March 2010 ISSN : 0974 - 7486 Volume 6 Issue 1

Materials Science

Trade Science Inc.

An Indian Journal

Full Paper

MSAIJ, 6(1), 2010 [37-40]

Electrical properties of Au /n -Si, Au/n-GaAs, Au/n-InP schottky diodes

R.K.Singh

Department of Electronics Engineering, KNIT Sultanpur (U.P.-228118), (INDIA)

Received: 2nd December, 2009 ; Accepted: 12th December, 2009

ABSTRACT

The schottky barrier diode fabricated by vaccum deposition of Au on n-Si (bulk), n-GaAS (L.P.E,), & n-InP (bulk) have been studied for their device performance by means of I-V & C-V measurements. Aluminum was used to make ohmic contacts on n-Si & Gold Indium alloy was used to make ohmic contacts on n-GaAs & InP. Electrical properties such as donar concentration N_d, barrier high (ΦB), Depletion width (W) have been calculated. In Particular, method of improving the performance of Au/n-InP had been discussed & its ideality factor (η) was reported.

INTRODUCTION

The Quality of contact dictated by the semiconductor surface features, controls the electronic flow throw metal-semiconductor devices . the epitaxial schottky barrier diodes were studied in great detailed by Scrafetter[1]. According to Padovam[2], it was clear that the influence of the traps can not be neglected in schottky barrier diodes as this is one of the man source of discrepancy between theory & experimental results. Good ohmic contacts were found by alloying Au, Sb,on n-Si. Metals investigated to form rectifying contact on N-Si, where Au, Ag, Cu, Ni, Pb, & Al[3]. As reported by Sinha et al[4]. Ti /N -GaAs diodes show near ideal characteristics with a barrier high (ΦB)=0.84 eV. The injection of minority carriers in high resistivity Ge can effect the I-V characteristics in such a way that the value of diode ideality factor (η) is increased significantly. Investigations on InP schottky diodes have been carried out by Wada et-al[5]. Low resistance ohmic contacts to n & P- InP were reported by E.Kupal[6] & C.L.Cheng et-al[7].

The measure problems with the groove IIIV compound semiconductors like GaAs, InP, etc is that when the materials are suitably heated there would be less component of As, &P In GaAs & InP respectively. According to T.Sebestyen et al[8]. Very shot alloying temperature cycle use to get best ohmic contacts.

A comparative study of various metal semiconductors diode: Au/n-Si,Au/nGaAs & Au/n-InP has been made.

EXPERIMENTAL

All the three schottky diode structure were fabricated by vaccume evaporation techniques. The substrate temperature was kept at 120^0C under bell-jaar pressure of $1*10^{-6}$ tor. Semiconductor wafers were boiled in trichloroethylene, acetone & methanol separately for five minutes, then rinsed in deionised water & cleaned thoroughly ultrasonically. Prior to evaporation all materials were properly degassed in vacuum & various layers were then deposited on them using suitably built Molybdenum boats. Aluminum & Gold-Indium Alloy were used for ohmic contacts, Gold (purity 99.999%) was used for obtaining rectifying contacts & nSi, & InP were used as semiconductor components of the diodes.

The Growth rate & thickness of the films were dully monitored to about 5 A^0 per second. & 0.6 to 0.8 micron respectively. To improve the reproducibility contact probability the completed schottky diodes were alloyed in tubular furnace with to Nitrogen gas at 450^0C for about 15 minutes. I-V measurements had been carried out using a precise voltmeter & solid state electrometer (model 610C, KEITHLEY INSTRUMENTS Inc; OHIO).boolton Direct capacitance bridge, (Model 75C-S23), was used for C-V Measurements.

RESULTS AND DISCUSSIONS

I-V Characteristics

Several authors[9,10] reported departures from the simple diode theory for the I-V characteristics of a metal-semiconductor contact. In the present case, the contacts formed by Aluminum on n-Si and gold-indium alloy on- nGaAs, n-InP were ohmic which have been observed by measurements of the I-V characteristics and C-V measurements.

