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ELECTRONIC PROPERTIES AND SOLAR DEVICE APPLICATIONS OF Bi AND Sb CONTACTS TO Si THIN FILMS

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ABSTRACT

The study examined the electronic properties and solar device applications of Bi and Sb contacts to Si thin films at temperatures 303-353K. The samples of thickness 1000 Å were vacuum deposited at a pressure of $5x10^{-5}$torr with the constituent elements of 99.99% purity, Ventron Germany. The analysis of the samples showed that the conductivity increases with temperature while the activation energies had values of 0.033 eV, 0.124 eV for the Bi/Si and Sb/Si samples respectively. These properties in addition to the electrical characterization of the samples were observed to compare favourably with that of semiconductor properties widely adapted for use in solar devices and opto electronic applications. Hence, the samples in the study have good potentials for use in the fabrication of solar devices and light amplification systems.

Key words: Electronic properties, semiconductor thin films, solar device applications.

INTRODUCTION

The development of metal-semiconductor thin films is of significant interest due to the outstanding technological applications in various facet of life. Research on metal semiconductor devices has evolved continued insights into new frontiers as to the use, implementation and adaptation of these materials in different forms. Improvement on metal semiconductors devices, such as metal oxide semiconductors had been described as the best candidate for gas sensing as they operate in a reverse manner and usually have stable chemical and thermal properties over extended period of use (Thaidun *et al*., 2013). Most devices in electronics and electrical works are fabricated from semiconductor based materials. This is due largely to their numerous benefits over other types of conducting devices. Among such advantages are small size and light weight. Operation of semiconductor devices requires low voltage supply, low power consumption rate and quick response time. Above all, semiconductor devices are more reliable, efficient and have appreciable long life (Pillai, 2007). Many of the properties of metal semiconductor devices of great importance such as structural sensitivity, mechanical strength, ductility, crystal growth, magnetic hysteresis, dielectric strength are greatly affected by relatively minor changes in crystal structure. Fabricated materials may contain imperfections of various kinds that produce both useful and such undesirable effects in the resulting device applications. Parameters like associative temperature, deposition rate, probe shapes, humidity, impurity concentration rate, etc had been reported to affect the electrical properties of metal-semiconductor thin films, the band gap of layers can also vary with the fraction of the grown layer (Thanailakis and Northrop, 1971; Oluyamo, 1999; Stakowski *et al*., 2002; Oluyamo *et al*., 2004; ITRS, 2005; Sze and Kwok, 2006; Edge and Schiome, 2006; Babych *et al*., 2011; Abram *et al*., 2013; Manoharam and Neelakanda, 2013, Myeong *et al.*, 2013). Various attempts are being made to find suitable applications of metal contacts to semiconductor thin films.

In this work, the electronic properties of Bi and Sb contacts to Si thin films are examined. Silicon semiconductors had proved to be useful in a wide array of applications. To this end, numerous latent potential applications yet unraveled require continued research to outline these properties for technological devices operation. Therefore, it is believed that the information in this study will complement existing applications of Silicon materials for technological use.

MATERIALS AND METHODS

The films in this study were prepared using the vacuum deposition technique with the aid of the Edward coating unit model-306. The desired shape of the films was achieved by a well designed mask positioned on a substrate (i.e. microscopic glass slide) and enclosed in the vacuum coating chamber. The substrate and mask were cleaned by boiling in Chromic acid and ultrasonic agitation in baths of dionised water, acetone and ethyl alcohol for twenty minutes in each of the solution.

Silicon films of thickness 1000Å were deposited on the substrate at a pressure of $5x10^{-5}$torr at a rate of 50Å/min. Sample contacts were further attached to the films by depositing Bi (Sb) film at both ends of the Si films. The deposition rate was determined with an Edward film thickness monitor model-FTM3. The set up was performed at a closed atmosphere where the temperature could be varied from 303-353K. The elements, Bi, Sb and Si, used in this study were of 99.99% purity, Ventron Germany. Figure 1(a and b) shows the final configuration of the deposited samples. The Current (I)-Voltage (V) characteristics of the samples were determined with the aid of digital multimeter/voltmeter.

