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# Low resistance ohmic contact to n-GaAs

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## ABSTRACT

In this paper, a technique for obtaining ohmic contact to n-GaAs is discussed. The contact resistance have been measured by plotting the V-I characteristics. For confirming the reliability and reproducibility of the method, A large number of sample were prepared and measurements were conducted. V-I characteristics for the samples were found to be linear and identical, which shows that the method developed is reliable and reproducible. An important factor that is generally recognized is that surface cleanliness is essential for reliable and reproducible ohmic contacts. The obtained specific contact resistance was in close agreement with the methods obtained by others.

## KEYWORDS

Specific contact registers;
Gallium arsenide;
Effective mass;
Blocking characteristics;
Tunneling parameters.

## INTRODUCTION

In recent year Gallium arsenide and related semiconducting compounds have drawn the attention of research workers mainly for two reasons. Firstly, some of their properties allow important improvement on the performance of classical devices: higher mobilities and wider energy gaps. Secondly, some characteristic features of Gallium arsenide and other compounds give rise to new physical phenomena not obtainable from Silicon.

All semiconductor devices need at least one ohmic contact and often the quality of the ohmic contact is one of the most significant factors affecting the performance of III-V semiconductor devices[1]. The electrical properties of ohmic contacts are characterized by specific contact resistance $r_c$(ohm-cm$^2$) defined by

$$r_c = [\partial I / \partial V]_{V=0}^{-1} \qquad (1)$$

or

$$r_c = \lim_{s \to \infty} R_c . s \qquad (2)$$

where $R_c$ is total contact resistance, s is contact area.

Theoretical expression for specific contact resistance was given by Yu[2]. Taking the theoretical I-V characteristics in the thermionic emission, thermionic field emission and field emission regions he has shown that $r_c$ is determine by the following factors.

$$\mathrm{Exp}\frac{\varphi_B}{E_{oo}} \qquad \text{for FE} \qquad (3)$$

$$\mathrm{Exp}\frac{\varphi_B}{E_{oo}}\mathrm{Coth}[E_{oo}/KT] \qquad \text{for TFE} \qquad (4)$$

$$\mathrm{Exp}\frac{\varphi_B}{KT} \qquad \text{for TE} \qquad (5)$$

Where $\varphi_B$ is the barrier height and $E_{oo}$ tunneling parameter defined by

$$E_{oo} = \frac{qh}{2}[ND/m^{*\epsilon}] \qquad (6)$$

Here m* is the effective mass of the tunneling carriers in the semiconductor, ε is the permittivity, NDA the dopant concentration, q the electronic charge, h plank constant, $E_{oo}$ is very useful parameter in predicting the blocking or ohmic characteristics of a metal semiconductor contact. For $KT/E_{oo} > 1$ the thermionic process dominates and the contact behaves as a schotky barrier. For $KT/E_{oo} << 1$, field emission dominates and the contact exhibits ohmic characteristics. In the range where $KT/E_{oo} = 1$ a mixed mode of transport occurs. The functional dependence of the specific contact resistance on semiconductor doping level and barrier height is shown in figure 1

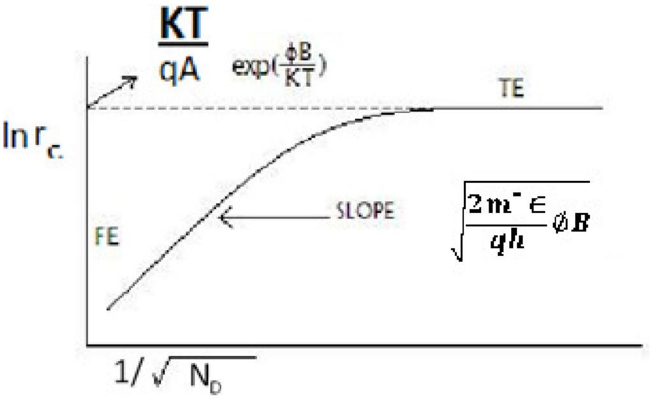

**Figure 1 : Theoretical dependence of the $r_c$ on semiconductor doping level and barrier Ht**

## FORMATION OF OHMIC CONTACTS

The accuracy of the electrical measurements performed for determining the characteristic of an electronic device is highly dependent on the quality of the electrical contact made to the devices. The good ohmic contact is the one which will not alter the semiconductor resistivity or device characteristics[3]. Other features of good ohmic contact are

1. The contact semiconductor interface must be planer.
2. The contact must be solid below 500°C.
3. The contact must be tin free.
4. The contact must have a low specific contact resistance.
5. The contact properties must be reliable, suitable and reproducible.

