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ELEVATED TEMPERATURE EFFECTS ON THE ELECTRICAL PROPERTIES OF Bi METAL PROBE TO Si THIN FILM.

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ABSTRACT

The effects of elevated temperatures on the electrical properties of Bi metal probe to Si thin films had been investigated for electric field values 10-100V/m. Measurements of current (I) – voltage (V) characteristics were obtained at temperatures 300,320,340,360,380 and 400K respectively. The results indicated linear I–V relationship over the voltage range 10 – 60V and at higher voltage (>60V) there was deviation from linearity and evidence of saturation was noticed at voltage close to 100V. The electrical surface conductance of the samples and the barrier heights increase with increasing temperature while the saturation current density decreases with increasing temperature. Hence, Bi metal probe have effects on the electrical properties of Si thin films at elevated temperatures.

KEY WORDS: Temperature, Electrical properties,Bi/Si, Conductance.

INTRODUCTION

Silicon happens to be one of the most important semiconducting elements because of its increasing technological and scientific applications in various forms. Most industries use Silicon as material for conduction controlled devices and detectors, for the fabrication of photovoltaic cells for direct conversion of solar energy to electricity (Mark, 1999; Komla, 1985; Herick, 1985; Oluyamo, 1998) and various forms in electronic circuits. Studies had been carried out on the electrical behaviour of Silicon and in other semiconductor thin films at different stages. Findings on these materials had shown that metal-semiconductor contacts exhibit ohmic behavior (Astroval, etal, 1985;Noboru et al, 1988; Ormar, 1997). This is partly from the fact that semiconductor devices need at least one ohmic contact and often, the quality of the ohmic contact is one of the most significant factors affecting their performance.

Several possible ways of achievering ohmic contacts have been identified. A layer of heavily doped semiconductor immediately adjacent to the metal, so that the depletion region in the semiconductor becomes thin that even in a high barrier, field emission dominates and the contact is ohmic. An introduction of recombination centre near the metal-semiconductor interface among others is methods of forming ohmic contacts (Grove, 1968;VanVechten, 1970;Sze, 1985;Ndukwe, 1995). Studies had been carried out on the behaviour of metal contacts to semiconductor thin films at room temperature. Such findings had shown that some metals formed ohmic contacts to semiconductor films (Okuyana et al, 1975; Mgbenu, 1975;Abbey, 1996).

In their electrical measurement on silicon materials, Heiland and Lamatch (1964) showed that absorption of oxygen causes the resistance of a p-type sample to decrease initially and then increase. Similarly, Phahle (1977) reported on the electrical conductivity, Hall Voltage and thermoelectical power of thin vacuum deposited tellurium films. These films were p-type with crystallographic defects providing additional acceptor centers and terminal assisted hopping conduction was found to be predominant at temperature below 150K.Above this temperature, intrinsic conductivity predominated.

The behavior of the junction formed by the contact of Bi to Te films with Sb as the reference electrode at temperature range of (303-353K) was studied by Oberafo et al (1994). The result of the study showed linear I-V behaviour at temperature close to room temperature. The electrical surface conductance was also found to increase with increasing temperature with evidence of symmetry at the Bi/Te and Sb/Te contacts. Recent research had shown that probe shapes have effects on the conducting behaviour of Te film at room temperature (Oluyamo, 1999). In the present work therefore, the effects of temperature on the electrical properties of Si with Bi metal probe is investigated. The nature of the contacts was determined by studying the current (I)-Voltage

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Table1 Voltage (Volts), Currents I (mA), and Current density J(mA/nm^2) values of the samples.

