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Ti/Pt SCHOTTKY CONTACT MEASUREMENTS FOR HEMT GATE METALLIZATION USING CURRENT-VOLTAGE METHOD

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ABSTRACT

A study of Schottky contact from Ti/Pt metal stack on Si-doped AlGaAs HEMT supply layer using current-voltage method is presented here. The Schottky barrier heights at metal-semiconductor junction were determined on two samples prepared by MBE. From plots of natural logarithm of current density versus voltage sweep, the values of current density at zero voltage were extrapolated, hence enabling the calculation of schottky barrier values. The effect of thermal annealing on Schottky barrier height for each sample were also discussed here. From this experiment, Schottky barrier heights with values for 0.65 eV has been successfully obtained from the metal-semiconductor interface.

INTRODUCTION

In the fabrication of High Electron Mobility Transistor (HEMT) devices, the gate structure is commonly placed within a recessed area to allow for a Schottky contact between the gate and the HEMT layers. In this configuration of the HEMT gate, Schottky contact allows fast switching time for the HEMT device to operate at microwave and millimeter-wave frequency range [1-3]. When a metal is placed in close contact with a moderate doped (~$10^{17}cm^{-3}$) wide-band-gap semiconductor, the resulting junction is rectifying which means it is essentially a diode contact. Therefore, in this paper we report our measurement results for Ti/Pt Schottky metal contact deposited on the supply of AlGaAs layer. The results obtained is comparable to the other research work done using Ti/Au metal contact [4].

THEORY

It is a common method to measure Schottky barrier heights of metal semiconductor contact as reported in various publications [1,4,5]. The determination is based on the relationship between current density and voltage bias to the structure consisted of metal-semiconductor contact. The current density in the forward direction of a metal-semiconductor junction may be expressed as:

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$$J = A^{**}T^2\left[\exp\left(-\frac{q\phi_b}{kT}\right)\right].\left[\exp\left(\frac{qV}{nkT}\right)\right] \quad \text{(Eq. 1)}$$

$$= J_S.\left[\exp\left(\frac{qV}{nkT}\right)\right] \quad \text{(Eq. 2)}$$

where;

$$J_S = A^{**}T^2\left[\exp\left(-\frac{q\phi_b}{kT}\right)\right] \quad \text{(Eq. 3)}$$

A^{**} is the Richardson constant (= 1.20173×10^6 A.m^{-2}.K^{-2})
T is temperature (in K)
n is the ideality factor (=1 for an ideal Schottky barrier diode)
q is electric charge (= 1.6×10^{-19} C)
k is Boltzman constant (=8.6×10^{-5} eV/K = 1.38×10^{-23} Joule/K)
ϕ_b is Schottky barrier height (eV)

From Eq. 2,

$$\ln(J) = \ln(J_s) + (q/nkT).V \quad \text{(Eq. 4)}$$

By plotting graph of $\ln(J)$ vs. V, we can determine the value of interception at V = 0V, which is equivalent to $\ln(J_s)$. Subsequently, the value of J_s can be determined. However, this interception values must be extrapolated from the curve because for sufficiently small current, the linear relationship does not hold [1]. Taking into account this value, the Schottky barrier height, ϕ_b, can then be calculated as follows:
From Eq. 3,

$$\phi_b = \ln\left(\frac{A^{**}T^2}{J_S}\right).\frac{kT}{q} \quad \text{(Eq. 5)}$$

EXPERIMENTAL METHODS

For measurement, Figure 1 shows the cross-sectional diagram of the samples and measurement setup that were used in this experiment. Titanium and platinum were deposited within a contact pad area on top of the samples while platinum deposited at the back of samples acts as a grounding contact. The samples were prepared with Si-doped AlGaAs HEMT supply layer using MBE for a concentration region of 10^{17} cm^{-3}. Meanwhile, Figure 2 shows the top view of the Schottky contact pads, with contact areas of 400μm x 100μm.
For current-voltage (I-V) characterization, voltage was biased from 0 to 10 V. This was carried out for were two various samples denoted with 030704_#3 and 030804_#6. The

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surface contact area, S of the schottky contact is calculated at $4x10^{-8}$ m^2 (from 100 µm x 400 µm pad structure). For comparison, the I-V measurements were taken twice that is before and after thermal annealing at 300 °C for 30s.