Figure 1-3 shows the typical I-V characteristics of these samples measured at room temperature. On comparing the I-V characteristics of Au/n-Si shown in Figure l, with that of a conventional Si diode (By 127), it was clear that the diode has a larger leakage current and low built-in potential. Analyzing these results, it is likely that there might have been the formation of an oxide layer on the surface on Si prior to Au evaporation and therefore the device may in effect be a MIS structure rather that a metal-semiconductor diode.

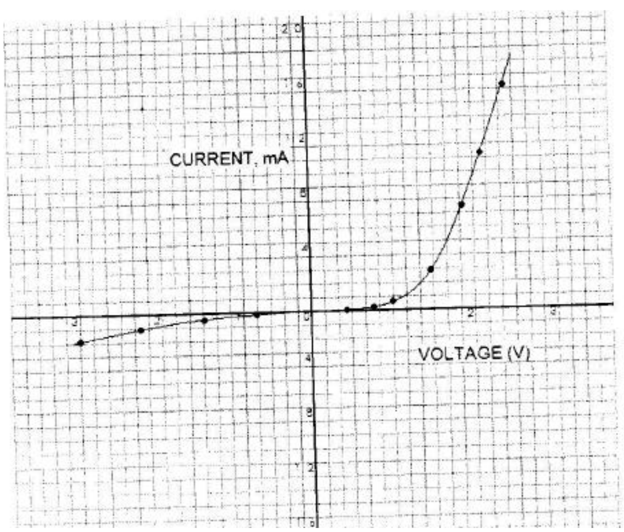

Figure 1 : I-V Characteristics of Au/n-Si schottky diode.

Figure 2 shows the result obtained from the I-V experiments on Au/ n- GaAs schottky diode.

This diode has a leakage current of 10µA for a reverse voltage of 7V. With an acceptable forward

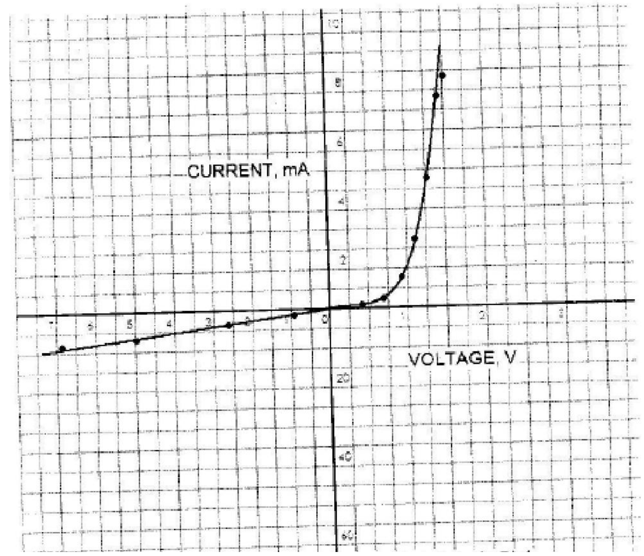

Figure 2 : I-V Characteristics of Au/n-GaAs schoottky diode.

characteristics.

It was observed that Au/n-InP,schottky diode had a large lekage current at a reverse voltage of 5V.with negligible built in potential. Such diodes are therefore less useful. to improve the performance of diodes they were subjected to the process of oxidation & subsequent removal of the oxide. I-V characteristics of these diode are shown in figure 3, which shows a reverse leakage current of 6µA for a reverse voltage of 5V & barrier high since to be highly improved.

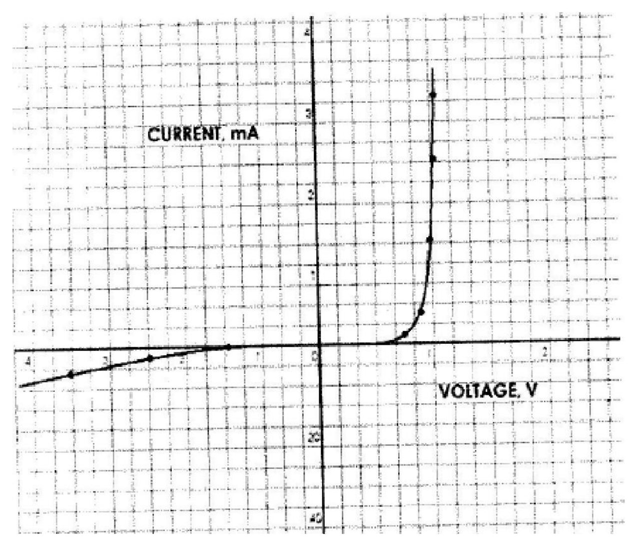

Figure 3 : I-V Characteristics of Au/n-InP schottky diode.

