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Electrical Properties of Annealed and Unannealed Al-Ge Thin Film Couples

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The electrical properties of annealed and unannealed Al-Ge thin films had been investigated at electric field values 0.1 - 0.85V/m. Measurements of current - voltage characteristics were obtained at a room temperature. The results of the study showed linear J - V relationship over the voltage range. Annealing changes the electrical properties of the films. As the conductance and barrier heights of annealed samples increase, the saturation current density reduces. Hence a more conducting junction may be obtained from the same metal-semiconductor contact by annealing the sample to a reasonable temperature without loss of surface parameter. In addition, the thickness of the sample also affected the electrical properties of the films.

Key words: Electrical properties, Al-Ge, Thin films, Conductance, Annealing, Barrier height, Saturation current density.

Introduction

Metal - semiconductor diodes had been studied in various forms and found to exhibit Ohmic characteristics. The behavior of most of these contacts has been reported to be reliable and reproducible. One basic property is that Ohmic contacts neither undergo electro migration under high electric fields nor modify active structure characteristics during device operation. Several ways of achieving 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 so thin that field emission dominates, hence the contact is Ohmic. The introduction of a recombination centre near the metal-semiconductor interface and having a negligible potential barrier at the metal-semiconductor interface are forms of making Ohmic contacts (Froeanf *et al* 1982; Oberafo 1994; Ndukwe 1998).

Most of the diodes investigated are in thin films and as a result, different properties of such films have been studied (Salau *et al* 1985; Astrova *et al* 1985; Noboru *et al* 1988; Omar 1997; Oluyamo 1999, 2003). It had been shown that room temperature inter diffusion of Au/Ge thin film significantly lead to increase in leakage current thereby increasing the conductivity of Ge film (Mgbenu 1979). In addition, the electrical and electrolytic behavior of some materials were extensively studied at room temperature (Oluyamo *et al* 2000). The study showed evidence of the dependence of conductance on temperature.

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The electrical properties of annealed and unannealed Al-Ge thin films are investigated in this study. Four samples were used labelled S1-S4. The required pattern of the film was obtained with the aid of mica mast while the nature of the film contacts was determined using the current - voltage characteristics at room temperature.

Experimental

The mica mask used to generate the required pattern were first cleaned with soap detergent and rinsed in distilled deionized water. The masks were then ultrasonically agitated in successive baths of trichloroethylene, acetone and ethyl alcohol for 20 min each. Similarly, the substrates (microscopic glass slide) were boiled in chromic acid and rinsed in distilled deionized water. This was followed by ultrasonic cleaning as described above. After cleaning, the masks and slides were left to dry. They were then positioned in the chamber of an Edwards model 306 coating unit.

Aluminium films of thickness $1000A^0$ were first evaporated on all the four substrates from a tungsten filament while Germanium films of thickness $500A^0$ and $1000A^0$ were then evaporated on two each of the Aluminium films. Two of the samples, one of Germanium film of thickness $500A^0$ and the other of thickness $1000A^0$ were further enclosed in an annealing chamber and annealed to about $400^{\circ}C$ for 30 min and allowed to cool down gradually for 3 h after the power was switched off. The annealing temperature was determined with the aid of a copper-constantine thermocouple attached to the base of the samples. After annealing, all the samples were further

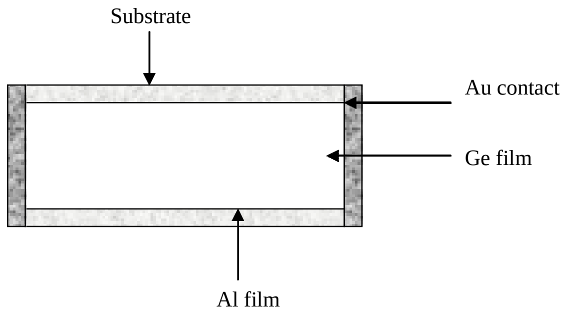

Fig 1. Final configuration of the deposited films.

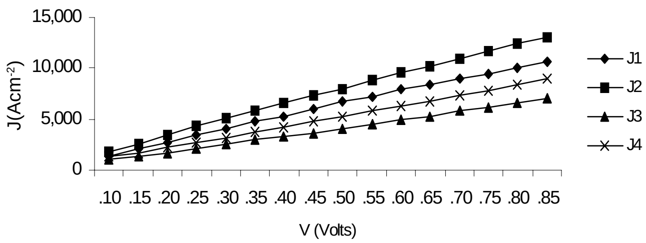

Fig 2. The graph of current density J against voltage V.

