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Electrical Nature of Antimony Probe Shapes on Surface Conductance of Tellurium Films

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Abstract: The geometrical effect of probe shape in a two point arrangements were investigated by measuring the surface electrical current density-voltage (J-V) characteristics as deposited thin films of tellurium with antimony probes. The chosen geometry of antimony probes in contact with the Te-samples were triangles, rectangles, semicircles and segments of circles whose each pair was of 2 types of probe extension. The first was the uniform electrode width configuration in which the metal (Sb) electrode width was continuous at the edge of the Te-sample while the second was the differential electrode configuration is which the metal electrode width was discontinuous as the edge of the Te-sample region. The results showed that the surface density-voltage characteristics were linear in every case. The rectangular electrode pair gave the least values, followed by the semi-circular pair and finally the triangular pair. In the latter 2 cases, the results for both uniform and differential electrode width configuration were practically the same.

Key words: Geometric effect, probe shape, current-voltage, tellurium, antimony, rectangular, triangular

INTRODUCTION

Considerable work has been done on metal-amorphous semiconductor junctions by Keller and Stuke (1965), Brodsky and Dohler, (1975), Mott and Davies (1975), Okuyama *et al*. (1975), Orlowski *et al*. (1977), Behal and Srivastava (1978), Thompson *et al*. (1983) and Rabinelli *et al*. (1989). Such research according to Mott and Davies (1975) revealed that the electrical conductivity of Selenium thin films of 99.99% purity and evaporated at 55°C onto Aluminium, nesa glass, gold-coated, glass substrates was independent of the electrode material used. The sample films used were in the 1-50 μ thickness range, with thin-film (500-800)Å of Gold or Aluminium electrode evaporated on them.

The electrical properties of Tellurium (Te) films or its compounds and contacts had also been widely studied by Krupanidhi *et al*. (1983), Phahle *et al*. (1977), Lin *et al*. (1981), Dino *et al*. (1974) and Grochowshi and Brenner (1971). Okuyama *et al*. (1975) investigated the behaviour of vapour deposited metal contacts to evaporated Tellurium films. They reported that current-voltage measurements in air indicated that Au, Ni, Co and Sb make ohmic contacts to Te, while on the other hand, Al-Te contacts showed ohmic behaviour in vacuum with a transition to blocking behaviour after the introduction of air or oxygen gas. The rate of this transition was found to be strong function of the grain size of the Te-films, which they interpreted as suggesting that an insulating layer was formed between the A1 and Te films by the diffusion of oxygen atoms through the grain boundaries of Te. Oberafo and Mukolu (1995) worked on Seleniun (Se), which have similar properties with Te and found that Bi/Se and Sb/Se contacts were ohmic.

However, the issues of ohmic contact probe shapes in two point probe configurations, especially their effects on the measured electrical surface parameters of thin films have not been given adequate attention. The choice of the shapes to use has been left largely to the convenience of the investigators. The present research, therefore aims at directing research interest to this area.

Amorphous Te has been described as a p-type semi-conductor, Dino *et al*. (1974), Phahle (1977) and Chaudhuri *et al*. (1981) of narrow band gap (0.34 ev), Grochowshi and Brenner (1971), while Sb/Te thin films contacts are said to exhibit ohmic characteristics Okuyama *et al*. (1975). Sb/Te contacts are therefore suitable for studying the effects of ohmic contact electrode probe shapes on the electrical transport properties of amorphous barrow band gap semiconductors.

The research work was, therefore aimed partly at determining the effects of Sb probe shapes on the surface conductance of Tellurium films. The shapes, considered pair-wise were to be triangles, rectangles, semicircles, segments of circles and their combinations. All probe

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patterns were to be of equal areas. The research also aimed at investigating whether or not there would be a departure from ohmic to non-ohmic behaviour due to changes in probe shapes with a view to finding suitable probe shape-dependent applications to this chalcogenide element (Te) and other semiconducting materials.

MATERIALS AND METHODS

The Sb probe shapes chosen were triangles, rectangles, semicircles and segments of circles. The area of overlap between each probe pattern and the underlying Te film was about 0.26 cm^2 and the other details are shown in Fig. 1.

Prior to assemblage and deposition, the mica masks used were first cleaned with soap-detergent solution and then rinsed thoroughly in distilled, de-ionised water. This was followed by successive ultrasonic agitation, each of 5 min duration, in Trichloroethylene, Acetone and Ethyl alcohol in that order. The glass slides were similarly cleaned, first in a soapy solution and rinsed in clean water, then boiled in solution of chromic acid. They were subsequently cleaned ultlrasonically as described above.

