MEASUREMENT AND ANALYSIS OF I-V-T CHARACTERISTICS OF A AUGENI/P-SI SCHOTTKY BARRIER DIODE

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ABSTRACT

In this work, we report measured forward current voltage characteristics of AuGeNi/p-Si schottky barrier diode in the temperature range of 295-400 °K. Forward current voltage characteristics were investigated. This investigation is based on the analysis of the dependency of extracted parameters such as ideality factor (η), barrier height (ϕ_{B0}) and saturation current (I_0) on temperature. The Richardson coefficient was examined by means of the saturation versus temperature. While η decreases, ØB0 increases with increasing temperature. Obtained Richardson constant value of the A*=11.5 x10-7Acm-2K-2 is very low compared to the standard value. The modified Richardson plot has given mean barrier height $\bar{\phi}_{B0}$ and Richardson constant (A*) as 1.15 eV and 30.53 Am-2K-2, respectively. The temperature dependence of the I–V characteristics of the AuGeNi/p-Si Schottky diode have been successfully explained on the basis of thermionic emission (TE) mechanism with Gaussian distribution of the Schottky barrier heights (SBHs).

KEYWORDS: Schottky contacts, current-voltage-temperature characteristics, Gaussian distribution, Barrier inhomogeneity.

1 INTRODUCTION

The contact between silicon and metal plays an important role in integrated circuit technology. The physics involved in this contact has been interpreted using the Schottky barrier concept. When the doping level in the silicon is low, the Schottky barrier acts as a diode that has a lower turn-on voltage than a p-n junction diode. With this advantage, the Schottky diode has been frequently used in high-speed devices such as those in GaAs [1,2] .The low noise level generated by Schottky diodes makes them especially suitable for uses in microwave receivers,detectors,photo transistors and space solar cells[3,4]. The important aspect of metal-semiconductor junctions is the process, which determines the flow of charge carriers over the barrier from the semiconductor to the metal and vice versa. Detailed knowledge of the conduction process involved is essential to extract barrier parameters, namely barrier height, ideality factor and series resistance.

Analysis of the current-voltage(I-V) characteristics of the Schottky barrier measured only at room temperature does not give detailed information about the conduction process and the nature of barrier formed at the metal semiconductor interface. In fact, it neglects many possible effects that cause non-ideality in the diode I-V characteristics and, in general, reduce the barrier height. The temperature dependence of the I-V characteristics gives a better picture of various conduction mechanisms and on the validity of various processes involved. Moreover, Schottky diodes with low barrier heights have found applications in devices operating at cryogenic temperatures asinfrared detectors and sensors in thermal imaging [5, 6].

The current-voltage (I-V) characteristics of the metal-semiconductor contacts usually deviate from the ideal thermionic emission (TE) current model [2, 6], and the ideality factor should be equal to unity (η=1). However, due to various factors such as device temperature, dopant concentration, device area, density of interface states, structural properties of interface etc., the current-voltage characteristics of Schottky contact exhibit deviations from TE-mechanism with temperature dependent ideality factor [1-3, 9][7].

The analysis of the I-V characteristics of the Schottky contacts based on TE theory usually reveals an abnormal decrease in the BH and increase in the ideality factor with decrease in temperature [1,5,6].

2 EXPERIMENTAL METHOD

The structure AuGeNi/Si is obtained on sample of p-type Si wafer of (100)orientation and 1 – 20Ωcm resistivity which have been subjected to chemical etching.For metal/p type Si Schottky contact, the AuGeNi is deposited by thermal evaporation with diameters of about 1.5 mm on the front surface of the wafer. The ohmic contact is obtained by evaporation of the eutectic AuGeNi. The current-voltage characteristics (I-V) are recorded at different temperatures (295K-400K) on the sample using a Keithley 2400 source-meter.The temperature was adjusted using Janis vpf-475 cryostat (SMU) Keithley 236.