Formation of ohmic contact to gallium arsenide material is relatively difficult as compared to elemental semiconductors[5]. Major problems encountered in the formation of the ohmic contacts to gallium arsenide are lack of wetting (uniform) of metal to gallium arsenide, metal segregation at the metal semiconductor interface high volatility of arsenide which causes pitting in gallium arsenide at high temperature, poor adhesion of contact metals and brittle nature of gallium arsenide.

## EXPERIMENT

The n-type GaAs wafers were obtained from Atomergic Chemetals New York. First of all, the substrates were boiled in trichloroethane, acetone and methanol for five minutes each and then rinsed in deionised water for several time to ensure through cleaning. In order to ensure the deposition of the film in the purest form, all accessories belonging to the vacuum chamber and the inner surface of the bell jar were throughly cleaned before fixing the heating filament, loading the filament with the material and the placement of the substrate at their respective location in the vacuum chamber. Low tension terminals were treated with sodium hydroxide solution, which was then followed by a rigorous wash in nanopure water, all other metallic parts and the inner surface of the vacuum coating unit were cleaned by acetone only. After the completion of the cleaning processes, the unit was always kept under vacuum in order to avoid contaminations from the atmospheric air.

The vacuum evaporation was carried out in a conventional evaporator capable of producing vacuum of the order of $1 \times 10^6$ torr inside a pyrex bell jar. The evacuation of the unit was started after mounting the gallium arsenide wafer in its position and charging gold-germanium alloy on its source. When the pressure was reduced to $5 \times 10^{-6}$ torr degassing of the system of the source was carried out by raising their temperature by applying the supply voltage to the radiant heater and sources. The system and the source were allowed to cool down to a lower pressure is achieved. This process of alternate heating and cooling was repeated three to four times, to ensure that the system was completely degassed. Finally as the system cooled down and a vacuum better than $5 \times 10^{-6}$ torr was attained, the temperature of the molybdenum boat was increased slowly by increasing the sources supply through an auto transformer till the Au-Ge alloy was started to melt. After the deposition were completed, the system was again allowed to cool down and the sampled was taken out for measurements.

## CONTACT EVALUATION

The electrical quality of ohmic contact is conveniently characterized by in evaluating ohmic contacts on thin epitaxial layer is the separation of the total resistance into spreading contact and residual resistance.

A separation can be achieved when contact resistance of the different diameter is measured and use is made of the dependence of the total resistance on contact diameter.

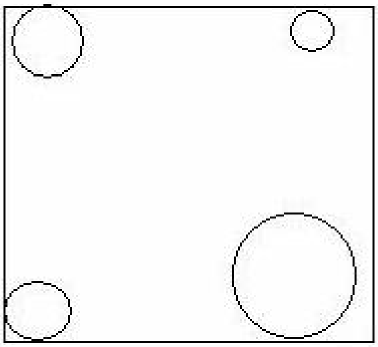

**Figure 2 : Four-dot array for measuring contact resistance**

Let us consider an array of circular contacts like those of figure 2. For a good ohmic contact besides the linearity of the characteristics the contacts should also have low specific contact resistance. The specific contact resistance of an ohmic contact is calculated from the V-I characteristics, if I is the current for the voltage V, the total measured resistance[5] of the sample is

$$\mathbf{R_T = \frac{V}{I}} \qquad (7)$$

Also

$$\mathbf{R_T = R_c + R_s + R_o + R_p} \qquad (8)$$

Where $R_c$ = contact resistance
$R_s$ = spreading resistance
$R_o$ = series resistance of the material and back contact
$R_p$ = probe resistance.

As a gold probe is used for making a pressure contact, it is in order to assume negligible probe resistance. Then equation (8) reduce to

$$\mathbf{R_T = R_c + R_s + R_o} \qquad (9)$$

Spreading resistance can be calculated[4]

$$\mathbf{R_s = \frac{\rho}{2d} B} \qquad (10)$$

Where $\rho$ = the resistivity for the sample used
d = contact diameter
B = a factor which corrects the finite

$$\mathbf{B} = \frac{\mathbf{2}}{\pi}\mathbf{\tan^{-1}\frac{4t}{d}} \qquad (11)$$

Where t = sample thickness

The contact resistance is

$$\mathbf{R_c = \frac{R\ sc}{\pi\left[\frac{d}{2}\right]^2}} \qquad (12)$$

Where $R_{sc}$ = specific contact resistance

Thus, substituting (10) and (12) in (9)

$$\mathbf{R_T = \frac{\rho}{\pi d}\tan^{-1}\frac{4t}{d} + \frac{4Rsc}{\eta d^2} + R_o} \qquad (13)$$

The fabrication of ohmic contact is still more of an art than a science[6] and every laboratory tends to have its own favorite recipes which involves particular method or alloy systems particular deposition methods, and particular form of heat treatment. All the recipes[7] appears to depend on one or other of the three principles.

