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Temperature dependence of 1/*f* noise in Ni/n-GaN Schottky barrier diode

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1/*f* noise measurements were performed on Ni/n-GaN Schottky barrier diode under forward bias over a wide temperature range from 80 to 300 K. The noise spectra exhibited frequency dependence proportional to $1/f^{\gamma}$ with γ varying between 0.8 and 1.1 down to 1 Hz. The spectral power density of current fluctuations, S_I, was found to decrease with increase in temperature. Current-voltage (*I-V*) characteristics of the diodes have been measured, and metal-semiconductor interface was found to be spatially inhomogeneous in the temperature range 80–300 K. The decrease in 1/*f* noise with increase in temperature is explained within the framework of spatial inhomogeneities model. © *2012 American Institute of Physics*. [http://dx.doi.org/10.1063/1.4737258]

I. INTRODUCTION

1/*f* noise studies in semiconductor material as well as semiconductor devices have been an active area of research over the years.[1,2] Noise studies are effective tool to measure the bulk as well as surface quality of semiconductors. These studies also become important from the viewpoint of controlling the noise in the devices and systems. As the device size is getting reduced day-by-day, these studies become even more important. GaN is a promising semiconductor material specially in blue light emitting diodes (LED) and HEMTs.[3,4] GaN based Schottky barrier diodes (SBDs) are very important from the technological point of view because of their widespread applications in high frequency, high power electronic, and UV photonic devices.[5–7] The current transport through a SBD takes place dominantly by thermionic emission, and it is fairly well understood.[8] However, low frequency noise behaviour of SBD is still not well understood. Several models have been proposed for explaining the behaviour of the noise on the lower frequency side. According to Hsu's model,[9,10] random occupancy of the trap states in the space charge region causes fluctuation in the barrier height. Occupancy of the trap states also fluctuates because of multistep tunnelling current flowing through the diode. This produces the low frequency noise in the diode. However, Hsu's model is not in agreement with the model given by Kleinpenning[11] which states that trap density and energy distribution responsible for 1/*f* noise given by Hsu's model are not realistic for actual devices. Luo *et al.*[12] proposed his model with some modification in the Kleinpenning's model. According to Luo's model, mobility and diffusivity fluctuations of the carries within the space charge region are responsible for the 1/*f* noise. According to this model, 1/*f* noise should increase with increase in temperature. But in many cases, opposite behaviour is seen, that is, noise decreases with increase in temperature.[13] Güttler and Werner[13] on the basis of their work on metal-silicide/Si Schottky diodes found noise to be increased upon cooling. They attributed this type of behaviour to the spatial inhomogeneities at the metal-semiconductor (MS) interface. Decreasing behaviour of noise with increase in temperature is also predicted by Jäntsch model.[14] Jäntsch used random walk model for explaining 1/*f* noise in Schottky barrier diodes.

Present study aims to understand the dependence of 1/*f* noise on temperature in the framework of spatial inhomogeneities model. Spatial inhomogeneities at MS interface arise due to surface defects, threading dislocations, surface treatment, metal deposition process, etc. These inhomogeneities results in local distribution of Schottky barrier height (SBH) which affect the current transport as well as noise properties. There are several reports on temperature dependent studies of electrical transport mechanism in spatial inhomogeneous M/GaN (M = Ni, Pd, Pt, Au, etc.) SBDs. Yildirim *et al.*[15] investigated current-voltage (*I-V*) and capacitance-voltage (C-V) characteristics of Ni/n-GaN SBDs in temperature range 80–400 K. The apparent barrier height and ideality factor (n) was found to decrease and increase, respectively, with decrease in temperature due to inhomogeneities at MS interfaces. Mamor[16] studied various metals (Ni, Pt, Pd) SBDs on n-GaN in temperature range 80–400 K and it was found that inhomogeneities at MS interface can be correlated with the interface state density. Ravinandan *et al.*[17] explained temperature dependence of SBH and ideality factor in Pd/n-GaN SBDs using spatial inhomogeneities at MS interface while Dogan *et al.*[18] investigated temperature dependent current-voltage (*I-V*) characteristics with Gaussian distribution of SBH. Arehart *et al.*[19] on the basis of their studies on Ni/n-GaN SBDs have reported that diodes with lower threading dislocation density show nearly ideal Schottky behaviour, while diodes with higher threading dislocation density show a significant deviations from the ideal behaviour. They explained this departure from ideal behaviour on the basis of Schottky barrier inhomogeneities arising due to higher threading dislocation density. Iucolano *et al.*[20,21] investigated the effect of annealing temperature on electrical properties of Pt/GaN SBDs and they found that barrier distribution became narrower (more homogenous) due to improvement of MS interface after annealing.