RESULTS

The results of the current-voltage characteristics for the Bi/Si and Sb/Si samples at temperatures 303-353K are illustrated in Figures 2 and 3. Figure 4 also shows the Conductivity-Temperature relationship for the two samples. The conductivities and activation energies of the samples at temperatures 303-353K are presented in Table 1.

Table 1: Temperature, conductivity (σ) and the activation energies (ε) for the Bi/Si and Sb/Si Samples

	Bi/Si		Sb/Si	
Temperature (K)	Conductivity σ x10^{-2} $(\Omega m)^{-1}$	Activation Energy ε (eV)	Conductivity σ x10^{-2} $(\Omega m)^{-1}$	Activation Energy ε (eV)
303	0.419		0.359	
313	0.523		0.432	
323	0.712	0.033	0.516	0.124
333	0.749		0.629	
343	0.766		0.652	
353	0.774		0.682	

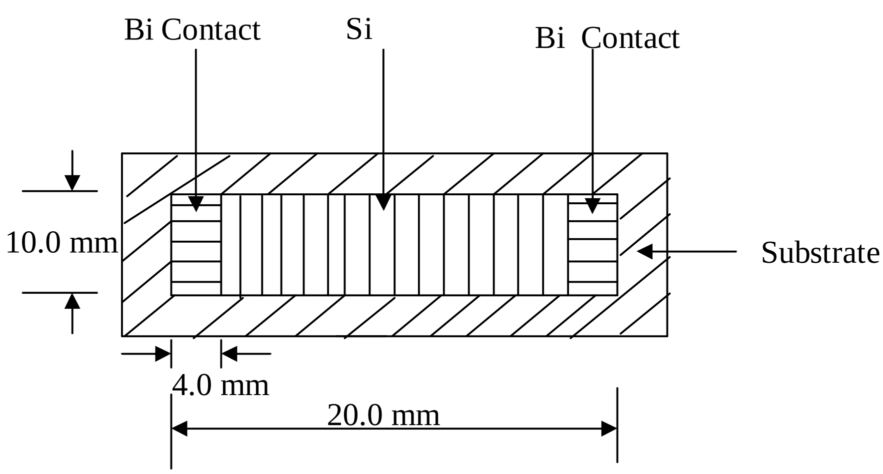

Figure 1(a): Final configuration of the deposited Bi/Si

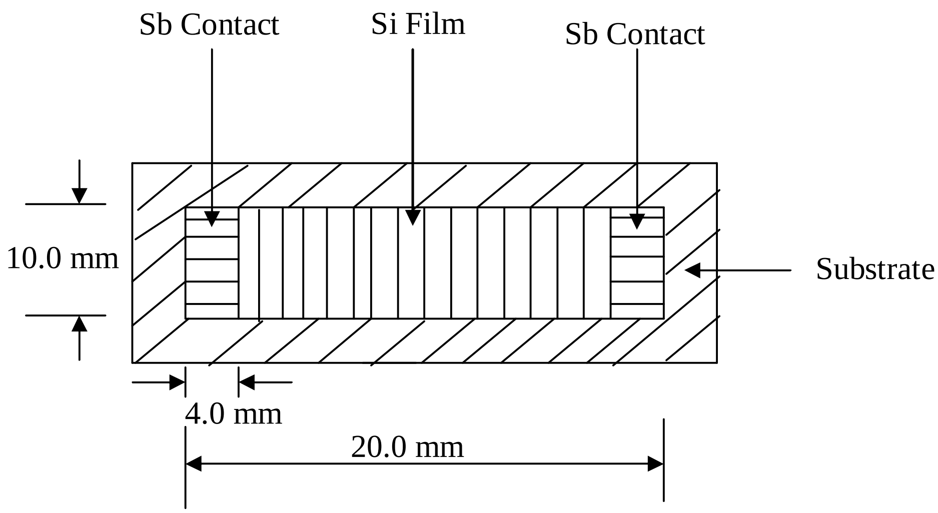

Figure 1(b): Final configuration of the deposited Sb/Si sample

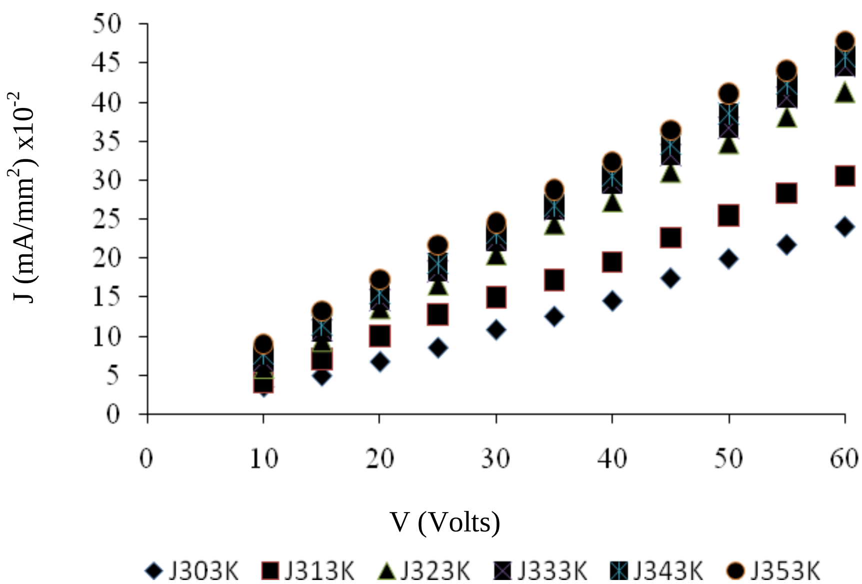

Figure 2: Current density (J)-Voltage (V) plots for Bi/Si samples at temperatures 303-353K

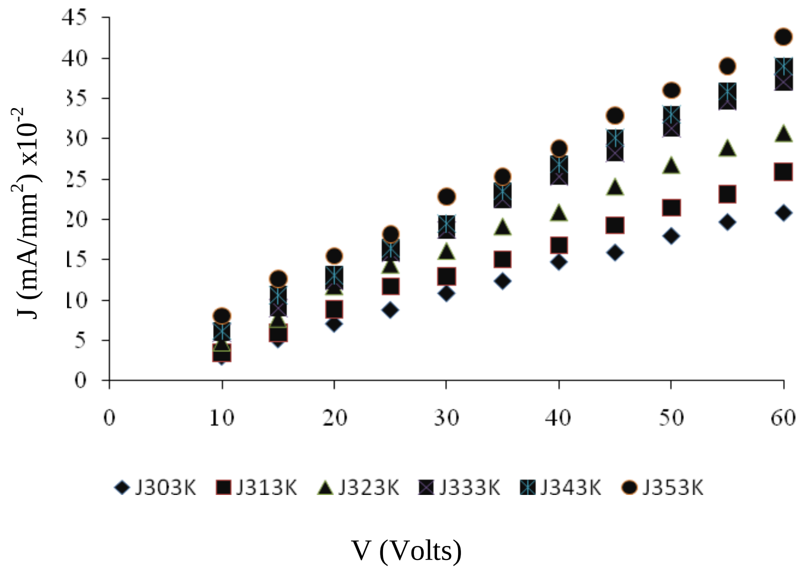

Figure 3: Current density (J)-Voltage (V) plots for Sb/Si samples at temperatures 303-53K.