V(volts)	I_1	J_1	LnJ_1	I_2	J_2	LnJ_2	I_3	J_3	LnJ_3	I_4	J_4	LnJ_4	I_5	J_5	LnJ_5	I_6	J_6	LnJ_6
10	8.0	0.0309	-3.477	9.0	0.0348	-3.359	12.5	0.0483	-2.030	15.5	0.0599	-2.815	16.0	0.0618	-2.784	21.0	0.0811	-2.512
20	18.5	0.0715	-2.638	23.0	0.0889	-2.421	30.5	0.1179	-2.138	32.0	0.1237	-2.090	34.0	0.1314	-2.030	37.5	0.1449	-1.932
30	26.0	0.1005	-2.298	33.5	0.1295	-2.045	44.5	0.1719	-1.761	48.5	0.1874	-1.675	50.5	0.1951	-1.634	54.0	0.2087	-1.568
40	35.5	0.1372	-1.987	43.5	0.1681	-1.783	60.0	0.2318	-1.462	65.5	0.2531	-1.374	67.0	0.2589	-1.351	69.5	0.2686	-1.315
50	44.0	0.1701	-1.772	55.5	0.2145	-1.539	77.5	0.2995	-1.206	81.0	0.3130	-1.162	85.5	0.3304	-1.108	87.5	0.3381	-1.084
60	54.0	0.2087	-1.567	67.0	0.2589	-1.351	91.0	0.3516	-1.045	98.5	0.3806	-0.966	101.0	0.3903	-0.941	104.0	0.4019	-0.9[illegible]7
70	60.5	0.2338	-1.453	71.5	0.2763	-1.286	94.5	0.3652	-1.008	104.0	0.4019	-0.921	110.0	0.4250	-0.856	110.5	0.4270	-0.851
80	63.0	0.2434	-1.413	73.5	0.2840	-1.259	96.0	0.3709	-0.992	109.0	0.4212	-0.865	113.0	0.4366	-0.829	115.0	0.4444	-0.811
90	65.5	0.2531	-1.374	75.0	0.2898	-1.239	98.0	0.3787	-0.971	110.0	0.4250	-0.855	114.[illegible]	0.4424	-0.816	115.5	0.4463	-0.807
100	66.0	0.2550	-1.366	76.5	0.2956	-1.219	99.0	0.3825	-0.961	110.0	0.4250	[illegible]	[illegible]	0.4444	-0.8[illegible]	[illegible]	0.4540	-0.790

(V) characteristics at various elevated temperatures.

EXPERIMENTAL

The mica and metal masks, which were used to generate the desired patterns were cleaned thoroughly, first with soap detergent and rinsed in distilled, deionized water. This was followed by ultrasonic agitation for ten minutes in successive baths of trichloroethylene, acetone and ethyl alcohol in that order. The polished microscopic glass slides used as substrates, were cleaned by boiling in distilled deionised water, followed by ultrasonic cleaning as for the masks. After cleaning, the substrates were enclosed in a vacuum chamber of an Edward coating model 306 coating unit and silicon films of 1000A^0 thick were deposited on the substrates by thermal evaporation from a tungsten filament in the coater chamber maintained at a pressure of 5x10^{-6} torr. Contacts were made at opposite ends of the films by depositing Bismuth (Bi) metal of about 1000A^0 on the appropriate electrode width. The deposition rate, which was about 500A^0/min, was determined with an Edward model FTM3 film thickness monitor. All the evaporated samples were of 99.999% purity (supplied fromVentron, Germany). The experiment was conducted in a closed controlled atmosphere where the temperature could be varied from 300K to 420K. At each temperature, the current (I)-voltage (V) characteristics of the samples were determined with a digital electrometer (Keittley type 160B) and a digital multimeter (Hewlett-Packard type 3465A). The final configuration of films after deposition is shown in figure 1

RESULTS AND DISCUSSION

The results of the current (I), current density (J) and voltage (V) measurements are shown in tables1 (a and b). The current in all the samples increases with increase in voltage and temperature, although, the increase in current is seen to reduce at high voltage (>60V) than at low voltage (<60V). The current (I)-voltage (V) plots for the samples are shown in figure2. All samples show linear I-V relationship over a specified voltage range (i.e. 10-60V). The current in the samples seems to approach saturation at higher voltages (between 60-100V). The study agrees with previous work by Omar (1975) and Oberafo et al (1994) for Ge and Bi/Te contacts respectively. However, records on Ge, and Bi/Te contacts showed deviation from ohmic characteristics at high fields usually above 100V at temperatures higher than room temperature. In

Table2: Temperature (K), Surface Conductance, Saturation Current density, and the barrier heights of the sample.

Temperature (K)	Conductance σ ($\Omega^{-1}mm^{-2}$)	Saturation current density Js($mAmm^{-2}$)	Barrier Heights ϕ_B(Volts)
300.00	0.20	78.50	0.93
320.00	0.25	66.69	0.97
340.00	0.32	44.70	1.05
360.00	0.36	38.48	1.12
380.00	0.37	31.50	1.19
400.00	0.38	27.11	1.26