There are some reports of temperature dependent 1/*f* noise measurements on SBDs. For example, the studies of Ouacha *et al*.[22,23] on Ir/p-Si and Singh and Kanjilal[24] on Pd/n-GaAs showed a clear dependence of 1/*f* noise on temperature. Temperature dependent noise behaviour in both the diodes (Ir/p-Si and Pd/n-GaAs) was not in agreement with the Hsu's model. Luo's model and spatial inhomogeneities model were used for explaining temperature dependence of current noise in these diodes. As such, there is no universal theory for explaining origin of 1/*f* noise and also for temperature dependence of 1/*f* noise in SBDs.

There are a few reports of 1/*f* noise measurements in GaN epitaxial layers and GaN based devices. Dyakonova *et al*.[25] studies on 1/*f* noise in n-GaN epitaxial layers revealed low level of structural quality of material as they found Hooge parameter as large as ~3. Levinshtein *et al*.[26] also reported low frequency noise measurements in n-GaN epitaxial layers. 1/*f* behaviour in GaN epitaxial layers was attributed to the occupancy fluctuations of the tail states near the band edges which are quite similar to mechanism responsible for 1/*f* noise in Si and GaAs. Osinsky *et al*.[6] and Rumyantsev *et al*.[7] investigated low frequency noise in AlGaN based Schottky barrier photodetectors. Osinsky *et al*.[6] using low frequency noise spectroscopy found noise equivalent power (NEP) of the photodetector while Rumyantsev *et al*.[7] studied the current dependence of low frequency noise. There are also some reports on low frequency noise measurements in GaN/AlGaN heterojunctions. Levinshtein *et al*.[27] on the basis of their studies on GaN/AlGaN heterojunctions reported the effect of band-to-band illumination on low frequency noise. To the best of our knowledge, we did not find any report of low frequency noise measurements in Ni/GaN SBDs.

In this article, we have reported the 1/*f* noise properties of Ni/n-GaN SBDs in the temperature range from 80 to 300 K with frequency varying between 1 and 100 Hz. Sec. III A (Results and Discussion) investigates *I-V* characteristics in temperature range 80-300 K, while Sec. III B correlates the origin and temperature dependence of 1/*f* noise Ni/n-GaN Schottky diodes to Schottky barrier inhomogeneities at MS interface.

II. EXPERIMENTAL

GaN samples used for present work were 3-μm epitaxial layers grown on c-plane sapphire substrates by metal organic chemical vapour deposition (MOCVD) technique. The doping concentration of epitaxial layer used for this work was 1.2×10^{16}cm^{-3}. Prior to metallization, the samples were ultrasonically cleaned in trichloroethylene, acetone, and isopropanol, respectively, at 70 °C. The samples were then dipped in 1:1 HCl for 2 min to remove the native oxides. Finally, the clean samples were rinsed with de-ionized water and blown with dry nitrogen before deposition. The four layer Ti/Al/Ni/Au Ohmic contacts with thickness of 20/100/20/100 nm were deposited on the periphery of the samples using e-beam deposition at a base pressure of 10^{-8} mbar. The contacts were annealed using two step rapid thermal annealing process, first at 550 °C for 1 min and then at 700 °C for 30 s. Again a pre-metal dip in 1:1 HCl was given before Schottky contact deposition. The Ni/Au bilayer dots of diameter 1.0 mm in the thickness of 40/100 nm were deposited using a metal window mask.

For temperature dependent current-voltage (*I-V*) characteristics and 1/*f* noise measurements, Ni/n-GaN Schottky diodes were loaded in an LN_2 cryostat and a vacuum of the order of 10^{-2} mbar was maintained inside the cryostat using a rotary pump. A computer controlled Keithley 2612 A Source Measurement Unit (SMU) was used for *I-V* measurements, and temperature was controlled using Lakeshore 325 temperature controller. The temperature was varied between 80 K and 300 K for both *I-V* and 1/*f* noise measurements. The temperature was stabilised within 0.01 K during each measurement.

For 1/*f* noise measurements, the Schottky diode was forward biased with 50 μA using a battery operated DC current source. The voltage developed across the diode was fed to a low noise preamplifier (model SR 552, Stanford Research System, USA). The preamplifier blocked the DC components and allowed only AC components to pass through it. The amplified AC signal was then fed to HP Dynamic Signal Analyzer (model HP 35665 A) that displayed the spectral power density of voltage fluctuations (S_V) as a function of frequency (*f*). For determining the 1/*f* spectra with frequency, noise spectra with and without (consisting of preamplifier + thermal noise) passing current were taken. Then, the latter spectrum was subtracted from the former and we obtained pure 1/*f* spectrum. Noise spectra were taken in the frequency range 1–100 Hz. Average of 30 noise spectra was taken at each temperature. The schematic diagram of experimental set up used for performing the 1/*f* noise measurement is shown in Fig. 1.