3 RESULTS AND DISCUSSION

Fig.1 shows the experimental typical forward and reverse current–voltage characteristics of AuGeNi/p-Si Schottky diodes in the temperature range of 295–400 K. For Schottky diode, the thermionic emission theory predicts that the current–voltage characteristic is given by [8, 9].

$$\mathbf{I} = \mathbf{I_0}\left[\exp\left(\frac{\mathbf{qV}}{\eta\mathbf{KT}}\right) - \mathbf{1}\right] \quad (1)$$

And

$$\mathbf{I_0} = \mathbf{AA^*T^2}\exp\left(\frac{-\mathbf{q}\varnothing_{\mathbf{B0}}}{\mathbf{KT}}\right) \quad (2)$$

Where I_0 is the saturation current, $\varnothing_{B0}$ is the zero-bias barrier height, A* is the effective Richardson constant, A is the diode area, T is the temperature in Kelvin, K is the Boltzmann's constant, q is the electronic charge and η is the ideality factor which describes the deviation of the practical diodes from the pure thermionic emission theory.

The values of saturation current I_0 and ideality factor η are obtained from the linear portion of ln(I) vs V plot at various temperature. The values of zero-bias barrier height at each temperature are determined from saturation current (I_0) using eq. (2) with A*=32Am-2K-2 for p-type silicon[10, 11] and A is the diode area.

Once I_0 is determined, the zero-bias barrier height ($\varnothing_{B0}$) is obtained by rewriting Eq. (2) as:

$$\varnothing_{B0} = \frac{KT}{q} ln\left(\frac{AA^*T^2}{I_0}\right) \quad (3)$$

From Eq. (1), ideality factor η can be written as:

$$\eta = \frac{q}{KT}\left(\frac{d(V)}{d\ln(I)}\right) \quad (4)$$

Using Eqs. (3) and (4) the values of zero-bias barrier height $\varnothing_{B0}$ and the ideality factor η of the diode at different temperatures are calculated and are plotted as a function of temperature (Fig. 2). The ideality factor has been found to increase, while the zero-bias barrier height $\varnothing_{B0}$ decrease with decreasing temperature, as seen from these values are given in Table 1. As can be seen in Fig.2, the experimental value of $\varnothing_{B0}$ decreased with decrease in temperature.

For the evaluation of barrier height, one may also make use of the Richardson plot of the saturation current, equation (3) can be rewritten as:

$$ln\left(\frac{I_0}{T^2}\right) = \ln(AA^*) - \frac{q\varnothing_{B0}}{KT} \quad (5)$$

As shown in Fig. 3 the temperature dependence of ln(I_0/T2) versus 1/T is found to be linear in temperature range of 295-400K.

The value of A* obtained from the intercept of the linear portion of the ordinate is A*=11.5 x10-7Acm-2K-2, which is much lower than the known value of A*=32Am-2K-2, barrier height value of 0,135 eV is obtained from the slope of the straight line.

The deviation of the Richardson plots may be due to the spatially inhomogeneous barrier heights and potential fluctuations at the interface that consists of low and high barrier areas.

The obtained value of A* is low since it is calculated from the temperature-dependent I–V characteristics which may be affected by lateral inhomogeneity of the barrier. A* is also different from the theoretical. [6, 12, 13, 14, 15].

These results confirm that the predominant current transport is not only the TE in our sample; rather, there are also Gaussian distributions barrier heights in the constant area.

The Gaussian distribution of the BHs is given by the following expression [8, 12, 13, 15].

$$\varnothing_{ap} = \bar{\varnothing}_{B0}(T = 0) - \frac{q\sigma_0^2}{2KT} \quad (6)$$

Table 1 : The experimental parameters obtained for AuGeNi/p-Si in the temperature range 295–400K

T (K)	I_0 (A)	η	$\varnothing_{B0}$ (eV)
295	2,78E-05	2,00965	0,55611
320	4,23E-05	1,78508	0,59615
340	5,77E-05	1,56802	0,62786
360	9,23E-05	1,49605	0,65377
380	9,80E-05	1,27016	0,69167
400	1,47E-04	1,12833	0,71745

