

Research Article

Electrical Properties of Rapidly Annealed Ir and Ir/Au Schottky Contacts on n-Type InGaN

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Received 23 August 2011; Accepted 24 October 2011

Academic Editor: Stefano Gialanella

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The effect of annealing temperature on electrical characteristics of iridium (Ir) and iridium/gold (Ir/Au) Schottky contacts to n-type InGaN have been investigated by means of current-voltage (I - V) and capacitance-voltage (C - V) techniques. It is observed that the barrier height of Ir/n-InGaN and Au/Ir/n-InGaN Schottky diodes increases after annealing at 300°C for 1 min in N₂ ambient compared to the as-deposited. However, the barrier heights are found to be decreased somewhat after annealing at 500°C for the both Ir and Ir/Au Schottky contacts. From the above observations, it is clear that the optimum annealing temperature for both Ir and Ir/Au Schottky contacts is 300°C. Moreover, the barrier height (ϕ_b), ideality factor (n) and series resistance (R_s) are determined using Cheung's and Norde methods. Besides, the energy distribution of interface state densities are determined from the forward bias I - V characteristics by taking into account the bias dependence of the effective barrier height. Based on the above results, it is clear that both Ir and Ir/Au Schottky contacts exhibit a kind of thermal stability during annealing.

1. Introduction

III-V nitride semiconductors, particularly gallium nitride (GaN) and related alloys, have received much attention because of the (or their) wide range of practical applications. Among the ternary compounds of group III nitride materials, InGaN has drawn a great deal of attention. GaN and InGaN have been considered as the most important and crucial materials used for the fabrication of light emitters which were active in entire visible and part of the near UV spectral regions. The development of high-quality Schottky contacts to InGaN is difficult because in obtaining high-quality InGaN layers with high composition of In, their low carrier mobility (compared to GaN), and a large amount of surface defects in InGaN layers [1]. Hence, the fabrication of Schottky contacts to InGaN with a high barrier height and good thermal stability is still a challenge.

Many research groups have extensively investigated the electrical properties of n-GaN Schottky diodes using various metal schemes such as W, WSi_x [2], Ru, Ru/Au [3], Rh, Rh/Au [4], Ni/Au [5], and Re [6]. Kim et al. [2] investigated the thermal stability of W and WSi_x Schottky contacts on

n-type GaN and reported that the WSi_x contacts showed improved thermal stability compared to pure W contacts. They also reported that the WSi_x contact was stable up to temperatures >600°C with the Schottky barrier height (SBH) of ~0.5 eV. Rajagopal Reddy et al. [3] studied the influence of thermal annealing temperature on the electrical properties of Ru and Ru/Au Schottky contacts to n-type GaN. They found that the Ru Schottky contacts exhibit a kind of thermal stability during annealing compared to the Ru/Au contacts. Rajagopal Reddy et al. [4] investigated the effect of annealing temperature on electrical properties of Rh and Rh/Au Schottky contacts to n-type GaN. They reported that there was a significant improvement in the electrical characteristics of Rh/Au Schottky contacts upon annealing compared to the Rh Schottky contacts. Miura et al. [5] investigated the thermal annealing effects on Ni/Au-based Schottky contacts on n-GaN and AlGaIn/GaN after inserting high work function metals such as Pt, Ir, Pd, or Mo. Venugopalan and Mohny [6] showed that the Re Schottky contact was thermally stable on n-GaN and reported a barrier height of 0.82 eV and 1.06 eV after annealing at 500°C by I - V and C - V methods. Jang et al. [7] investigated

