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Temperature Dependence Of Current-Voltage Characteristics Of Pt / InN Schottky Barrier Diodes

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Abstract. The Current-Voltage (IV) measurements on Pt / InN Schottky barrier diodes in the temperature range 10 - 280 K were done. It was found that the contact was Schottky up to 280 K, becoming irreversible ohmic for higher temperatures. The ideality factor, the saturation current and the apparent barrier height were calculated by using the thermionic emission (TE) theory. The ideality factor is temperature dependent, while the saturation current and the barrier height are not. The non conventional Richardson plot exhibits good linearity, corresponding to an activation energy of 2.08 eV and a Richardson constant of 18.7 A m⁻² K⁻². The Cheung’s method to estimate the value of a possible series resistance $R_S$ yields a negligible resistance. From reverse-bias IV analysis, it is found that the experimental carrier density ($N_D$) value increases with temperature.

Keywords: InN, Schottky contact, Pt contact, temperature dependence, IV, IVT, Richardson constant, electron affinity, carrier density,

PACS: 72.15 Eb, 72.80 Ey, 73.40 Sx, 73.61 Ey

INTRODUCTION

In this paper we continue a former work about Schottky contacts on InN [1]. Herein, we report the temperature-dependence Current-Voltage (IVT) of Pt Schottky contact on InN using thermionic emission theory.

FORWARD BIAS ANALYSIS

The measurements were done from 10 K to 290 K, with steps of 10 K. The Pt Schottky contact became irreversible ohmic at 290 K.

A negligible internal resistance in the order of $10^{-3}$ Ω was found using the method of Cheung [2] et al and was totally discarded.

The forward bias current in a Schottky contact is modeled [3] according to

$$I = I_S \left[ \exp \left( \frac{qV}{nkT} \right) - 1 \right].$$

(1)

The ideality factor $n$ was also found using the method of Cheung [2] et al and the thermionic emission theory. As it is shown in Fig. 1, $n$ followed the $T_0$ effect [4]

$$n(T) = n_0 + T_0/T$$

(2)

where $n_0$ and $T_0$ are constants with values 1.335 and 1450.16, respectively.

The expression for the saturation current $I_S$ is [3]

$$I_S = A A^* T^2 \exp(-q\phi_0/kT)$$

(3)

where $A$ is the Schottky area (in this case 0.8 mm²), $A^*$ the Richardson constant and $\phi_0$ the barrier height. This expression can be used to determine $\phi_0$ if $A^*$ is
known. To our knowledge, there is no value for $A^{**}$ in the literature. Nevertheless, Eq. (3) can be rewritten as

$$\ln(I_S/T^2) = \ln(AA^{**}) - q\phi_B/kT$$

(4)

and $\phi_B$ and $A^{**}$ can be determined by a linear fitting, in case the relation is linear. In Fig. 2, the variation of $\ln(I_S/T^2)$ against $10^3/T$ and $10^3/(nT)$ are shown. The dependence of $\ln(I_S/T^2)$ versus $10^3/T$ is found to be non-linear; however, the dependence of $\ln(I_S/T^2)$ versus $10^3/(nT)$ gives a straight line.

![Fig. 2. Richardson plot of $\ln(I_S/T^2)$ versus $10^3/(T)$ and $10^3/(nT)$.](image)

The non-linearity of the conventional Richardson plot is caused by the temperature dependence of the ideality factor. Similar results have also been reported by other authors [5]. Linearly fitting $\ln(I_S/T^2)$ versus $10^3/(nT)$, gives $18.7$ A m$^{-2}$ K$^{-2}$ and $2.08$ eV for $A^{**}$ and $\phi_B$, respectively. Using the model for the Schottky barrier [3], one can write

$$\phi_B = \phi_m - \chi$$

(5)

where $\phi_m$ and $\chi$ are the metal work function and the electron affinity for InN. To our knowledge, nobody has reported $\chi$ for InN. Nevertheless, Neff [6] et al. assumed a value of $4.25$ eV in order to simulate their solar cells. And values for GaN and BN are 4.1 and 4.5 eV at 300 K [7]. Using the value [3] of $\phi_m = 5.65$ eV for Pt and $\chi$ between 4.1 and 4.5 eV for InN, one obtains $\phi_B$ between 1.15 and 1.55 eV, in reasonable agreement with our value. On the other hand, if our $\phi_B$ is correct, $\chi$ for InN should be 3.57 eV.

Regarding $A^{**}$, no value has been found in the literature. But Tan [8] et al. and Ali [9] et al. reported values of 13 and 26 A m$^{-2}$ K$^{-2}$ for $A^{**}$ on their Pt Schottky contacts on p- and n-type GaN, respectively. Our value is between them.

**REVERSE BIAS ANALYSIS**

A reverse bias analysis yields the donor concentration [3]. It is shown in Fig. 3. We use a value of $1.35 \times 10^{10}$ F/m for $\varepsilon_S$ [7].

![Fig. 3. Donor concentration $N_D$ as function of temperature.](image)

**CONCLUSIONS**

The IVT technique has been applied to Pt / InN Schottky contacts. The ideality factor shows the $T_0$ effect. The Richardson plot of $\ln(I_S/T^2)$ versus $10^3/(T)$ is not linear, due to the temperature dependence of the ideality factor. Removing this temperature dependence by plotting $\ln(I_S/T^2)$ versus $10^3/(nT)$ yields a Richardson constant of $18.7$ A m$^{-2}$ K$^{-2}$ and a barrier height of $2.08$ eV. Using the metal work function of $5.65$ eV for Pt, yields an electron affinity of $3.57$ eV for InN. To our knowledge, this is the first time the Richardson constant and the electron affinity for InN are reported. The reverse bias analysis yields a temperature dependent donor concentration.

**REFERENCES**