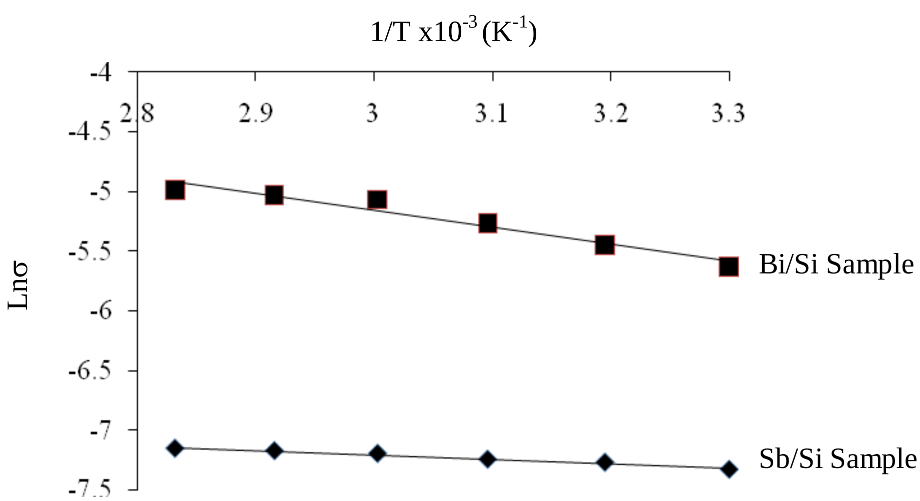

Figure 4: Conductivity (σ)-Temperature (T) plots for the Bi/Si and Sb/Si samples

DISCUSSION

The current-voltage characteristics of the fabricated samples showed that the current in both samples increases as the voltage increases. Hence, the microscopic form of Ohms law $J = \sigma V$, where J is the current density, σ is the conductivity and V is the voltage across the length of the sample; was used to estimate the conductivity at temperatures 303-353K. The obtained conductivity was found to increase with temperature for the two samples. This agrees with the expected trend in the conductivity and temperature characteristics of semiconductor materials. This is so since the conductivity of semiconductor materials depends strongly on temperature because of the need for thermal energy to excite electrons into the conduction band. The higher the temperature, the greater the number of electrons that are excited. Oluyamo and Ojo (2004) had attributed the increase in conductivity to the expected increase in carrier density with increase in temperature.

The activation energy of the samples were obtained from the Conductivity-Temperature relationship in figure 4 using the Arrhenius relation, $\sigma = \sigma_0 exp(-\varepsilon/kT)$, where σ_0 is the conductivity at zero voltage, ε is the activation energy, k is the Boltzmann's constant and T is the temperature. The estimated activation energies for the samples were 0.033 eV and 0.124 eV for the Bi/Si and Sb/Si samples respectively. These low values of the activation energies suggest that the thin film material have the ability to raise electrons to a higher energy state with little absorption of heat. This property revealed that the fabricated materials in this study could enhance light-generation current which involves the absorption of incident photons to create electron-hole pairs. This is one of the basic steps in the operation of solar cells and photo electronic systems.

The electrical characterization, range of conductivities and the values of the activation energies obtained for the samples are found to be comparable to the properties of materials used for the production of solar cell devices and fabrication of photo electronic materials (Bowden and Rohatgi, 2001; Pysch *et al* 2007). Hence, the fabricated samples have great potentials for the production of solar cell devices and opto electronic development.

CONCLUSION

Most of the devices in electronic industrial application today are built from semiconductor materials. The search for improved varieties of this materials had generated numerous and attractive attempts to fabricate different forms of semiconducting devices. The electronic properties of the contacts between Bi/Si and Sb/Si in this study, revealed the potential of the samples for use in solar cell devices and optoelectronic applications. The materials in this study could be harnessed to complement the existing technological benefits of Silicon semiconductor material devices especially in solar device applications, optoelectronics and light amplification developments.

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