volts), A-Ammeter (MA), R_1 - Fixed Resistor, R_2 - variable Resistor, E-Source of power.

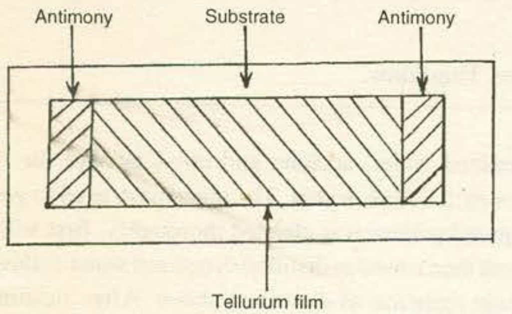

Fig 2a. Final configuration of the deposited samples.

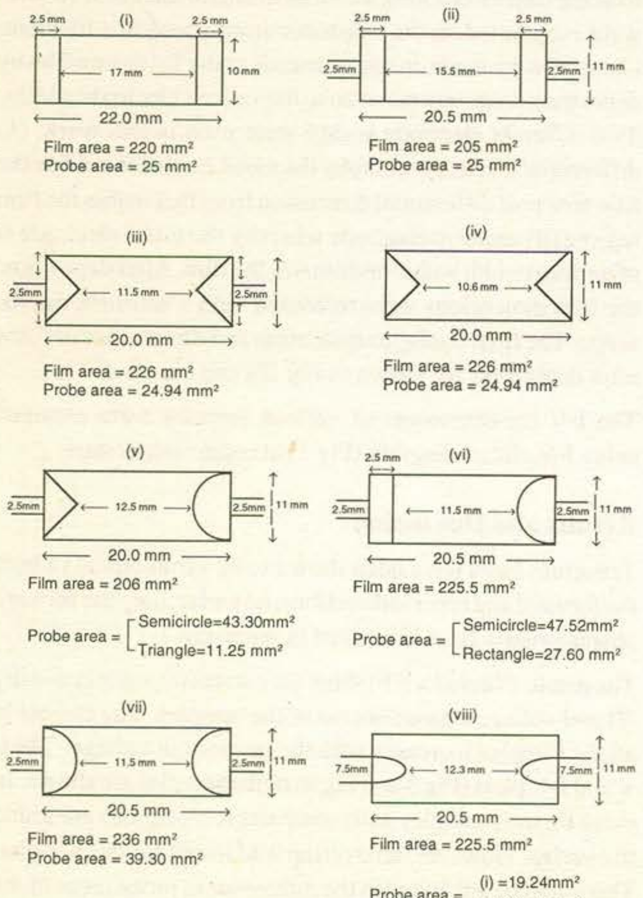

Fig 2b. (i-viii) Areas and dimensions of films after deposition.