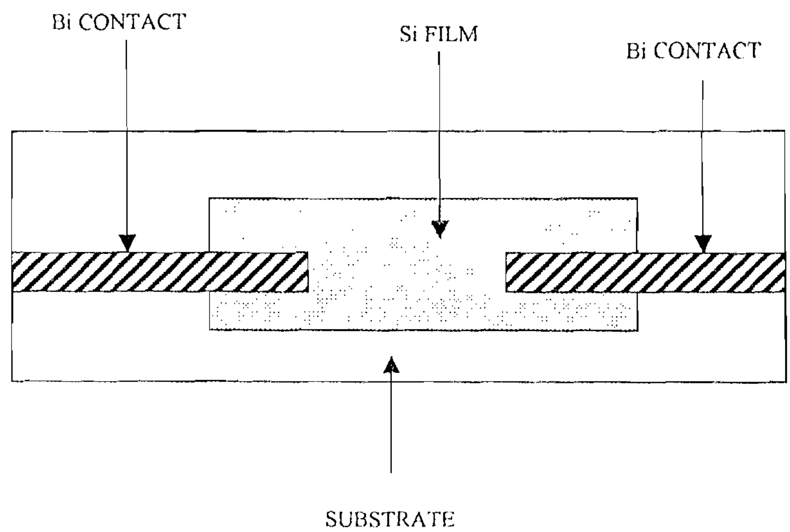

Fig: 1. Final configuration of films after deposition.

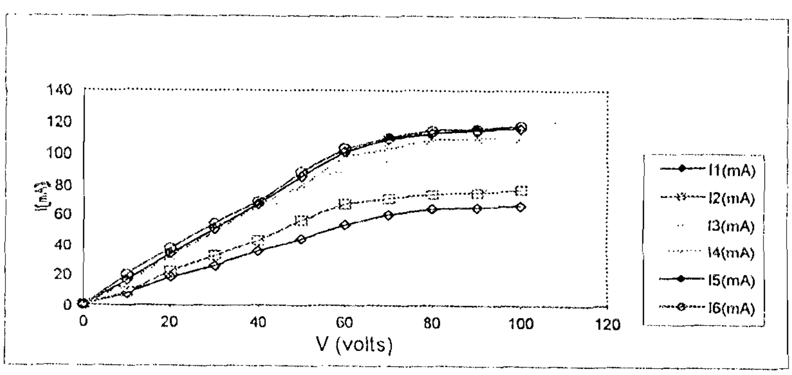

Fig 2: Current I(mA) against Voltage(volts) plots of the samples

our investigation Bi/Si was found to deviate from ohmic behaviour at a voltage as low as 60V and at temperatures above 300K.

The values of the temperature (K), surface conductance (A/mm^2) and barrier heights (Volts) are shown in table 2.The values of the surface conductance increases with increasing temperature while the saturation current density decreases with increasing temperature. The values of the barrier height of the samples showed relative increase with increasing temperature. The increase in surface conductance with temperature could be due to the expected increase in carrier density with increase in temperature. The surface conductance of the samples was obtained by taking the slope of the line of best fit of the current (I)- voltage (V) plots and using the relationship.

$$\sigma = Ln2/\pi \, (I/V)$$

where (I/V) = slope of line of best fit.

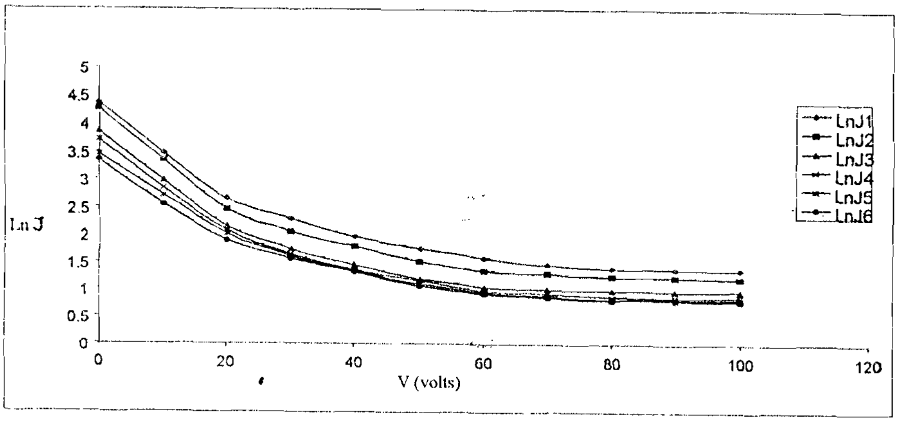

Fig 3: LnJ against Voltage (volts) plots of the samples

The slope of the line of best-fit is obtained from the Ohmic region of the graph in fig.2.The barrier height was calculated from the current (I) - Voltage (V) characteristics using the thermionic emission theory for high mobility semiconductors with I-V relationship given as,

J= Js {exp (qv/kT) −1}, V is the voltage across the device terminal.

For negligible series resistance,

$J = A^{**} T^2 \exp(-q\Phi_B/k\,T)$.