1. If the semiconductor is one which conforms approximately to the simple Mott theory,it should be possible to create an ohmic contact by finding a metal with a work function of an n-type semiconductor or greater than the work function of a p-type semiconductor. If the inequality is nearly but not quite satisfied, the result should be a rectifying contact with a low barrier height which in practice may serve effectively as an ohmic contact.
2. The vast majority of ohmic contact depends on the principle of having a thin layer of very heavily doped semiconductor immediately adjacent to the metal. The depletion region is then so thin that field emission takes place and the contact has a very low resistance at zero bias.
3. If the surface of the semiconductor is damaged, crystal defects may be formed near the surface which act as an efficient recombination centers. If the density of these is high enough recombination in the depletion region will become the dominant conduction mechanism and will cause a significant decrease in the contact resistance.

## CHARACTERIZATION OF OHMIC CONTACTS

The characterization of the ohmic contacts formed is desired for its quality evaluation. The quality of the contact is estimated mainly from its current voltage characteristics. For measuring these characteristics[8] of these samples, a microprobe is designed. In this, the sample was placed on a brass platform which serves as a base electrode terminal. The electrical connection with the top contact was made with the help of gold probe held in the micromanipulator. The gold probe can be moved in x-y-z directions with the help of screw arrangement which provides the flexibility of making as good electrical contact without damaging the alloyed contact. The entire setup was placed in an electrically shielded metallic box to eliminate the effect of radiation, noise etc. on the measurements.

The basic circuit diagram for the measurement of the current voltage characteristics is shown in figure 3.

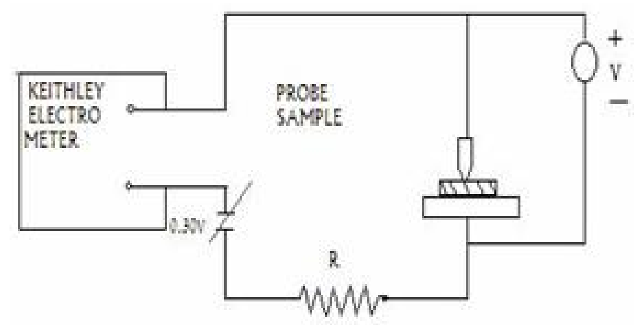

**Figure 3 : Current diagram for evaluating current voltage characteristics of contact**

This set up, current for different voltage across the sample were measured. The voltage-current characteristics of the gallium arsenide wafer having ohmic contacts on the both sides were studied under forward as well as reverse bias condition. A variable dc voltage source was connected across the sample for applying suitable bias voltage. A Keithley electrometer model 610 C was used for measuring the forward and reversed characteristics. The observed result are plotted in figure 4.

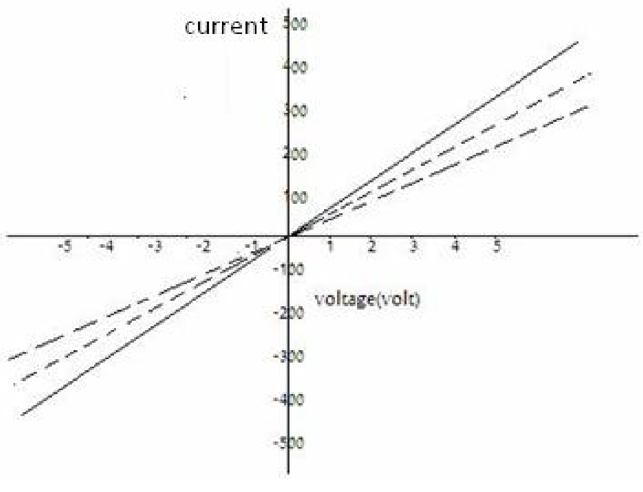

**Figure 4 : Current voltage characteristics of ohmic contact for different contact dia**

It can be seen from this figure that the current increases the linearly with the rise the voltage in both directions. Performance study of ohmic contact to GaAs and other compound semiconductor. The current-voltage characteristics plotted for all samples of different contact areas are linear, which confirms that the contact made by the technique adopted were ohmic.

The specific contact resistance was found of the order of 2 × 10-4 ohm-cm2 which agrees with he specific contact resistance values reported by Cox and Strack[4], A.Y.C. Yu[2], Sinha and Smith[9].

For conforming the reliability and reproducibility of method, large number of sample were prepared and measurements were conducted. V-I characteristics for the samples were found to be linear and identical, which show that the method developed is reliable and reproducible.

## CONCLUSION

Ohmic contacts to n-GaAs have been made and contact resistance found. Furthermore, these contacts have good technological properties which make them suitable for device applications of lasers and Gunn oscillators etc.

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