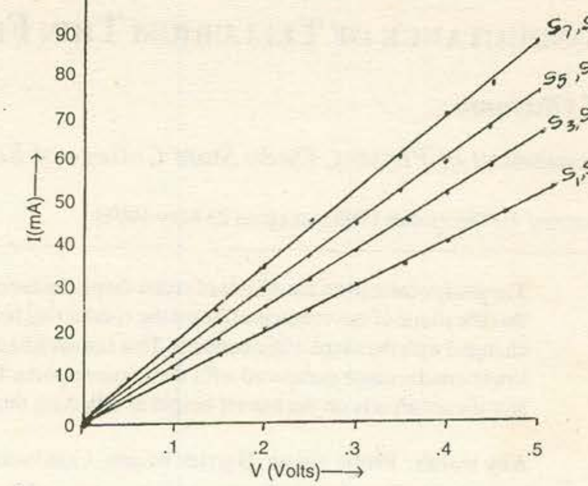

Fig 3. Current (I) versus voltage (V) plots for the eight

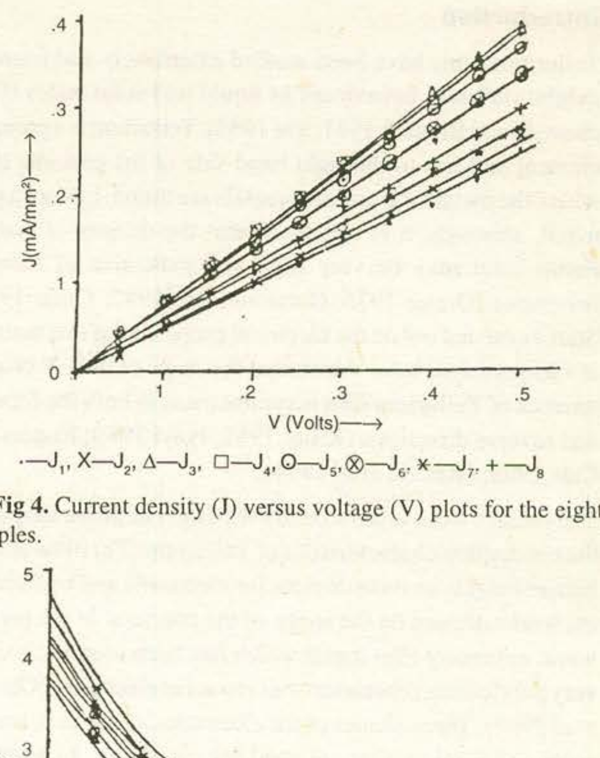

Fig 4. Current density (J) versus voltage (V) plots for the eight samples.

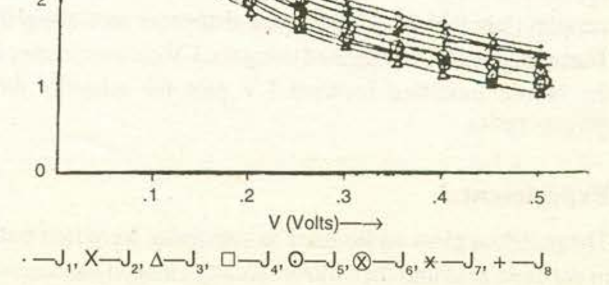

Fig 5. In J versus voltage (V) plots for the eight samples.

shapes of contacts. Table 2 shows the sample area (mm^2), probe area (mm^2) and the conductance (Ω^{-1}/mm^2) of each sample. The conductances of the samples were estimated from I-V plot and were calculated from the slope of the best line of fit of the I-V plots in fig 3, using the relation (Ormar 1975; Rogers and Cale 1993).

$\delta_8 = dI/dv/\Delta s$..(i)

where Δs is the contact surface area of the samples.

On the other hand, the barrier height was calculated from the current-voltage forward characteristics. The thermoionic emission theory adequately describes the conduction mechanism in contacts to high mobility semiconductors such as tellurium and silicon (Iyayi 1989; Ng *et al* 1990). The I-V relationship in this case is given by

$J = J_8$ (exp (qV/kT) -1

V is the voltage across the junction which is equal to the voltage across the device terminals. For negligible series resistance.

$$J_s = A^{**} T^2 \exp \frac{(-q\phi_B)}{kT}$$

In the forward direction, with V>3kT/q a modified expression for the relationship is given by (Norde 1979)

$$J = A^{**} (- \phi f_{Bo})/kT \exp \frac{q(\Delta\phi + V)}{kT}$$

where ϕ_{Bo} is the zero-field asymtotic barrier height, A^{**} is the effective Richardson constant, $\Delta\phi$ the Schottky barrier lowering, and k the Boltzmann's constant, T the absolute temperature and q the magnitude of the electronic charge.

Table 1a

Current I(mA) and voltage V(volts) values J-current density (mAmm^2) (LnJ gives the magnitude only)

	Samples 1 & 2					Samples 3 & 4				
V	I	J1	LnJl	J2	LnJ2	I	J3	LnJ3	J4	LnJ4
.05	5	.023	3.77	.024	3.73	10	.044	3.12	0.43	3.15
.10	11	.050	3.00	.054	2.92	19	.084	2.48	.083	2.49
.15	18	.082	2.50	.088	2.43	27	.119	2.13	.117	2.15
.20	21	.095	2.35	.102	2.28	36	.159	1.84	.157	1.85
.25	26	.118	2.14	.127	2.06	45	.199	1.62	.196	1.63
.30	32	.145	1.93	.156	1.86	54	.239	1.43	.235	1.45
.35	37	.168	1.78	.180	1.72	62	.274	1.29	.270	1.31
.40	42	.191	1.66	.205	1.59	72	.319	1.14	.313	1.16
.45	48	.218	1.52	.234	1.45	81	.358	1.03	.352	1.04
.50	55	.250	1.39	.268	1.32	89	.394	0.93	.387	0.95