Φ_B is the zero field asymptotic barrier height, A** is the effective Richardson constant, k is the Boltzmann's constant the temperature and q is the magnitude of the electronic charge. Figure 3 for the LnJ- voltage V plots give curves for all the samples. This is being expected at the region V<3kT/q for the study. The saturation current density Js is then obtained from the extrapolated values of LnJ to zero voltage while the barrier height is estimated using the relationship

$\Phi_B = kT/q\ Ln\,(A^{**}T^2)/Js$

CONCLUSION

The current in all the samples increases with voltage and temperature. All the samples also exhibit linear I-V relationship over specified range of voltage 10-60V. While at higher voltage between 60-100V, the current in all the samples seems to approach saturation. Hence, within the voltage range 10-60V,Bi metal forms ohmic contact to Si thin films at temperature above 300K.The study is in agreement with previous work by Omar (1975), Oberafo et al (1994), and Oluyamo (1999) for Ge, Bi/Te and Sb/Te respectively. The electrical surface conductance increases with increasing temperatures and this is attributed to increase of carrier density with increasing temperature. The saturation current density decreases with increase in temperature. However relative increase in barrier heights of all the samples with temperature was observed. Hence, Bi metal probe have effects on the electrical properties of Si thin films at elevated temperatures.

REFERENCES

Abbey, T. M. 1996. H_2O Induced surface states on Amorphous semiconductor thin films. Nigerian Journal of Physics, 85, 80-83.

Astroval, E.A., Bolshokov, L.B., Lebeedev, A.A and Mikhmo, O.A., 1985. Photoconductivity of Selenium Doped Silicon. Soviet Physics of Semiconductors, 19(5): 565-570.

Grove, A.S., 1968. Physics and Technology of Semiconductor Devices. John willey and sons Inc., Pp 55-60.

Heiland, G.and Lamatsch, H., 1964. Electrical Resistance measurements on silicon materials. Surface Science. 2,P18.

Herick, O., 1985. Solar Energy Thermal Converters. In Olumuyiwa Awe (ed). The workshop on the physics and Technology of solar Energy conversion. University of Ibadan, Nigeria.

Komla G. Adamu, 1985. A strategy for the development and application of Photovoltaic electricity generation for rural development in African countries. In Olumuyiwa Awe (ed). The workshop on the physics and Technology of solar Energy convertion, University of Ibadan, Nigeria.

Mark Ladd, 1999. Introduction to Physical Chemistry (3rd edition). Cambridge University press, United kingdom, Pp266-268.

Mgbenu, E.N., 1979. Diffusion studies in Al-Ge thin film couples. Physics statistical solidi. (a) 53: 397-401

Ndukwe, I. C., 1995. Characterization of Calcium Selenide Thin Films Prepared by the Electrodes Method. Nigerian Journal of Physics,3: 78-81.

Noboru Tahge Kanda. K. and Mimami. T., 1988. Electrical and photovoltaic properties of Amorphous chalcogenide thin film p-n junctions. Appl. Phys. Lett, 53(7): 580-585.

Oberafo. A. A. Odunaike. R. K. and Mukolu, A. I., 1994. The behaviour of Bi metal contacts to Te films. Int.J.Biochemiphysics. 3: 78-81

Okuyana, K, Yamamoto. H and Kumagai,Y., 1975.The behaviour of some metal contacts to evaporated tellurium films. Journal of Applied Physics, 45, 3328-3333.

Oluyamo, S. S., 1998. Photovoltaic Energy Conversion in Semiconductor Based Devices.M.Sc Thesis, University of Ibadan, Nigeria.

Oluyamo, S.S., 1999. Effects of probe shapes on the Barrier height and surface conductance of tellurium thin films. Pakistan Journal of Scientific and Industrial Research, 42(3): 113-116.

Omar. M. A., 1975. Elementary Solid State Physics. Addison Wesley publishing company, London, Pp287-290.

Ormar. M.S., 1997. A trichlinic superlatice structure for the bended sphalerite unit cell of the compound Cu_2 Ge Se_3.Arab Gulf Journal of Scientific Research, 15(2): 3353-3356.

Phahle, A. M., 1977. Electrical conductivity, Hall Voltage and thermoelectrical power of thin vacuum deposited tellurium films. Thin Solid Films,45: 235-240.

Sze, S. M., 1985. Physics of Semiconductor Devices. John Willey and sons, London, Pp363-403

Van Vechten, J. A. and Berstresser, T. K., 1970. Electronic Structures of Semiconductor Alloys. Physical Review, 81: 3351-3353.