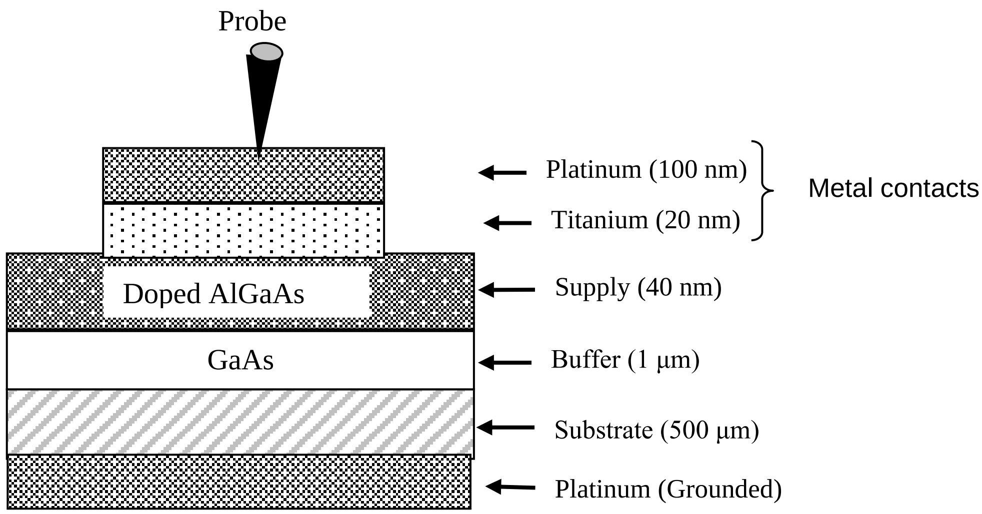

Figure 1: Sample cross-sectional view showing layer compositions and I-V measurement setup

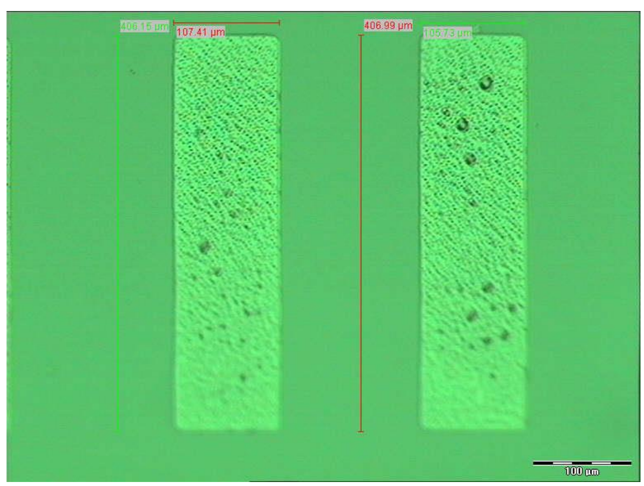

Figure 2: Image of top view for Schottky contact area pads

RESULTS AND DISCUSSION

From the measurement, it was obtained a relationship between current density and voltage as shown in Figure 3 and 4. These figures were used to determine extrapolated

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value of current density. The Schottky barrier heights, $\phi_{b,}$ for Ti/Pt deposited on the AlGaAs supply layer were then calculated using equation, Eq. 5. From the metal contact was found to be 0.65 eV. This result is comparable to the research work done by other researchers for Ti/Au metal contact [4] which obtained for 0.621 eV. For a thermal annealing introduced to the samples at 300 °C for 30 s, the results are tabulated in Table 1. From the tables, it is shown that Schottky barrier height is considerably consistent for different sample by given the standard deviation of 5 %. Slightly different in values between two different samples is assumed due to slightly different condition during preparation such of surface layer of supply before metallization. From Figure 3, the curve shifts to upper position after annealing process, meanwhile in Figure 4, the curve shifts to lower position. Nevertheless, the slope of curve across to y axis are considerably consistent. This consistency leads to unchange value of Schotkky barrier height.