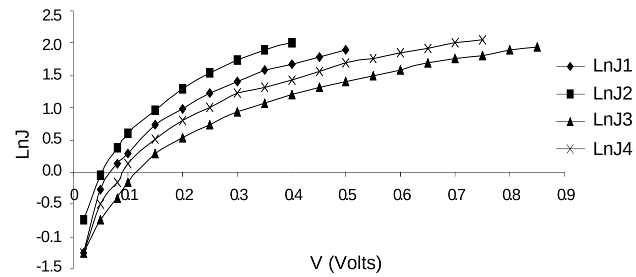

Fig 3. The graph of LnJ against V.

enclosed in the Edward coater and Ohmic contacts of the same dimension were made to both ends of the Al-Ge films with Au into the electrode width making firm contacts to both films at the electrode widths. The deposition was made at a pressure of $5x10^{-5}$ torr while the deposition rate, which was $500A^0$/min was determined by an Edward model FTM3 film thickness monitor. All the evaporants were of 99.99% (Ventron, Germany). The current - voltage characteristics were measured with a digital electrometer (Keithley type160B) and a digital multivoltimeter (Hewlett-Packard type 3465A) at room temperature. The film dimensions were measured using a sensitive travelling microscope. The final configuration of the deposited film is shown in Fig 1.

Results and Discussion

The results of the current density J (mA/cm^2) and voltage V (volts) of both annealed and unannealed samples are shown in Fig 2. The result showed linear current - voltage relationship over the voltage range 0.2 - 0.85V/m and that annealed samples have lower voltage than their unannealed counterparts.

Table 1

Conductance σ ($\Omega^{-1}cm^{-1}$),saturation current density $J_s(Acm^{-1})$ and the barrier height (Volts) of the samples

Sample	Conductance $\sigma(\Omega^{-1}cm^{-1})x10^{-2}$	Saturation current density $J_s(Acm^{-1})$	Barrier heights ϕ_B (Volts)
S_1-500A^0 (Unannealed)	1.35	9.97	5.93
S_2-500A^0 (Annealed)	1.85	3.32	6.22
S_3-1000A^0 (Unannealed)	0.82	6.08	6.06
S_4-1000A^0 (Annealed)	1.05	5.21	6.10

The values of the conductance ($\Omega^{-1}cm^{-1}$), saturation current density (Acm^{-2}) and the barrier heights (volts) of the samples are recorded in Table 1. Annealed samples have higher conductance, barrier heights and lower saturation current density than the unannealed samples. The conductance of the samples is estimated from the current density (J) - voltage (V) plots. Since the samples were found to be symmetrical, the microscopic form of Ohm's law was used to estimate the conductance of the sample (Arthur 1983; Sze 1985). The current density for a finite specimen of conducting material which has total resistance R is given by $J = V/\rho$ where V is the voltage across the specimen and ρ is the resistivity. Replacing the resistivity by its reciprocal, the conductance σ can be obtained (i.e. $\sigma = 1/\rho$). The microscopic form of Ohm's law becomes, $J = V\sigma$. The conductance of the samples is then estimated from the slope of the best line of fit of the current density (J) - voltage (V) plots (Fig 2). The barrier height was calculated using the thermionic emission theory which adequately describes the current (I) - voltage (V) relationship given as:

$J = Js(\exp(qv/kT)-1)$. V is the voltage across the terminals. For negligible series resistance,

$$Js = A^{**}\, T^2 \exp\{\frac{-q\phi_B}{KT}\}$$

Where A^{**} is the effective Richardson constant, ϕ_B is the zero field asymptotic barrier height, k the Boltzmann's constant, T the absolute temperature and q the magnitude of the electronic charge. The LnJ - voltage V plots (Fig 3) give curves which is expected at the region $V < 3kT/q$ for the study. The saturation current density Js is obtained from the extrapolated value 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 electrical properties of Al-Ge thin films were found to change with the annealed samples within the voltage range 0.2 -0.85V/m with linear J - V relationships. The thickness of the films also affected the electrical properties of the films. As the conductance and barrier height of the annealed samples increase, the saturation current density reduces. Since the manufacture and assemblage of electronic and metallurgical devices require reasonable amount of heat, a more conducting junction may be made from the same sample by annealing to a desired temperature. Such diodes may also be obtained by reducing the thickness of the contacts.

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