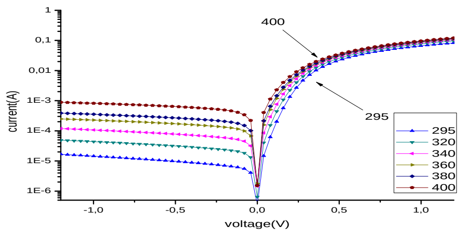

Figure 1: Experimentally Current-Voltage characteristics of the AuGeNi/p-Si Schottky barrier diode at various temperatures.

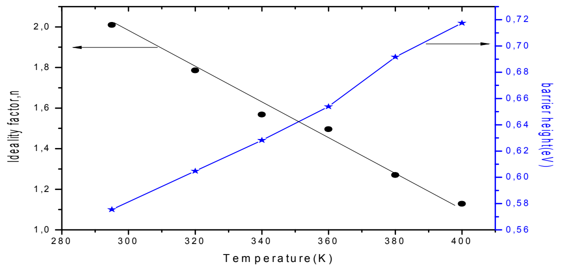

Figure 2: Temperature dependence diode in the temperature range 295–400K of the ideality factor and zero-bias barrier height for AuGeNi/p-Si Schottky.

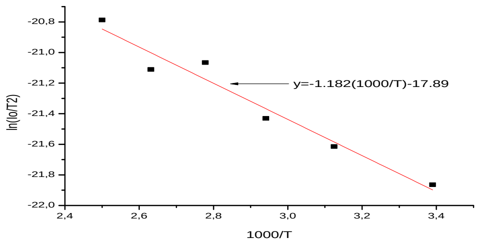

Figure 3: Plot of ln(I_0/T^2)vs 1000/T of AuGeNi/p-Si Schottky Diode

Where $\bar{\phi}_{B0}$ and σ_0 are the zero-bias mean barrier height and zero-bias standard deviation.

The temperature dependence of σ_0 is usually smalland can be neglected. The observed variation of ideality factor with temperature is given by[12].

$$\left(\frac{1}{n_{ap}}-1\right)=-\rho_2+\frac{q\rho_3}{2KT} \quad (7)$$

Where η_{ap} is apparent ideality factor and the coefficients ρ_2 and ρ_3 quantify the voltage deformation of the BH distribution.

However, it is assumed that the standard deviation σ and the mean value of the SBH $\bar{\phi}_{B0}$ are linearly dependent on Gaussian parameters, given by $\phi_{ap}=\bar{\phi}_{B0}+\rho_2 V$ and $\sigma_s=\sigma_0+\rho_3$ V, where ρ_2 and ρ_3 are the voltage coefficients that may depend on temperature (T) and quantify the voltage deformation of the BH distribution[3, 12, 16]. It is evident that the decrease of zero-bias BH caused by the existence of the Gaussian distribution and the extent of influence determined by the standard deviation itself.

The plot of ϕ_{ap} versus 1/T (Fig. 4) should be straight line with the intercept at the ordinate determining the zero-bias mean BH ($\bar{\phi}_{B0}$) and a slope giving the standard deviationσ_0. According to Fig.4, the value of $\bar{\phi}_{B0}$ = 1.16 eV and σ_0 = 176 mV are obtained from the ϕ_{ap}versus 1/T plot and in the Fig 5, the plot of 'ηap' versus 1/T must be a straight line that gives voltage coefficients ρ2 and ρ3 from the intercept and slope of the curve respectively. The values of ρ_2 =- 0.89V and ρ_3 = -0.073 V are obtained from the η versus 1/T plot.

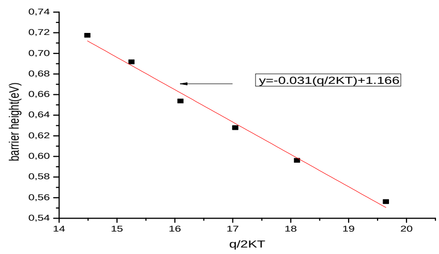

Figure 4: Zero-bias barrier height ϕ_{ap} versus 1/(2kT) curve of the AuGeNi/p-Si Schottky diode.

