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Effects of Surface Area on the Electronic Parameters of Vacuum Deposited Bismuth-Silicon Schottky Junctions

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Abstract: Vacuum deposited Bismuth-Silicon junctions of different areas had been studied. Electrical characterisations of the junctions were carried out and electronic parameters such as surface conductance, ideality factor and barrier heights were determined. The surface areas of the junctions were found to affect the surface conductance while the values of the ideality factor and the barrier height showed no significant dependence on the surface area of the junctions. The values of the ideality factor, which range between 0.70-0.83 revealed that, the contacts are close to ideal (i.e., unity). This equally stresses the fact that vacuum deposition is an ideal method for making metal-semiconductor junctions.

Key words: Electronic parameters, vacuum, effects, surface area

INTRODUCTION

The junctions between Metals and Semiconductors (MS) are of great importance in modern electronics. Their uses include among others, the fabrication of devices such as infrared detector, modulation doped field effect transistors, schottky collector heterojunction bipolar transistors, photoconductors, lasers and solar cells (Nur *et al.*, 1996; Basol *et al.*, 1981; Robert *et al.*, 1981; Ou and Stafsudd, 1994; Waag *et al.*, 1970; Mukolu, 2004). MS contacts are improvements in the solid-state device fabrication technology, which involves three basic aspects; material, contacts and encapsulation. This is achieved through synthesis, processing and precise control of dopants in the device material (Misra *et al.*, 1992). Electrochemical deposition of metals and semiconductor materials onto metallic substrates plays important role in many modern technologies. In the electronic industry, electrochemical and electrodeless deposition are widely used for applications in copper printing multilayer read/write heads and their magnetic recording media (Ramanankiv and Palumbo, 1998). MS devices have been found to be essential elements of the silicon-based integrated circuit technology (Nur *et al.*, 1996).

The electrical properties of n-Si/Au schottky junctions were investigated by Oskan *et al.* (1998). The study showed that high quality continuous gold films were formed with an average grain size of the order of 50-70 nm. The possibility of obtaining visible light emission from silicon devices has been considered an important target for years. Various applications have been attempted and it has been discovered that porous silicon is a promising material for visible light emission (Lazarouk *et al.*, 1996). Studies had also been carried out on the effect of electrical properties of silicon –metal contacts at different stages (Hoffman *et al.*, 1993; Frojdh and Petersson, 1996; Abbey, 1996; Oluyamo, 2003; Oluyamo and Ojo, 2004). Findings in these studies had revealed that various factor such as temperature, humidityand environmental condition e.t.c have great influence on the electrical characteristics of metal-semiconductor contacts.

In this research, we report the electronic parameters of vacuum deposited Bismuth-Silicon Schottky junctions at different surface areas. This is motivated due to the fact that metal-semiconductor contacts prepared by the evaporation of metal on semiconductor surfaces, which have been etched, exhibits two kinds of instability. The barrier height may vary systematically with time and the current at a constant applied voltage may change (Thanailakis and Northrop, 1971). The present study is therefore undertaken to investigate the effects of surface area on the electronic properties of bismuth-silicon junctions, since etching is known to affect the surface area of the devices. The parameters of the junctions were determined by studying the current-voltage characteristics at room temperature.

EXPERIMENTAL

The experimental procedure in this study follows the sequence in Oluyamo (2003) and Oluyamo and Ojo (2004). In particular, the silicon films $1000A^0$ thick were first

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evaporated on the already cleaned microscopy glass slide (used as substrate) at a pressure of 5×10^{-6} torr using an Edward model 306 coating unit. Contacts were made at opposite ends of the films by evaporating bismuth metal of about $1000A^0$ thick on the electrode width. The different areas of the films were obtained with the aid of designed mica mask, which exposes only those area of film desired to the evaporant. The deposition rate ($500A^0$ min) was determined with an Edward model FTM3 film thickness monitor. All the evaporant were of 99.999% purity, obtained from Ventron, Germany. The current-voltage measurements of the samples were determined with a digital electrometer (Keithley type 160B) and a digital multimeter (Hewlett-Packard type 3465A) at room temperature.