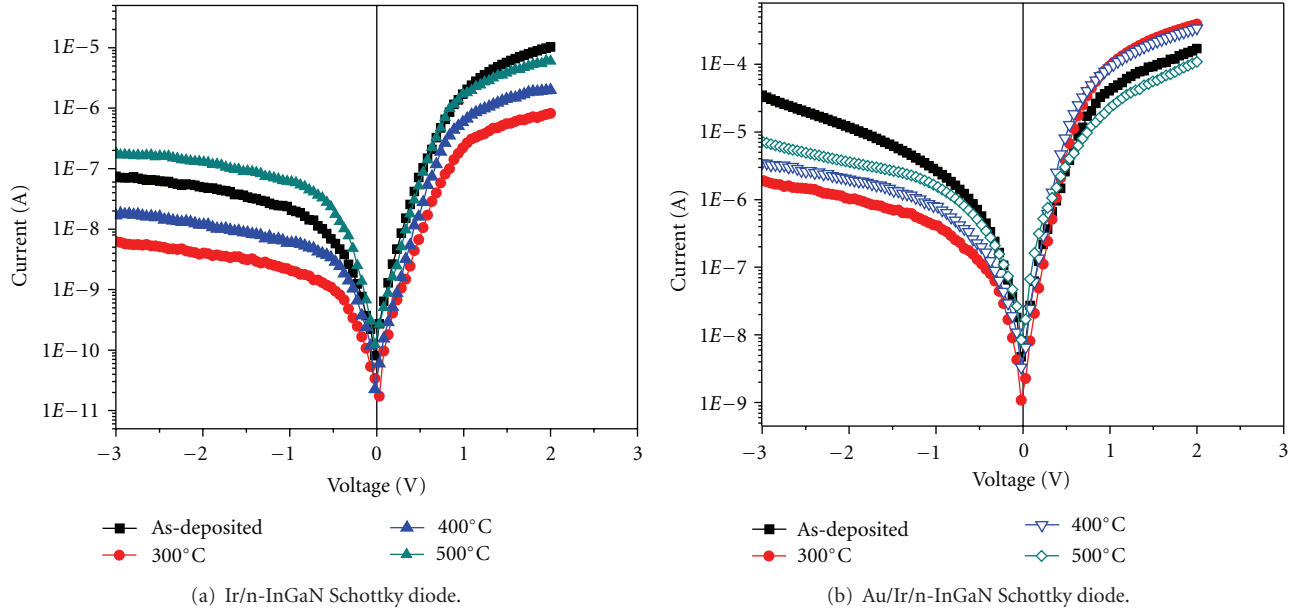


FIGURE 1: (a) The typical current-voltage characteristics for the Ir Schottky contacts on n-type InGaN. (b) The typical current-voltage characteristics for the Ir/Au Schottky contacts on n-type InGaN.

the Schottky barrier characteristics of Pt contacts on n-InGaN by the I - V and C - V methods. They found that there was a large difference in SBHs obtained by the TE and TFE modes using the I - V data. Xue et al. [8] fabricated large-area Au/Pt/ $\text{In}_{0.2}\text{G}_{0.8}\text{N}$ Schottky contacts for photovoltaic devices and investigated the current transport mechanisms of the Schottky diodes with different background carrier concentrations.

There are, however, only limited works on metal-InGaN ($N_d = 6 \times 10^{17} \text{ cm}^{-3}$) Schottky barriers. Hence, the main aim of the present work is to fabricate and characterize the Ir-based Schottky contacts on InGaN. To the best of our knowledge, Ir metal scheme has not been explored as Schottky contacts on InGaN. In this work, Ir is selected because it has a high work function of 5.46 eV. From a device point of view, it is important to know what happens to metal contacts when they are annealed. Therefore, our main focus in the present work is to investigate the electrical characteristics of Ir and Ir/Au Schottky contacts on n-InGaN by means of current-voltage (I - V) and capacitance-voltage (C - V) measurements as a function of annealing temperature.

2. Experimental Details

2 μm -thick unintentionally doped GaN layer on a 40 nm-thick nucleation layer/(0001) sapphire substrate was grown by metal organic chemical vapor deposition (MOCVD). This was followed by the growth of $\sim 0.25 \mu\text{m}$ -thick n-InGaN: Si ($N_d = 6 \times 10^{17} \text{ cm}^{-3}$) with 10% of indium (In) composition. Prior to the metal deposition, the n-type InGaN layer was first ultrasonically degreased with warm trichloroethylene followed by acetone, methanol, and ethanol for 5 min in each step and then rinsed with deionized (DI) water. This

degreased layer was then dipped into boiling aquarezia [$\text{HNO}_3 : \text{HCl} = 1 : 3$] for 10 min to remove the native oxide. For ohmic contacts, bilayer of Ti (25 nm)/Al (100 nm) was deposited on InGaN and then annealed at 650°C for 1 min in flowing N_2 atmosphere using rapid thermal annealing (RTA) system. Ir (50 nm) and Ir/Au (20 nm/30 nm) Schottky contacts were fabricated on n-InGaN with a circular diameter of 0.7 mm using electron beam evaporation system with a vacuum pressure of 5×10^{-6} mbar. In order to investigate the thermal annealing effect on Schottky diodes, the Ir and Ir/Au contacts were annealed at 300°C , 400°C , and 500°C for 1 min in N_2 ambient. The electrical characteristics of Schottky contacts were determined by means of current-voltage (I - V) and capacitance-voltage (C - V) characteristics using Keithley source measure unit (model no. 2400) and deep level transient spectrometer (DLS-83 D), respectively.

3. Results and Discussion

3.1. Current-Voltage (I - V) Characteristics. Figures 1(a) and 1(b) show the semilogarithmic plots of forward and reverse I - V characteristics of Ir and Ir/Au Schottky contacts measured as a function of annealing temperature. It is noted that the properties of Ir and Ir/Au Schottky diodes are uniform over different temperatures. It is observed that the leakage current of as-deposited Ir Schottky diode is $2.38 \times 10^{-8} \text{ A}$ at -1 V . For the contact annealed at 300°C , the leakage current decreases to $2.21 \times 10^{-9} \text{ A}$, whereas for the contacts annealed at 400°C and 500°C , the leakage current values are $6.0 \times 10^{-9} \text{ A}$ and $6.49 \times 10^{-8} \text{ A}$ at -1 V , respectively. In the case of as-deposited Ir/Au Schottky diode, the leakage current at -1 V is $2.78 \times 10^{-6} \text{ A}$. For the contacts annealed at 300°C , 400°C , and 500°C , the obtained leakage current values are

TABLE 1: The various parameters obtained from the I - V and C - V characteristics of Ir and Ir/Au Schottky contacts on n-InGaN as a function of annealing temperature.