Tellurium films, of thickness 100Å, were deposited on glass slides by filament evaporation in a vacuum of about 10^{-5} torr, using Edwards, model 306, vacuum coater. The various Sb probe shapes, each 1000 A thick, were similarly deposited. All the evaporated materials were of 5 N 9 purity (Ventron, Germany). The film thicknesses were determined with an Edward model FTM3 film thickness monitor. Both films and probe dimensions were measured with a traveling microscope and the values of the calculated areas and other parameters are displayed in Table 1. All measurements were made under vacuum.

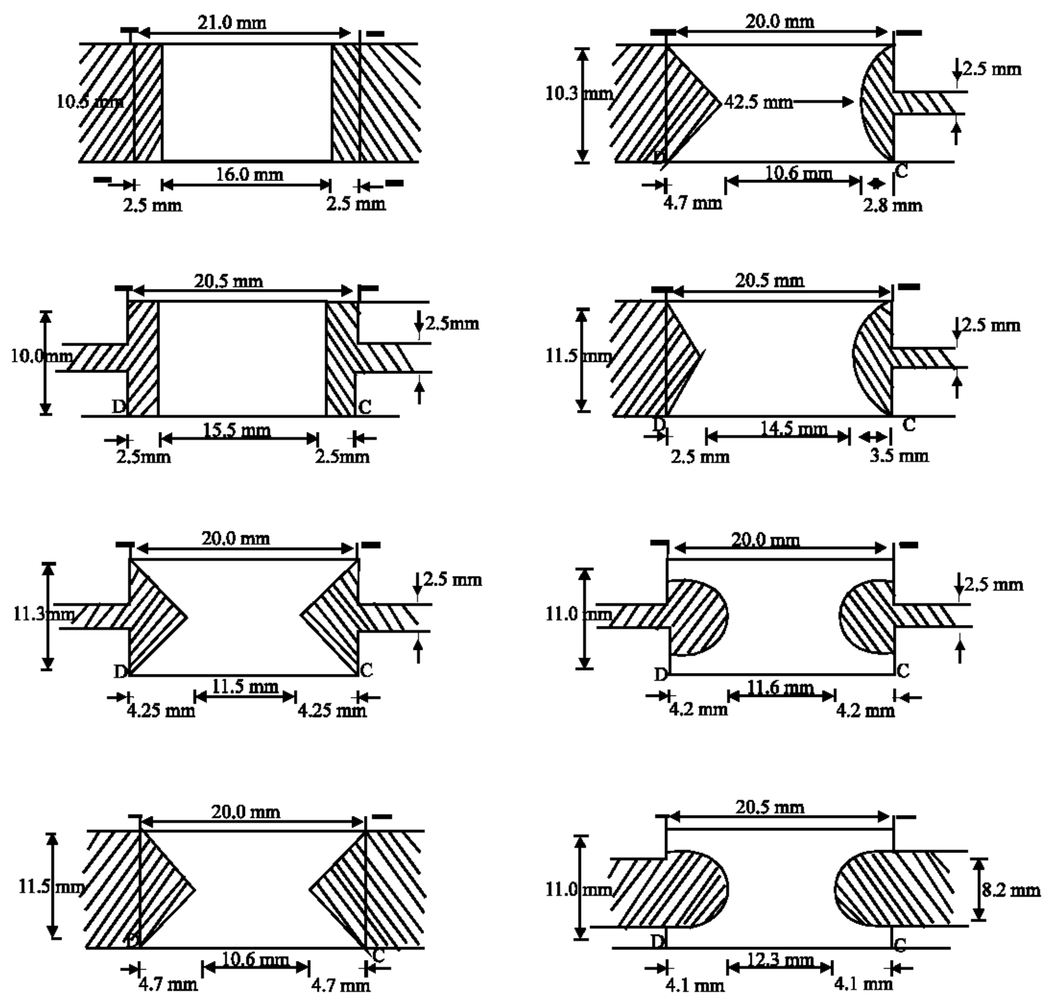

Fig. 1: Le sample configurations (ABCD) and dimensions (The shaded are portions are Sb probe coverage)

Table 1: Values of the Te film and Sb probe areas and the corresponding conductance at room temperature (L and R denote respectively the left and right probes in Fig. 1)