C-V Measurrements

These C-V measurements of Au/n-Si Schottky diode was shown in figure 4. These slop ‘S’ is given by S.M.Sze[11].

$$S = 2/A^2\epsilon_0\epsilon_r qN_d \quad (1)$$

With $S = 5*10^{19} V^{-1} F^{-2}$ Area of contact
$A = 5.57810^{-4} Cm^2$
Permittivity of free space $\epsilon_0 = 8.85*10^{-14}$ F/Cm
Relative Dielectric constant ϵ_r for Si = 11.8.

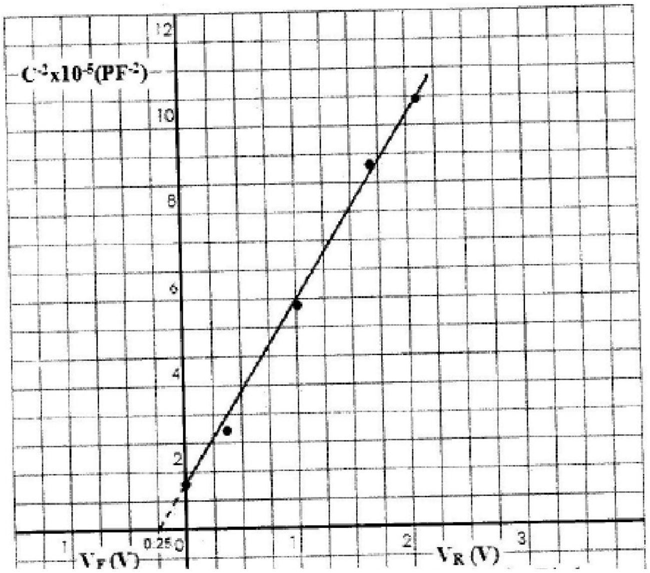

Figure 4 : C-V Characteristics of Au/n-Si schottky diode.

The equation 1 gives $N_d = 7.7*10^{17}$ Cm^{-3}. Knowing the contact potential Vbi, The barrier height Φ_b can be determine using

$$\Phi_b = V_{bi} + V_n \quad (2)$$

Where $V_n = E_c - E_f$
Which in turn can be determine from

$$N = N_d = 4v2/hq(m_n^*KT)^{3/2} \exp[-(Ec-Ef)/KT] \quad (3)$$

Where K = Voltzman constant
H = Planks constant
T = Absolute temperature
m_n^* = Effective mass of an electron
E_c = Energy at the bottom of conduction band
E_f = Fermy level energy.
The contact potential as obtained from equation (3) was 0.38 eV.Then from equation (2) Φ_b = 0.63eV. The depletion width Wis worked out to

$$W = [2\epsilon_0 \epsilon_r (V_{bi} - V)/qN_d]^{1/2} \quad (4)$$

Where V represents applied potential.

The C-V characteristics obtained for Au/n-GaAs schottky diodes are shown in figure 5

Which gives a contact potential of V_{bi} = 0.4V. Using equation 1 to 4 and substituting $S = 0.48*10^{20} V^{-1} F^{-2}$, $A = 1.97*10^{-2} Cm^2$ and ϵ_r = 13.1 for GaAs, the value were calculated to be $N_d = 5.7*10^{14} Cm^{-3}$, $\Phi_{b=}$ 0.83eV and W = 10μm.

