Effects of Surface Area on the Electrical Properties of Tellurium Thin Films

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ABSTRACT

The study investigates the effects of surface area on the electrical properties of tellurium thin films for electric field values 0.05 – 0.50V/m. Different areas of the films were prepared by vacuum evaporation method at a pressure of 5×10^-5torr. Measurements of current – voltage characteristics were obtained at room temperature. The areas of the films were found to affect the electrical properties of the films. The surface conductance of the films decreases with increase in area while the saturation current density increases with increase in area. The reduction in surface conduction could be attributed to larger resistance imposed by films of larger areas. However, the study revealed that there is little variation in the values of the barrier heights of the samples. Therefore within the limit of the study, surface area has no significant effect on the barrier height of tellurium thin films.

Key words: Surface area, Tellurium, Electrical properties.

INTRODUCTION

Tellurium is a semiconducting element with very wide application in electronic and metallurgical works. This is because; Tellurium sometimes behaves like metals with high density of state at the fermi level. It also exhibits different behaviours in liquid and solid states (Grove, 1968; Orma, 1975; Thurn and Rusica, 1975; Sze, 1985). Studies had been carried out on the electrical behaviour of this material at various stages which indicate that the shape of the current – voltage characteristics is symmetrical in both the forward and backward directions (Kittel, 1985; Van Vechten, 1970).

Studies had shown that various factors such as probe shapes, temperature, humidity, pressure etc, have effects on the conducting behaviour of semiconducting thin films (Owate and Akpata, 1998; Oluyamo, 1999 and 2003; Oluyamo and Ojo, 2004; Alamri and Brinkman, 2000). Phahle (1977), reported on the electrical conductivity, hall voltage, and thermoelectric power of vacuum deposited tellurium thin films. The study showed that the films were p-type with crystallographic defects providing additional acceptor centres. Terminal assisted hopping conduction was also found to be predominant at temperature below 150K.

The present study investigates the effects of surface area on the electrical properties of tellurium films as most devices for electrical, electronic and metallurgical works depend to a large extend on the shape of the material. The area of films is also known to be a major factor in the manufacture and assemblage of electrical and electronic devices. The desired shapes of the films were generated using mica mask while the nature of the configuration was determined using the current – voltage characteristics at room temperature.
EXPERIMENTAL

The mica mask used to generate the required design were washed with soap detergent and rinsed with water. This was followed by ultrasonic agitation in deionised water, acetone, and ethyl alcohol for twenty minutes each. The polished glass slides that were used as substrates were first boiled in chromic acid and ultrasonically cleaned as described for mica mask above. The substrates (glass slides) were then enclosed in a vacuum chamber (Edward coating Unit model 306) and tellurium films of thickness 1000Å were deposited on the substrate from a tungsten filament at a pressure of 5x10⁻⁵torr. Electrical contacts were made to opposite ends of the films by depositing Sb metal on the electrode width. All the evaporant were of 5N9 purity. The final configuration of films is shown in fig. 1. The current – voltage characteristics of the samples were measured with a digital electrometer (Keittley, type 160B) and a digital multivoltmeter (Hewlett – Packard type 3465A) at room temperature.

RESULTS AND DISCUSSION

Figure 2 shows plots of current density (J) and the Voltage (V) measurements for all the samples. The current in the samples increases with increase in voltage. In addition, the samples show linear J – V relationship over the voltage range 0.05 – 0.50V. The values of the surface conductance, saturation current density and the barrier heights of the samples are recorded in table 1. The conductance of the samples decreases with increase in surface area while the saturation current density increases with increase in surface area. The decrease in conductance with increase in area could be attributed to larger resistance imposed by films of larger areas thereby resulting to increase in saturation current density. However, only little variations were observed in the values of the barrier height of the samples. The results in this study are in agreement with previous works by Oberefo et al (1994); Oluyamo (1999 and 2003) for Bi/Te, Sb/Te and Sb/Si contacts respectively.

The conductance of the samples were calculated from the slope of the best line of fit of the current density – voltage plots (fig2) and using the relationship,

\[ J = \sigma V \] (Arthur, 1983; Sze, 1985; Oluyamo and Babalola, 2006). Where \( \sigma \) is the conductance of the samples and obtained from the best line of fit of the J –V plots.

The barrier heights were calculated from the current – voltage forward characteristics using the thermionic emission theory with the current – voltage relationship given as;

\[ J = J_s \exp \left( \frac{qV}{kT} \right) \]

For negligible series resistance;

\[ J_s = A^*T^2 \exp \left\{ -\frac{q\phi_B}{kT} \right\} \]

Where \( A^* \) is the Richardson constant, \( \phi_B \)

<table>
<thead>
<tr>
<th>Area(mm²)</th>
<th>Conductance ( \sigma \times 10^{-2}(\Omega^{-1/mm²}) )</th>
<th>Saturation Current density ( J_s (A/mm²) )</th>
<th>Barrier heights (Volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>5.13</td>
<td>41.80</td>
<td>0.18</td>
</tr>
<tr>
<td>220</td>
<td>2.07</td>
<td>48.61</td>
<td>0.18</td>
</tr>
<tr>
<td>225</td>
<td>1.90</td>
<td>49.80</td>
<td>0.21</td>
</tr>
<tr>
<td>230</td>
<td>1.87</td>
<td>50.45</td>
<td>0.19</td>
</tr>
<tr>
<td>235</td>
<td>1.71</td>
<td>81.45</td>
<td>0.20</td>
</tr>
<tr>
<td>240</td>
<td>1.63</td>
<td>89.37</td>
<td>0.19</td>
</tr>
<tr>
<td>250</td>
<td>1.50</td>
<td>99.40</td>
<td>0.20</td>
</tr>
<tr>
<td>260</td>
<td>1.30</td>
<td>102.50</td>
<td>0.21</td>
</tr>
</tbody>
</table>
is the zero field asymptotic barrier height, k, the Boltzmann's constant, T, the absolute temperature and q, the magnitude of the electronic charge.

Figure 3 shows the LnJ – Voltage plots for the samples. This figure gives curves which is expected at the region $V<3kT/q$ for the study. The values of the saturation current density $J_s$ were obtained from the extrapolated LnJ to zero voltage. The barrier heights were also estimated using the relationship,

$$\phi_B = \frac{kT}{q} \ln \left( \frac{A^{*2}T^2}{Js} \right)$$

![Antimony Substrate Antimony](image)

**Tellurium film**

![Image of Tellurium film](image)

**Fig. 1: Final configuration of the deposited samples**

![Image of current density plots](image)

**Fig. 2: Current density ($J$) versus - voltage ($V$) plots for the eight samples**

![Image of LnJ - Voltage plots](image)

**Fig. 3: LnJ - Voltage ($V$) plots for the samples**
CONCLUSION

The current in all the samples increases with increase in voltage. Hence, the samples are ohmic within the voltage range 0.050 – 0.50V. The conductance reduces with increase in the area of the films while the saturation current density was found to increase with increase in the area of films. This could be due to the fact that films with larger areas create higher resistance thereby, reducing the conductance, which results to increase in saturation current density. However, the study revealed that there exist little variation in the values of the barrier heights of the samples. The study agrees with previous works by Oberafo et al (1994), Oluyamo (1999 and 2003) for Bi/Te, Sb/Te, Sb/Si contacts respectively.

REFERENCES