Sample	Tellurium film sample area (cm^2)	Antimony probe area (cm^2)	Conductance G_s ($\Omega^{-1}cm^{-2}$) × 10^{-5}
1	2.20	L: 0.26 R: 0.26	4.83
2	2.05	L: 0.25 R: 0.25	5.01
3	2.26	L: 0.24 R: 0.24	7.77
4	2.30	L: 0.27 R: 0.27	7.67
5	2.06	L (Triangle): 0.24 R (Segment): 0.25	7.50
6	2.26	L (Rectangle): 0.28 R (Segment): 0.27	5.33
7	2.20	L: 0.28 R: 0.28	6.13
8	2.26	L: 0.26 R: 0.26	5.90

RESULTS AND DISCUSSION

Figure 2 and 3 show the surface current density (J) plotted against Voltage (V) at room temperature. All the samples showed linear and symmetrical J-V characteristics of the 2 polarities. This ohmic behaviour is in agreement with previous research of Okuyama *et al*. (1975) on Sb/Te contacts.

The surface conductance of the Te-films, as calculated from the plots, are displayed in Table 1 together with corresponding Te film areas and their areas of overlap with the Sb probe patterns.

The results show that the calculated values of the surface conductance (Ga) is least for the rectangular electrode pair, followed by the semi-circular pair and finally for the triangular pair. Figure 2 also shows that for both the semi-circular pair and the triangular pair, the results for the uniform and differential electrode configurations are practically the same with the differential values being always slightly higher. However, for the rectangular pair, the uniform and differential results are markedly different, with the differential results being much higher. These results show that G_s increases as the electrode curvature increases. This may be explained by the fact that the electric field is greatly enhanced at points of greatest curvature. This is also the reason why the differential results are higher than the uniform ones because of the existence of discontinuity at the back edges of the electrode overlap regions with the Te samples.

Figure 3 shows that for the mixed triangle-circle segment and rectangle-circle segment configurations, the former gives higher value of G_s, which may again be attributed to the much enhanced field contribution expected at the apex of the triangle.

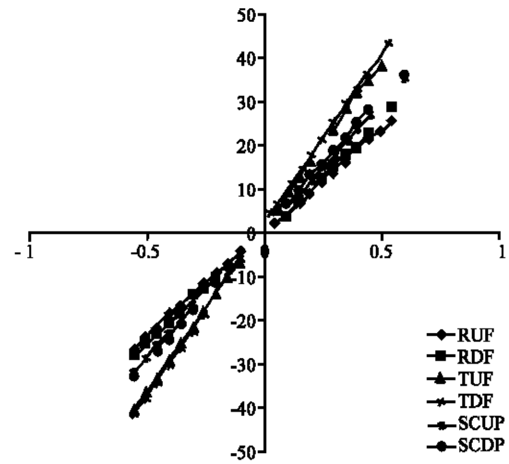

Fig. 2: Electrical current density-voltage (J-V)

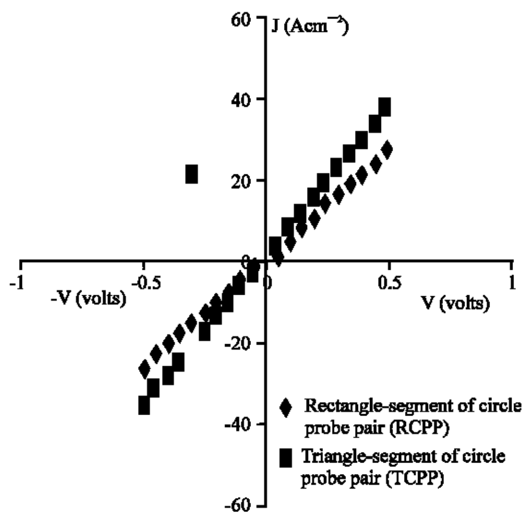

Fig. 3: Electrical current density-voltage (J-V)

Thus, the overall trend of the surface conductance with pattern is, in decreasing order, as follows: triangle, semicircle, circle segment and rectangle.

CONCLUSION

The study showed that while, the shape of the patterns does not alter the ohmic property of Sb/Te contacts, it however affects the measured electrical conductance, which increases as the curvature increases. This behaviour and the trend are consistent with the expected electric field enhancement with increasing curvature of the pattern edges.

RECOMMENDATIONS

It is however, recommended that shapes of films be deposited in such a configuration that would enhance electrical conductance with little or no loss from the edge effects.

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