Sample	Schottky barrier height (SBH) ϕ_b (eV)			From I - V n	Cheung's functions			
	I - V	C - V	Norde		$dV/d\ln(I)$ versus I R_s (Ω)	n	$H(I)$ versus I ϕ_b (eV)	R_s (Ω)
Ir								
As-dep	0.79	1.17	0.81	1.60	188	2.15	0.80	226
300°C	0.85	1.21	0.88	1.10	62	1.38	0.86	74
400°C	0.84	1.11	0.86	1.25	83	1.61	0.85	102
500°C	0.80	1.07	0.82	1.50	122	1.93	0.81	133
Ir/Au								
As-dep	0.70	1.00	0.73	1.51	171	1.93	0.71	179
300°C	0.74	1.03	0.76	1.23	90	1.46	0.75	109
400°C	0.71	0.96	0.74	1.43	109	1.89	0.72	128
500°C	0.67	0.93	0.71	1.77	231	2.04	0.68	260

4.22×10^{-7} A, 7.87×10^{-7} A, and 1.66×10^{-6} A at -1 V, respectively. The smallest leakage current values are obtained for both Ir and Ir/Au Schottky contacts after annealing at 300°C, accompanied by the corresponding increase in the barrier height. This indicates that the electrical characteristics of both the Ir and Ir/Au contacts are improved upon annealing at 300°C compared to the as-deposited contacts. It also is noted that the reverse leakage current decreased for Ir/n-InGaN Schottky diode compared to the Au/Ir/n-InGaN Schottky diode upon annealing temperature.

The barrier height and the ideality factor of a metal-semiconductor contact are determined using thermionic emission theory and are given by [9]

$$I = I_S \exp \left[\left(\frac{q(V - IR)}{nKT} \right) - 1 \right], \quad (1)$$

with

$$I_S = AA^{**} T^2 \exp \left(\frac{-q\phi_b}{kT} \right). \quad (2)$$

Here, I_S is the saturation current, q is the electron charge, V is the applied voltage, R is the series resistance, T is the absolute temperature, n is the ideality factor, k is the Boltzmann's constant, A is the contact area, and A^{**} is the effective Richardson constant. The theoretical value of A^{**} was $23 \text{ A cm}^{-2} \text{ K}^{-2}$ based on the effective mass ($m^* = 0.19m_0$) of the n-InGaN [7] and was used to deduce ϕ_b . In general by using a linear curve fit to the forward characteristics of $\ln(I)$ against V data, barrier height (ϕ_b) and ideality factor (n) can be determined from the y -intercept and the slope of the fitted curve, respectively. Calculations yield that the Schottky barrier height (SBH) of as-deposited Ir/n-InGaN Schottky diode is 0.79 eV. For the contacts annealed at 300°C, 400°C, and 500°C, the calculated barrier heights are 0.85 eV, 0.84 eV, and 0.80 eV. The Schottky barrier height estimated in the case of Ir/Au contact is 0.70 eV (as-deposited), 0.74 eV after annealing (at 300°C), 0.71 eV (400°C), and 0.67 eV (500°C).

The ideality factor is determined from I - V plot, specifically at small forward currents, where the effect of series

resistance is considered to be small. In case of Ir and Ir/Au Schottky diodes, the typical values of ideality factor are found to be 1.60 and 1.51 (as-deposited), respectively. However, it is observed that the ideality factors are improved to 1.10 for Ir and 1.23 for Ir/Au Schottky contacts upon annealing at 300°C. The ideality factor calculated from the forward bias I - V plot is found to be greater than unity. This may be due to a potential drop in the interface layer and the presence of excess current and the recombination current through the interfacial state between the semiconductor/insulator layers [10]. Also, when the bias is applied, part of the voltage is dropped across the interface layers. Thus, the barrier height becomes dependent on the bias voltage, leading to an ideality factor greater than one. Moreover, the larger values of ideality factors are attributed to secondary mechanisms that include interface dipoles due to interface doping or specific interface structure as well as fabricate-induced defects at the interface [11, 12]. The high value of ideality factor can also be attributed to the presence of a wide distribution of low-SBH patches caused by laterally inhomogeneous according to Tung [13]. Another possibility may be the image-force effect, recombination generation, and tunneling mechanisms that could be lead to the ideality factor value greater than unity [14]. The barrier heights and the ideality factors of Ir and Ir/Au Schottky diodes as a function of annealing temperature are given in Table 1.

Generally, at low voltages, the linear forward bias current-voltage (I - V) characteristics in the semilogarithmic scale deviate considerably from linearity, which is due to the effect of parameters such as R_s and N_{SS} when the applied voltage is sufficiently large. The series resistance values are evaluated using the method developed by S. cheung and N. cheung [15]. Cheung's functions given as

$$\frac{dV}{d(\ln I)} = IR_s + n \left(\frac{kT}{q} \right), \quad (3)$$

$$H(I) = V - n \left(\frac{kT}{q} \right) \ln \left(\frac{I}{AA^{**}T^2} \right), \quad (4)$$