Figure 6 shows the C-V chracertiscs of Au/n-InP schottky diodes. The slop of straight line 'S' is $1.6*10^{19} V^{-1} F^{-2}$ And V_{bi} = 0.6V. Substituting these val-

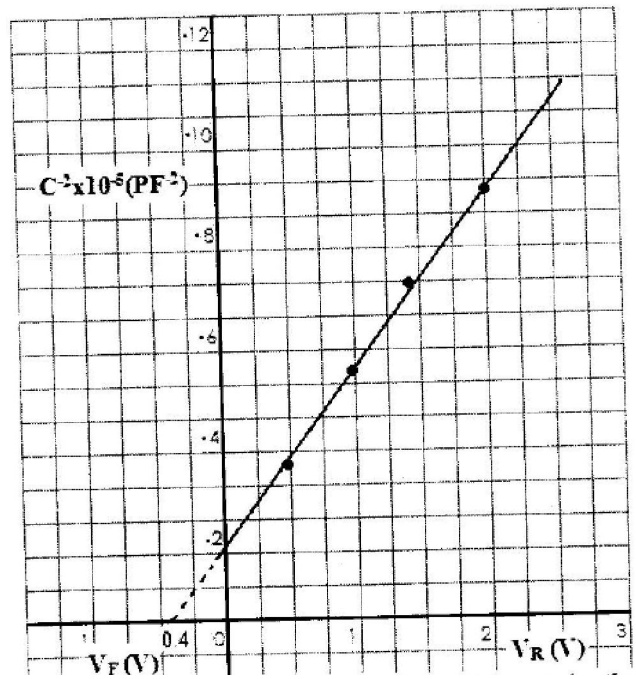

Figure 5 : C-V Characteristics of Au/n-GaAs schottky diode.

ues and $A = 2*10^{-3} Cm^2$ in equation 1, we get the value of $N_d = 1.7*10^{-17} Cm^{-3}$. Using equation 4 the value of 'W' was calculated to be equal to $6.9*10^{-2}$ μm. Finally using equation 2 the value of Φ_b was found to be 0.83eV.

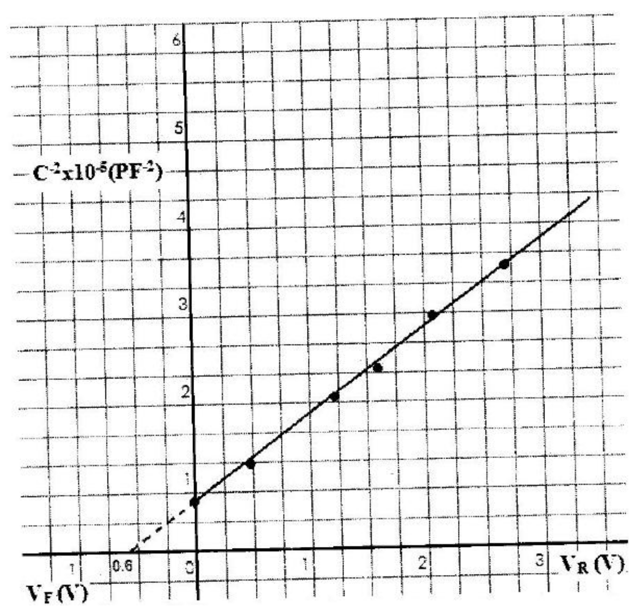

Figure 6 : C-V Characteristics of Au/n-InP schottky diode.

Ideality factor (η) for Au/n-InP schottky diodes

The value of Au/n-InP diode ideality factor (η) can be calculated using the log I_f-V_f graph shown in figure 7 & then equation

H (q/KT)(dV^f by/dln I_f) = 0.1066 then from equation 5, ideality factor(η) = 1.78

The difficulty of making low leakage of schottky barriers ton-InP arises from low metal- semiconductor barrier heights Φ_b Kim et al[12] investigated Au, Al & Au /Ti on each InP surfaces & found barrier height values in the range 0.4 to 0.54eV as reported by Wada & meager field in[13] Au schottky barrier, Au schottky barrier in corporating & interfacial native oxide has been formed & InP. Depending on the oxide thickness & annealing condition, these diode exhibited high barrier height Φ_b >0.75eV, ideality factor & as low as 1.04 & very low saturation current density i.e.< 10^{-7}A/cm^2. From the present work we have found Φ_b = 0.83eV, η = 1.78 & low leakage current density of $1.48*10^{-7}$A/cm^2. The result obtain from the = author's experiments were better to the result obtain by Wada & meajerfiild[13]. They have basically grown an interfacial oxide on n InP prior to the formation of rectifying contacts. Thus the resulting device is basically a MIS structure. It is to be realized here that the oxide layer grown on the n InP surface would create an Interface between an InP surface & oxide layer. Moreover there would be a lattice mismatch between native oxide & surface of n InP . it is quit possible that it may even crate traps in the structure & thereby deteriorates the characteristics of the device.