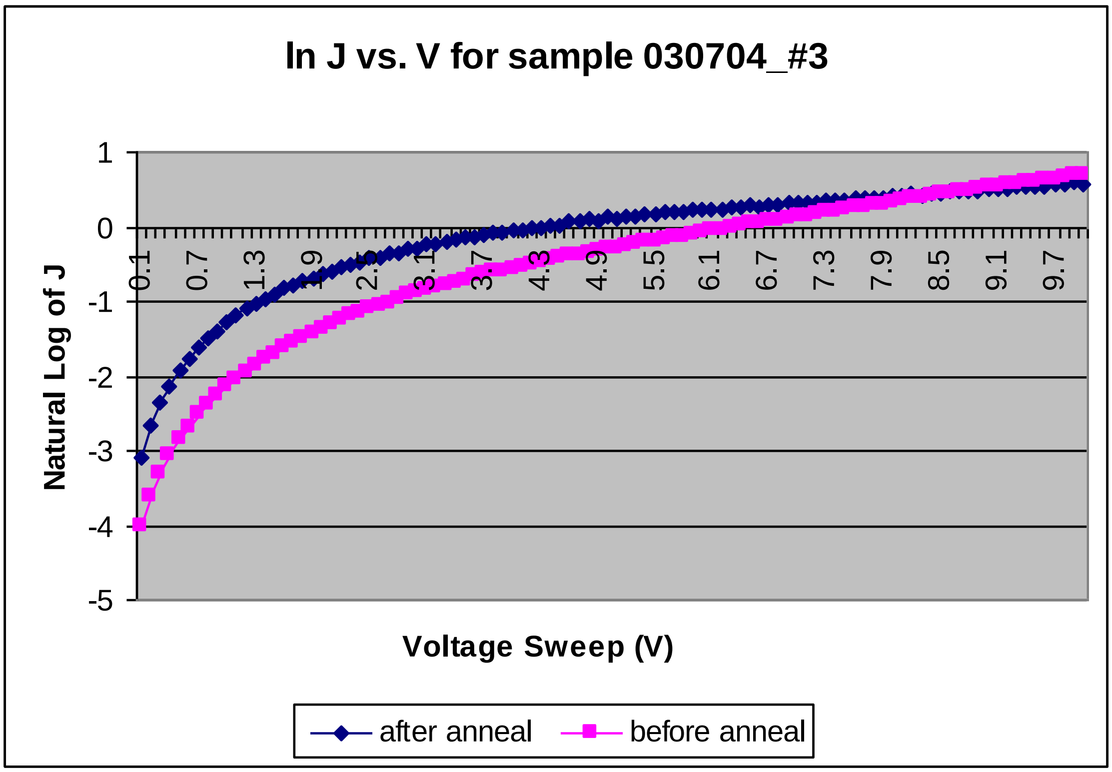

Figure 3: Current density vs voltage plot for sample 030704_#3

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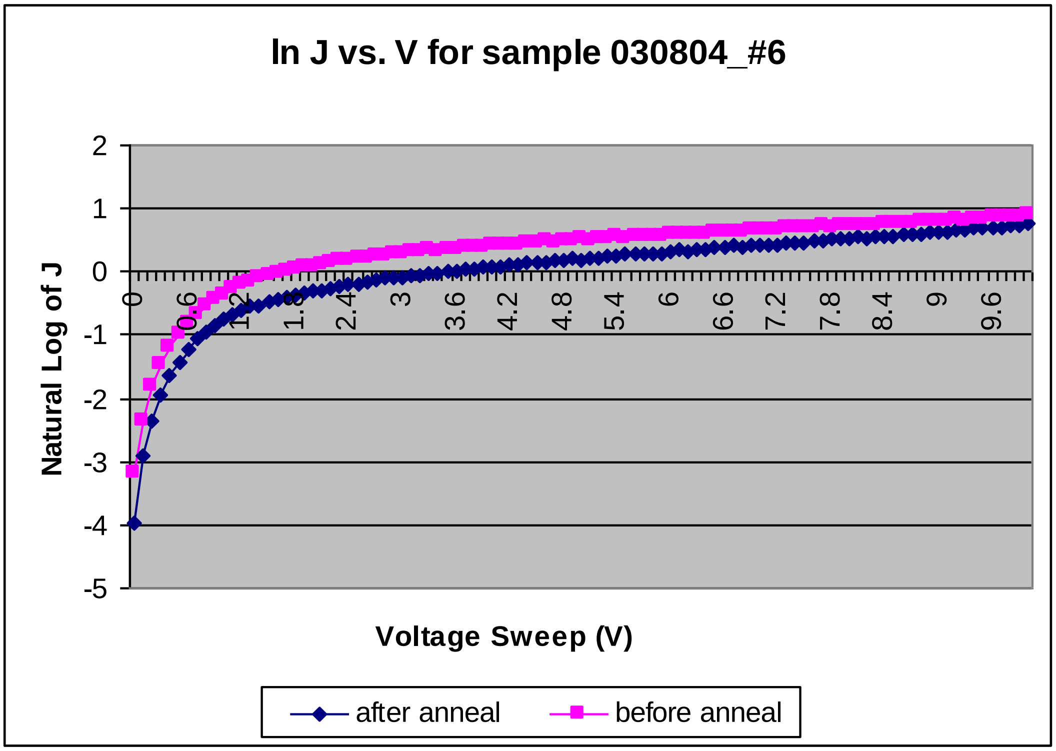

Figure 4: Current density vs voltage plot for sample 030804_#6

Table 1: Calculated Schottky barrier height for various samples

Sample	Schottky barrier height (eV)	
	Before Annealing	After Annealing
030704_#3	0.68	0.67
030804_#6	0.65	0.66

From this study, it can be observed that the conditions of the contacts formed by metal depositions onto surface of III-V semiconductors may be subject to the quality of the substrate surface, temperature of the substrate during metal deposition and thermal annealing process. These conditions was reflected in the Schottky barrier calculation of this experiment.

CONCLUSION

Based on the measurement, it was proven that current-voltage method has been successfully employed in getting the Schottky barrier height values of the Ti/Pt metal stacks on Si-doped AlGaAs HEMT layers. Schottky barrier heights for 0.65 eV has

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been obtained from the two samples measured in this experiment. From the observation for thermal annealing treatment to the samples, it was no effect for the barrier height at annealing for 300 °C. Further improvement in the experiment will be done to test Schottky barrier heights on samples with complete HEMT layers, as well as placing gold on the top contact metal stack (Ti/Pt/Au) and using gold as backside grounding metallization to improve conductivity.

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