$$H(I) = IR_s + n\phi_b \quad (5)$$

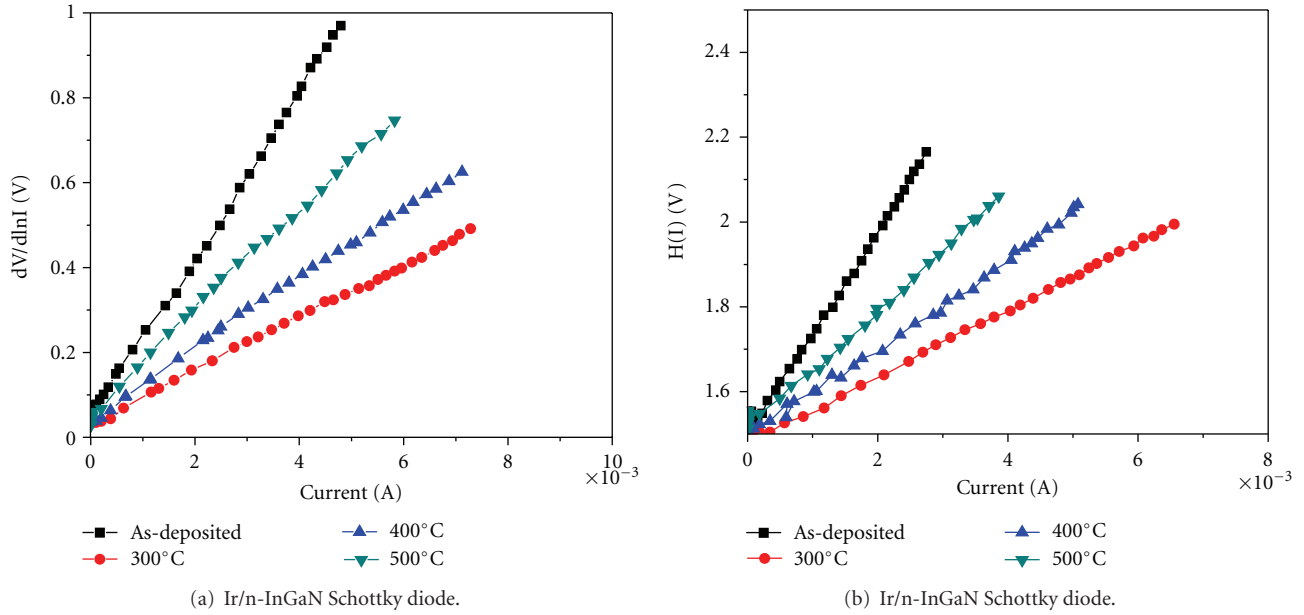


FIGURE 2: (a) Plot of $dV/d \ln I$ versus I for the Ir/n-InGaN Schottky contacts. (b) Plot of $H(I)$ versus I for the Ir/n-InGaN Schottky contacts.

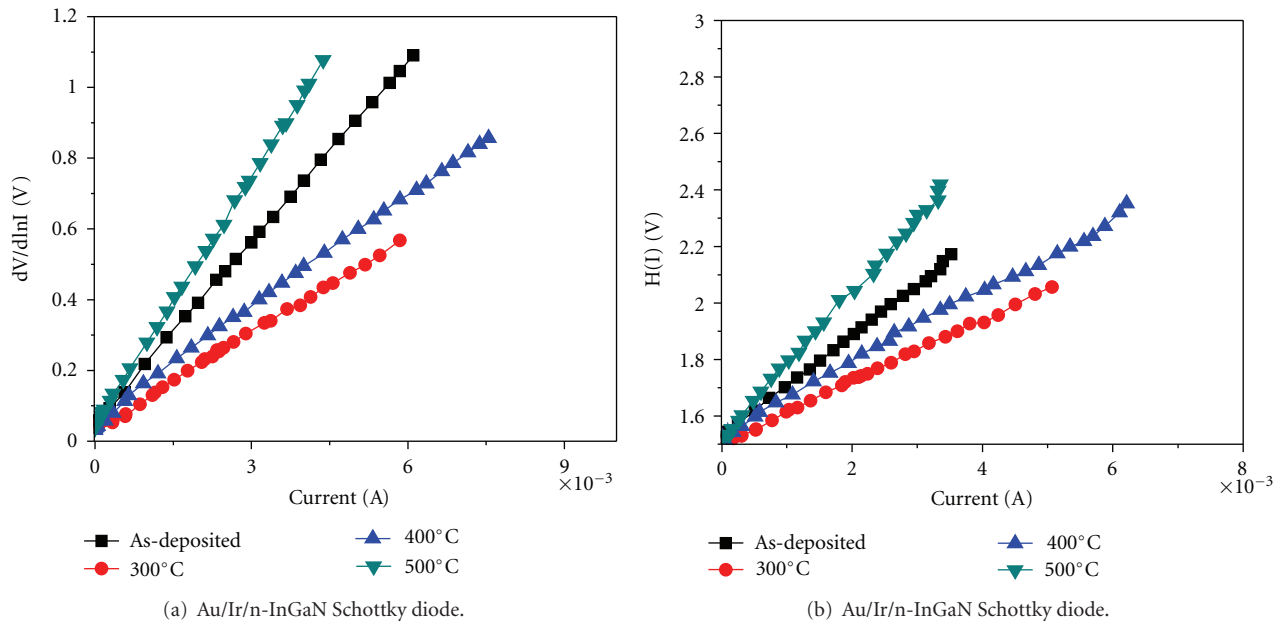


FIGURE 3: (a) Plot of $dV/d \ln I$ versus I for the Ir/Au/n-InGaN Schottky contacts. (b) Plot of $H(I)$ versus I for the Ir/Au/n-InGaN Schottky contacts.