Table 1b

Current I(mA) and voltage V(volts) values J-current density (mAmm^2) (LnJ gives the magnitude only)

	Samples 5 & 6					Samples 7 & 8				
V	I	J5	LnJ5	J6	LnJ6	I	J7	LnJ7	J8	LnJ8
.05	8	.039	3.24	.035	3.35	7	.030	3.51	.031	3.47
.10	16	.078	2.55	.071	2.65	14	.059	2.83	.021	2.28
.15	24	.117	2.15	.106	2.24	20	.085	2.45	.090	2.40
.20	31	.150	1.80	.137	1.99	27	.114	2.17	.120	2.12
.25	39	.189	1.67	.173	1.76	34	.144	1.94	.151	1.89
.30	46	.223	1.50	.204	1.59	40	.170	1.77	.177	1.73
.35	54	.262	1.34	.239	1.43	47	.199	1.61	.208	1.57
.40	61	.296	1.22	.271	1.31	54	.230	1.47	.240	1.43
.45	69	.335	1.09	.306	1.18	60	.254	1.37	.266	1.32
.50	77	.374	0.98	.341	1.08	67	.284	1.26	.297	1.21

Table 2
Sample area, probe area, conductance, saturation current density and barrier height of each sample

Sample	Sample area (mm^2)	Probe area (mm^2)	Conductance $\delta_3 \times 10^{-2}(\Omega^{-1}/mm^2)$	Saturation current density Js (A/mm^2)	Barrier height ϕ_{Bn} (Volt)
1	220	25	2.07	99.48	0.18
2	205	25	5.13	81.45	0.18
3	226	24.94	1.90	40.45	0.20
4	230	28.75	1.79	49.40	0.19
5	220	Semicircle-43.30 Rectangle-11.25	1.51	44.70	0.20
6	225.50	Semicircle-47.52 Rectangle-27.50	1.20	60.35	0.19
7	258.00	39.30	2.54	66.00	0.19
8	225.50 (ii) 22.10	(i) 19.24	8.14	73.70	0.18

Since $A^{\#}$ and $\Delta\phi$ depend on applied voltage, a more precise representation of forward J-V characteristic is given by

$J \sim \exp(qV/nkT)$, where n is the ideality factor.

Hence, the LnJ versus V plot (Fig 5) gives a curve which is being expected at the region $V < 3\ kT/q$ for this study.

$$n \text{ is given by } n = \frac{q}{kT} \quad \frac{\delta V}{\delta(\mathrm{Ln}J)}$$

The saturation current density Js is obtained from the extrapolated value of LnJ to zero voltage (Fig 5). With A^{**}, T and k as constants, the barrier height is then obtained from the expression,

$$\phi_{Bn} = \frac{kT}{q} \frac{\mathrm{Ln}\,(A^{**}T^2)}{Js} \quad \text{..(ii)}$$

The expressions in equations (i) and (ii) were used to calculate the surface conductances and barrier heights of the samples. The values are shown in Table 2.

Conclusion

Table 2 shows the contact and probe areas, conductance and barrier heights of all the samples. It is seen from the table that all samples have different conductances. This variation may be attributed to (i) the effect of the corners and sharp edges of the contacts (ii) the differences in film and the probe areas.

Furthermore, films of differential electrodes have relatively lower conductance than their counterparts. Moreover, the current density versus voltage plots (Fig 4 and 5) show little disparity in shapes of graph. This in effect, resulted to insignificant differences in the barrier heights of the samples even at 95% confidence. The little disparity could be due to experimental error.

Within the limit of the experiment, antimony probe shapes is found to have effect on the surface conductance of Tellurium thin films at room temperature. Further studies are to be extended to temperatures higher or lower than room temperature.

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