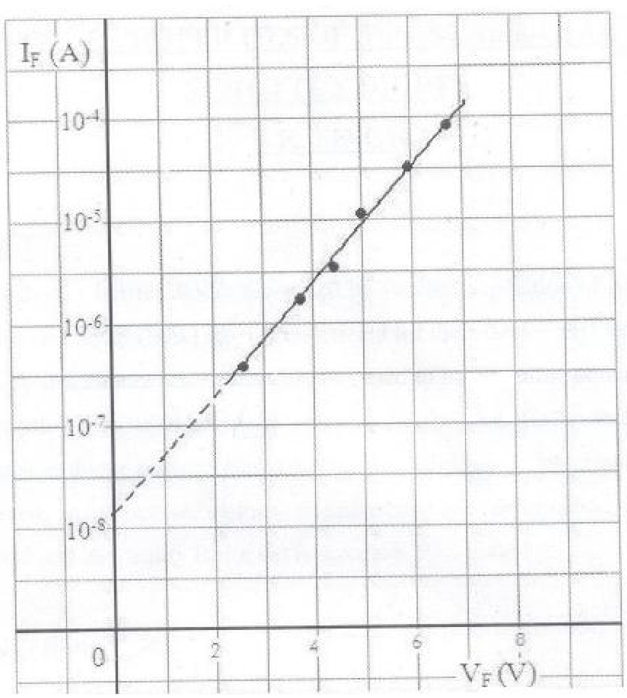

Figure 7 : Log I_F–V_F Characteristics of Au/n-InP schottky diode.

CONCLUSIONS

Inspecting the results obtained from Au/n-Si schottky diode it appears that there might have been the formation of an oxide layer of considerable thickness formed on the surface of Si prior to Au evaporation & therefore the device may be a MIS structure rather than a metal-semiconductor diode. The problem of making metal- semiconductor contact on Si was taken as a practical exercise & therefore no further efforts were put to improve their characteristics. Au/n-Si. Some of the problems associated with MIS structure have been discussed earlier. But Au/n-InP schottky diode is fabricated without a native oxide as the interfacial layer between the InP surface & Au layer & therefore the resulting structure is indeed a true metal-semiconductor diode. Hence, it is but natural to expect good device performance from such diodes.

REFERENCES

[1] D.L.Scharfetter; Solid State Electronics, **8**, 299-311 **(1965)**.
[2] F.A.Padovan; Solid State Electronics, **11**, 291-300 **(1968)**.
[3] M.J.Turner, E.H.Rhoderick; Solid State Electronics, **19**, 489-492 **(1976)**.
[4] A.K.Sinha, T.E.Smith, M.H.Read, J.M.Poate; Solid State Electronics, **(1976)**.
[5] O.Wada, A.Majarfield, P.N.Robson; Solid State Electronics, **25**, 381-387 **(1982)**.
[6] E.Kupal; Solid State Electronics, **24**, 68-78 **(1981)**.
[7] C.L.Cheng, L.A.Coldren, B.I.Miller, J.A.Rentschler; Electronics Letters, **18**, 755-756 **(1982)**.
[8] T.Sebestyen, H.Hartnagel, L.H.Herron; Electronics Letters, **10**, 372-373 **(1974)**.
[9] H.C.Card; Solid State Electronics, **18**, 881-883 **(1975)**.
[10] J.D.Levine; Journal of Applied Physics, **42**, 39991-39995 **(1971)**.
[11] S.M.Sze; 'Physics of Semiconductor Devices' Second Edition, (New Delhi; Wiely Eastern Limited), **(1981)**.
[12] H.B.Kim, A.F.Lovas, G.Sweene, T.M.S.Heng; Proceeding of the Sixth International Symposium on GaAs & Related Compounds, St. Louis, 145-153 **(1976)**.
[13] O.Wada, A.Majarfield, P.N.Robson; Electronics Letters, **14**, 125-126 **(1978)**.