should give a straight line for the data of downward curvature region in the forward bias I - V characteristics. The term IR_S is the current drop across the series resistance of Schottky diodes. Figures 2(a) and 3(a) show the experimental $dV/d \ln I$ versus I plot for the Ir and Ir/Au Schottky diodes, respectively. The values of R_S and nkT/q are calculated from the slope and y -axis intercepts of the $dV/d \ln I$ versus I plot, respectively. From Figures 2(b) and 3(b), it is evident that the plot of $H(I)$ versus I gives a straight line with the y -axis intercept equal to $n\phi_b$, and the slope parameter can be

used to check the consistency of Cheung's method. From (3), the values of ideality factor and series resistance for Ir/InGaN and Au/Ir/InGaN Schottky diodes are calculated. The values of barrier height and series resistance for Ir/InGaN and Au/Ir/InGaN Schottky diodes are calculated from (5) which is given in Table 1. Thus, it can be clearly seen that there is relatively a difference between the values of ideality factor calculated from the downward curvature regions of forward bias I - V plots and from the linear regions of the same characteristics. This can be attributed to the existence of

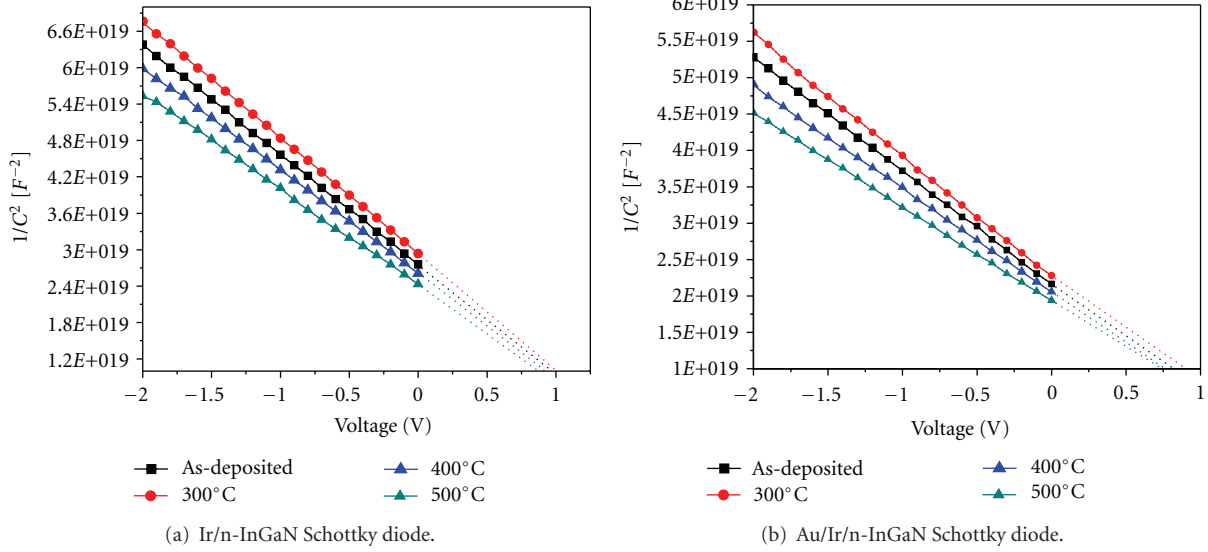


FIGURE 4: (a) Plot of $1/C^2$ versus V for the Ir Schottky contacts annealed at different temperatures. (b) Plot of $1/C^2$ versus V for the Ir/Au Schottky contacts annealed at different temperatures.

effects such as series resistance and the bias dependence of Schottky barrier height according to the voltage drop across the interfacial layer and change of the interface states with the bias in the low-voltage region of the current-voltage plot.

The accurate evaluation of the barrier height from the standard $\ln(I)-V$ plot can be effected by the high series resistance. To include this effect, Norde method is also used to compare the SBH of Ir and Ir/Au Schottky contacts. The Norde function $F(V)$, being plotted against $V \cdot F(V)$, is given by [16, 17]

$$F(V) = \frac{V}{2} - \frac{kT}{q} \ln \left[\frac{I(V)}{AA^{**}T^2} \right]. \quad (6)$$

The Schottky barrier height ϕ_b is given by

$$\phi_b = F(V_{\min}) + \frac{V_{\min}}{2} - \frac{kT}{q}, \quad (7)$$

where $F(V_{\min})$ is the minimum value of $F(V)$, and V_{\min} is the corresponding voltage. Measurements showed that the SBHs are 0.81 eV for as-deposited, 0.88 eV for 300°C, 0.86 eV for 400°C, and 0.82 eV for 500°C for Ir Schottky contacts. In the case of Ir/Au Schottky contacts, the calculated barrier heights are 0.73 eV for as-deposited, 0.76 eV for 300°C, 0.74 eV for 400°C, and 0.71 eV for 500°C, respectively. It is observed that these values are in good agreement with those calculated by $I-V$ method.