RESULTS AND DISCUSSION

The current density-voltage characteristics of the junction with different surface areas are shown in Fig. 1. It is apparent that the current-voltage characteristics of samples exhibit linear rectifying relationship over the voltage range [10-60V]. This revealed that the ohmic behaviour of silicon-metal contacts as recorded in previous researches (Oluyamo and Ojo, 2004; Oluyamo, 2003) within this voltage range is not affected by surface area. In addition vacuum deposited devices are known to show better rectification than those prepared by other methods (Misra *et al.*, 1992). This is due to the fact that a more intimate contact exists at the interface of such junctions.

Table 1 showed the values of the area, surface conductance, ideality factor and the barrier height of the junctions. The conductance was found to increase with increase in surface area. This is being expected since larger areas are exposed for conduction as the surface area of the device increases. The ideality factor and the barrier height show little variation. However, statistical analysis on these values indicates that there exist no significant different between them. In other words, the surface areas of the junctions had no effect on both the ideality factor and the barrier height. Since the ideality factor for an ideal rectifier is unity, the values obtained in this study, which range between 0.70-0.83 attest to the fact that the junctions are ideal.

The surface conductance of the samples was calculated from the line of best fit of the current density-voltage plot using the relation.

$J = \sigma V$ (Arthur, 1983; Oluyamo, 2003), where σ is the surface conductance estimated from the slope of the line of best fit in Fig. 1.

Other electronic parameters of the junction were calculated using the relation.

Table 1: The values of the surface area A (mm^2), conductance σ (mA mm^{-2}), barrier height x_b (volts) and ideality factor n of the junctions

Area (A)	Conductance ($\sigma\times10^{-3}$)	Barrier Height ($x_b\times10^{-3}$)	Ideality factor (x_b)
250.0	2.98	2.21	0.70
260.0	3.70	0.20	0.78
270.0	4.98	2.21	0.70
280.0	5.44	2.20	0.72
290.0	5.59	2.21	0.68
300.0	5.75	2.22	0.83

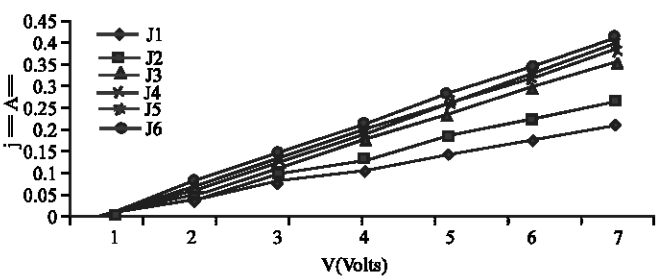

Fig. 1:Cuirrent density (J)-Voltage (V) plots

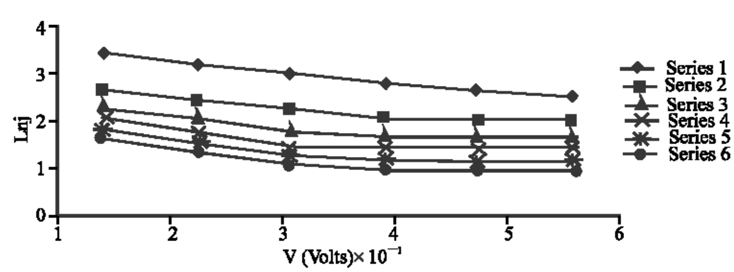

Fig. 2: LnJ-Voltage (V) plots

CONCLUSION

The junction between Bismuth and Silicon at different areas were made by vacuum deposited method. The method was found to be accurate in forming rectifying contacts as the ideality factor for the junction ranges from 0.70- 0.83 which is near ideal (i.e., unity) for a perfect rectifier. The surface area of the junctions had no significant effects on the barrier height and the ideality factor. The study revealed that the area of the samples affected the surface conductance. This had been attributed to the fact that larger areas are being exposed for rectification with increase in area, hence, an increase in the surface conductance.

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