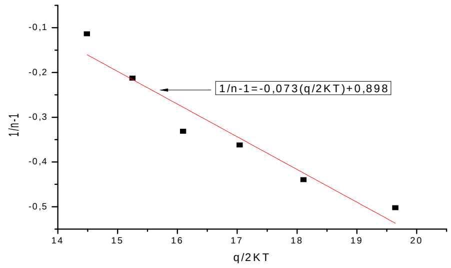

Figure 5: Temperature dependence of the ideality factor 'ηap' for AuGeNi/p-Si Schottky diode.

The predictable Richardson plot is now modified by combining Eqs. (2) and (6) as:

$$ln\left(\frac{I_0}{T^2}\right)-\left(\frac{q^2\sigma_0^2}{2K^2T^2}\right)=\ln(AA^*)-\frac{q\bar{\phi}_{B0}}{KT} \quad (8)$$

A modified ln($\frac{I_0}{T^2}$)–($q^2\sigma_0^2$ /$2K^2T^2$) versus 1/T plot according to Eq. (8) should give a straight line with the slope directly yielding the mean $\bar{\phi}_{B0}$ and the intercept$(=\ln(AA^*))$at the ordinate determining A^* for a given diode area A. As shown in Fig. 6, the modified Richardson plot of ln($\frac{I_0}{T^2}$)–($q^2\sigma_0^2$ / $2K^2T^2$) versus 1/T gives A^* =30,53 Acm-2K-2 and $\bar{\phi}_{B0}$=1.15 eV respectively, without using the temperature coefficient of the flat-band BH. The value $\bar{\phi}_{B0}$=1.15 eV is obtained from ln($\frac{I_0}{T^2}$) –($q^2\sigma_0^2$ / $2K^2T^2$) versus 1/T plot. This value is close to the value $\overline{\phi}_{B0}$=1.16 eV obtained from the ϕ_{ap} versus 1/T (Fig. 4).

Also, the value of the modified Richardson constant is A*=30.53Am-2K-2, which is close to the theoretical value $A^*=32Am^{-2}K^{-2}$.

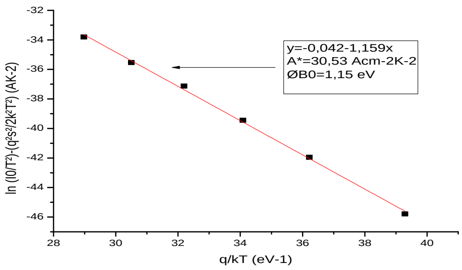

Figure 6: Modified Richardson ln($\frac{I_0}{T^2}$)–($q^2\sigma_0^2$ / $2K^2T^2$) versus (1/T) plot for AuGeNi/p-Si Schottky diode.

4 CONCLUSIONS

The current–voltage (I–V) characteristics of AuGeNi/p-Si Schottky barrier diodes have been made in the temperature range of 295–400K. It is found that the I–V barrier heights increases in the range with the ideality factor decreasing with increasing temperature.

The origin and nature of the decrease in the ideality factor and increase in the barrier height with increase in temperature in AuGeNi/p-Si Schottky diodes have been successfully explained on the basis of the thermionic emission with Gaussian distribution of the barrier heights. This behavior is attributed to spatial variations of the BHs.

The Richardson plot (ln (I0/T2) versus (1/T)) yielded a straight line with an effective BH value of 0.101 eV. The modified ln(I0/T2)-(q2σ02/2K2T2) versus (1/T) plots yielded zero-bias mean BH value of 1.15 eV and Richardson constant as 30.53 Am-2K-2for AuGeNi/p-Si is obtained considering Gaussian distribution of the barrier height, which is close to theoretical value of 32 Am-2K-2for P-Si.

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