3.2. Capacitance-Voltage (C-V) Characteristics. Capacitance-voltage (C-V) characteristics of Ir and Ir/Au Schottky contacts are measured at a frequency of 1 MHz with an ac modulation of 100 mV in the dark. Figures 4(a) and 4(b) show plots of $1/C^2$ as a function of bias voltage for as-deposited and annealed contacts of Ir and Ir/Au Schottky contacts,

respectively. The C-V relationship for Schottky diode is given by [9]

$$\frac{1}{C^2} = \frac{2[V_{bi} - (kT/q) - V]}{A^2 q N_d \epsilon_s}, \quad (8)$$

where V_{bi} is the flat band voltage, N_d is the donor concentration, A is the area of the Schottky contact, and ϵ_s is the permittivity of the semiconductor ($\epsilon_s = 8.4\epsilon_0$). The x-intercept of the plot of $(1/C^2)$ versus V , V_o is related to the built in potential V_{bi} by equation $V_{bi} = V_o + kT/q$, where T is the absolute temperature. The barrier height (ϕ_{CV}) is given by the equation $\phi_{CV} = V_{bi} + V_n$ where $V_n = (kT/q) \ln(N_c/N_d)$. The density of states in the conduction band edge is given by $N_c = 2(2\pi m^* kT/h^2)^{3/2}$, $m^* = 0.19m_0$, and its value was $7 \times 10^{17} \text{ cm}^{-3}$ for InGaN at room temperature. Measurements showed that the barrier heights of Ir Schottky contacts are 1.17 eV for as-deposited, 1.21 eV for 300°C, 1.11 eV for 400°C, and 1.07 eV for 500°C annealed contacts. For Ir/Au Schottky contacts, the estimated barrier heights are 1.00 eV (as-deposited), 1.03 eV after annealing the contacts (at 300°C), 0.96 eV (400°C), and 0.93 eV (500°C) by C-V method.

Figure 5(a) shows a plot of barrier height of Ir/n-InGaN as a function of annealing temperature. It can be seen clearly from Figure 5(a) that the barrier height of Ir/n-InGaN Schottky diode increases upon annealing at 300°C for 1 min in the N_2 ambient compared to the as-deposited contact. However, there is a slight decrease in the Schottky barrier height for the contacts annealed at 400°C and 500°C. The interface states and chemical reactions between metals and semiconductors at the interface may be the reason for the variation in the barrier heights [18]. From Figure 5(a), it is also noted that the ideality factor is improved and reaches near unity value (1.10) after annealing at 300°C. However, the values of

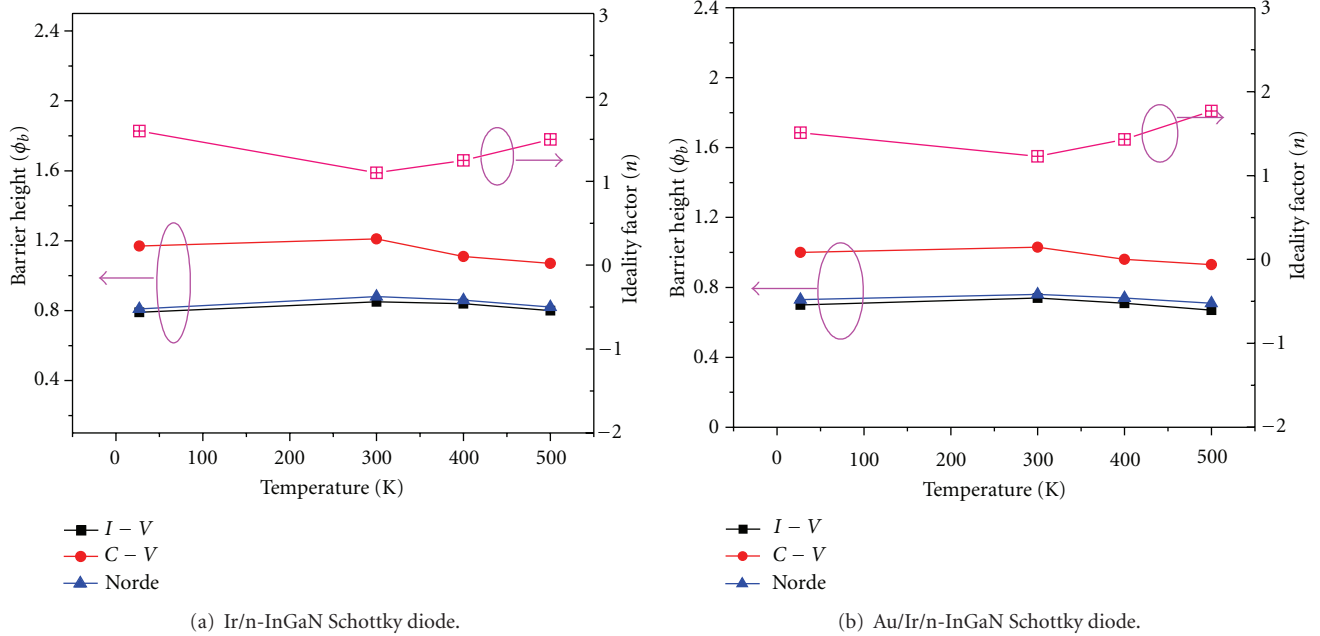


FIGURE 5: (a) The barrier height and ideality factors of the Ir Schottky contact as a function of annealing. (b) The barrier height and ideality factors of the Ir/Au Schottky contact as a function of annealing.

ideality factor slightly increase upon annealing at 400°C and 500°C compared to the contact annealed at 300°C.

The plot of barrier heights and ideality factors of Ir/Au Schottky contacts as a function of annealing temperature is shown in Figure 5(b). It is noted that the barrier height calculated for the as-deposited Ir/Au contacts is less than annealed contacts (300°C and 400°C). When the contact is annealed at 300°C, it is found that the Schottky barrier height increases for Ir/Au contact. Rajagopal Reddy et al. [3] had observed similar behavior in Au/Ru/n-GaN Schottky diode. Also, Miura et al. [5] had observed similar behavior in Ni/Pt/Au, Ni/Au, and Ni/Mo/Au Schottky contacts on n-GaN. Upon annealing temperature, the increase in the barrier height may be due to the reduction in the nonstoichiometric defects in the metallurgical interface [19, 20]. Also, it is observed that the increase in the barrier height is accompanied by the corresponding decrease in the reverse leakage current. Duboz et al. [21] had reported that the metal/n-GaN interface remains unaffected even after annealing. They also found that the nature of the metal does not play a major role in the improvement of barrier height on annealing temperature. Many researchers had observed the pinning of Fermi level at metal/n-GaN interface because of the interface defects. Further, a modification in the defect density on annealing could change the pinning, which leads to the change of barrier height. Significant improvement in the electrical characteristics in the case of Ir/n-InGaN Schottky diode is observed upon annealing temperature compared to the Au/Ir/n-InGaN Schottky diode. It is also observed that the electrical characteristics of Ir Schottky contacts are fairly more thermally stable than that of Ir/Au Schottky contacts. Also, Figure 5(b) shows that the ideality

factor value decreases upon annealing at 300°C. With a further increase in the annealing temperatures up to 500°C, the ideality factor is slightly increased.

It can also be seen from Figures 5(a) and 5(b) that the barrier heights obtained from $I-V$ measurements are lower than those obtained from $C-V$ measurements. This difference in the values of ϕ_{I-V} and ϕ_{C-V} may be due to the presence of native oxide layer at the metal/InGaN interface [22]. Lowering the barrier height by an image force due to current flow across the barrier can also have some effect [9]. However, with high-temperature annealing, the metal perhaps comes into intimate contact with the semiconductor. Furthermore, the differences in the barrier height calculated from $I-V$ and $C-V$ methods may also cause the Schottky barrier height inhomogeneities that prevail at the metal semiconductor interface [23]. Another possibility is that the surface damage at the metal-semiconductor interface affects $I-V$ measurements because defects may act as recombination centers for trap-assisted tunneling currents. $C-V$ measurements are normally less prone to interface states. Hence, the calculated barrier heights are considered more reliable, though the depletion width can be altered by interface defects if they are deeper into the space charge region [24]. It may also be the transport mechanism in these diodes which is not purely due to thermionic emission. To these diodes, ϕ_b obtained from $I-V$ method is voltage or electric field sensitive unlike the ϕ_b obtained from $C-V$.

3.3. Interface State Density (N_{SS}) from $I-V$ and $C-V$ Measurements. It is noted from Figures 6(a) and 6(b) that the interface state density N_{SS} has an exponential increase with the bias from the midgap towards the top of the conduction

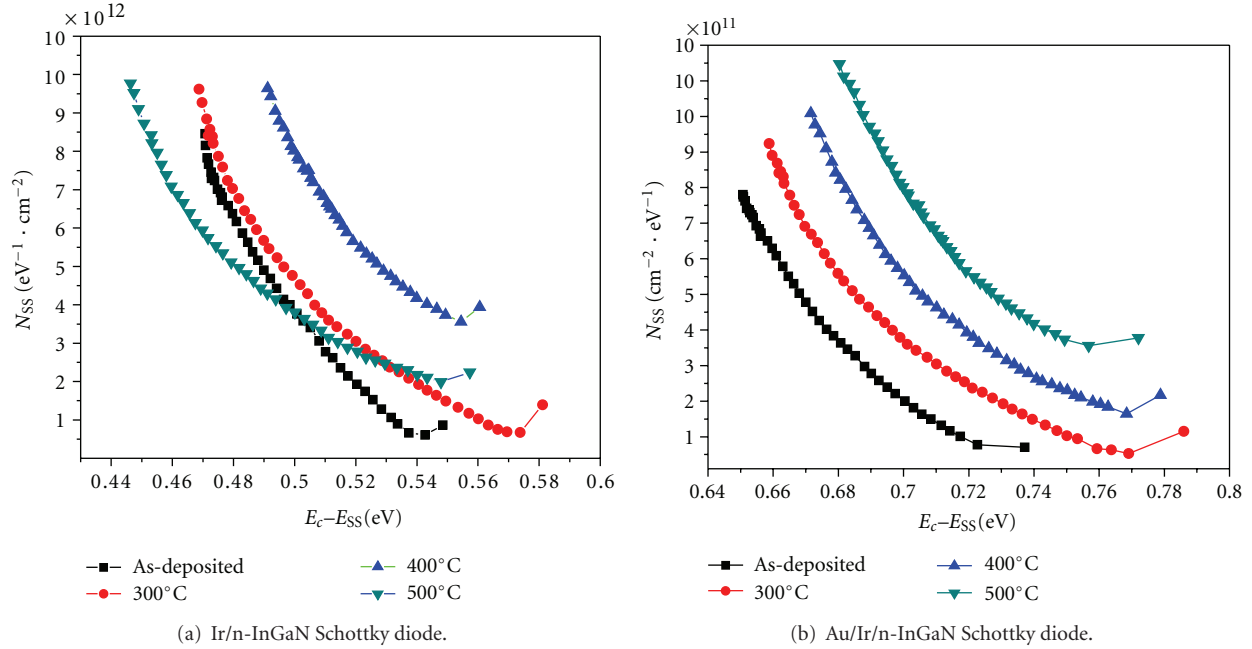


FIGURE 6: (a) Interface state density distribution profiles as a function of $E_{CC} - E_{SS}$ for Ir Schottky contacts. (b) Interface state density distribution profiles as a function of $E_{CC} - E_{SS}$ for Ir/Au Schottky contacts.

band. According to Card and Rhoderick, for a real Schottky diode having interface states in equilibrium with the semiconductor, the ideality factor n becomes greater than unity and is given by [9, 25]

$$n(V) = 1 + \frac{\delta}{\varepsilon_i} \left[\frac{\varepsilon_s}{W_d} + q \cdot N_{ss}(V) \right], \quad (9)$$

where N_{SS} is the density of interface states, W_d is the width of the semiconductor, and ε_s and ε_i are the permittivity of the semiconductor and the interfacial layer, respectively. The voltage-dependent ideality factor $n(V)$ can be expressed as $n(V) = (qV)/(kT \ln(I/I_s))$ [26]. The expression for the interface state density can be given as

$$N_{SS} = \frac{1}{q} \left[\frac{\varepsilon_i}{\delta} (n(V) - 1) - \frac{\varepsilon_s}{W_d} \right]. \quad (10)$$

In the n-type semiconductor, the energy of the interface states E_{SS} with respect to the bottom of the conduction band at the surface of the semiconductor is given by [25, 27, 28]

$$E_C - E_{SS} = q(\phi_e - V), \quad (11)$$

where ϕ_e is the effective barrier height. The voltage dependence of the effective barrier height ϕ_e is contained in the ideality factor n through the relation

$$\frac{d\phi_e}{dV} = \beta = 1 - \frac{1}{n(V)}, \quad (12)$$

where β is the voltage coefficient of ϕ_e . The effective barrier height ϕ_e is given by [29]

$$\phi_e = \phi_b + \beta(V). \quad (13)$$

From Figures 6(a) and 6(b), it can be seen that the N_{SS} value decreases with the increase in the $E_C - E_{SS}$ value. The increase in N_{SS} values forms from midgap towards the bottom of the conduction band which is probably due to the increase in the series resistance (R_s). The change in the charge of the interface states and thus the interface state energy distribution due to the potential drop across the interfacial layer varies with the bias. It alters the diffusion potential and therefore the depletion capacitance [9, 30–33].

4. Conclusions

We have investigated the electrical properties of Ir and Ir/Au Schottky contacts on n-type InGaN ($N_d = 6 \times 10^{17} \text{ cm}^{-3}$) by I - V and C - V measurements as a function of annealing temperature. Measurements showed that the barrier height of as-deposited Ir Schottky contact is 0.79 eV (I - V) and 1.17 eV (C - V). Upon annealing at 300°C for 1 min in nitrogen ambient, the Schottky barrier height increases to 0.85 eV (I - V) and 1.12 eV (C - V). After annealing at 400°C and 500°C, the Schottky barrier heights decrease to 0.84 eV (I - V), 1.11 eV (C - V) and 0.80 eV (I - V), 1.07 eV (C - V). In the case of as-deposited Ir/Au Schottky contacts, the estimated barrier height is 0.70 eV (I - V) and 1.00 eV (C - V). However, the Schottky barrier height increases upon annealing temperature at 300°C, and the corresponding value is 0.74 eV (I - V) and 1.03 eV (C - V). Further, with an increase in annealing temperature up to 500°C, the barrier height decreases to 0.67 eV (I - V) and 0.93 eV (C - V), respectively. Based on the above results, the optimum barrier heights are obtained after annealing at 300°C for both Ir and Ir/Au Schottky contacts. Therefore, the optimum annealing

temperature for both Ir and Ir/Au Schottky contacts is 300°C. The values of diode parameters such as ideality factor (n), series resistance (R_S), and barrier height (ϕ_b) are also calculated by Cheung's and Norde's methods. The interface state density has an exponential raise with bias from the midgap towards the top of the conduction band. From the above observations, it is clear that the electrical properties of Ir and Ir/Au Schottky contacts are improved with an increase in annealing temperature compared to the as-deposited one. Moreover, both Ir and Ir/Au Schottky contacts showed relatively thermal stability during annealing temperature.

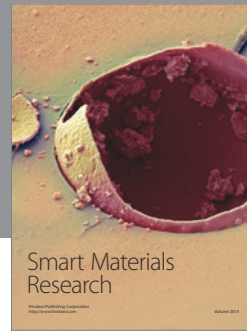
Acknowledgment

The authors thank the University Grant Commission (UGC), New Delhi, for providing the financial assistance (Grant no. 39-530/2010 (SR)).

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