III. RESULTS AND DISCUSSION

A. Current-voltage characteristics

Current-voltage (*I-V*) characteristics for Ni/n-GaN Schottky diodes were performed in the temperature range of 80–300 K. Fig. 2 shows the semilog forward bias *I-V* characteristics of Ni/n-GaN Schottky barrier diode in the temperature range of 80–300 K. The diode was fairly rectifying in the temperature range of 80–300 K with an ideality factor of 1.5 at 300 K. According to thermionic theory,[8] the current across the SBD is given by

$$I = I_s[\exp(qV/nkT) - 1], \tag{1}$$

where

$$I_s = AA^*T^2\exp\left(\frac{-q\phi_{bo}}{kT}\right). \tag{2}$$

Here, I_s is the saturation current, n is the ideality factor, V is the applied bias, T is the absolute temperature, q is the electronic charge, k is the Boltzmann constant, A is the effective Schottky contact area, A* is the effective Richardson coefficient of 26.8 Acm^{-2}K^{-2} for n-GaN,[27] and $q\phi_{bo}$ is the apparent zero bias Schottky barrier height. The value of the

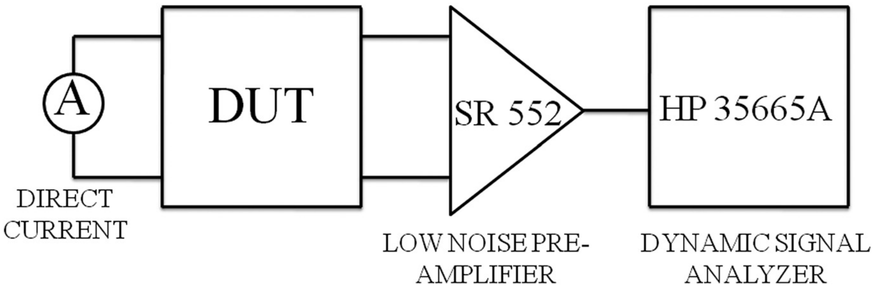

FIG. 1. Schematic of experimental set up for 1/*f* noise measurements.

ideality factor n is calculated from the slope of the linear region of the logI-V plot using the relation

$$n = \frac{q}{2.303kT}\left(\frac{dV}{d(logI)}\right). \tag{3}$$

The saturation current I_S is calculated from the y axis intercept of the logI-V plot. From I_S, ϕ_{bo} is calculated using the relation

$$\phi_{bo} = \frac{kT}{q}\ln\left(\frac{AA^*T^2}{I_s}\right). \tag{4}$$

With the help of Eqs. (3) and (4), the value of ideality factor (n) and apparent Schottky barrier height (ϕ_{bo}) is calculated at different temperatures in the range of 80–300 K.

The temperature dependence of the apparent SBH ϕ_{bo} and ideality factor (n) is shown in Fig. 3, and it was found that n increases while ϕ_{bo} decreases with decrease in temperature. The temperature dependence of n and ϕ_{b0} can be explained by the existence of Schottky barrier inhomogeneities at MS interface.[15–19] One of the major reasons behind the origin of Schottky barrier inhomogeneities is that the metal contacts are not epitaxially grown on n-GaN surface, so the interface is not atomically flat but rough. This will result into local variations of the electric field which in turn causes SBH to vary locally. So, it is reasonable to assume that SBH is not constant, but it varies spatially on the nanometer scale. The other reasons of the Schottky barrier inhomogeneities can be surface treatment, threading dislocation density, etc. Due to Schottky barrier inhomogeneities at MS interface, at lower temperatures, current dominantly flows through the patches of lower barrier height, so current conduction is dominated by the low ϕ_{b0} patches with larger n. Also, at lower temperatures, thermionic emission is no longer the dominant current transport mechanism and mechanisms like thermionic field emission (TFE), carrier recombination might dominate at low temperatures causing an increase in value of n. As temperature increases, patches of higher ϕ_{b0} take part in conduction process as carriers gain sufficient energy to surmount them. This causes n to be close to unity and apparent barrier height increases.

Werner and Güttler[28] proposed an analytical potential fluctuation model for explaining the electrical transport properties in Schottky contacts using Schottky barrier inhomogeneities. An inhomogeneous Schottky contact is characterized by a distribution of patches with low and high SBH. The spatial barrier inhomogeneities are described by considering that apparent SBH follows a Gaussian distribution given by[28]

$$P(\phi_{b0}) = \frac{1}{\sqrt{2\pi\sigma_s}}\exp\left[-\frac{(\overline{\phi_{b0}} - \phi_{b0})^2}{2\sigma_s^2}\right], \tag{5}$$

where $\overline{\phi_{b0}}$ and ϕ_{b0} are zero bias mean and zero bias apparent barrier height, respectively. σ_s is the standard deviation of Gaussian distribution, and it gives the information about Schottky barrier inhomogeneities. Current flowing across an inhomogeneous Schottky contact is calculated by integrating current (given by thermionic theory) over $P(\phi_{b0})$

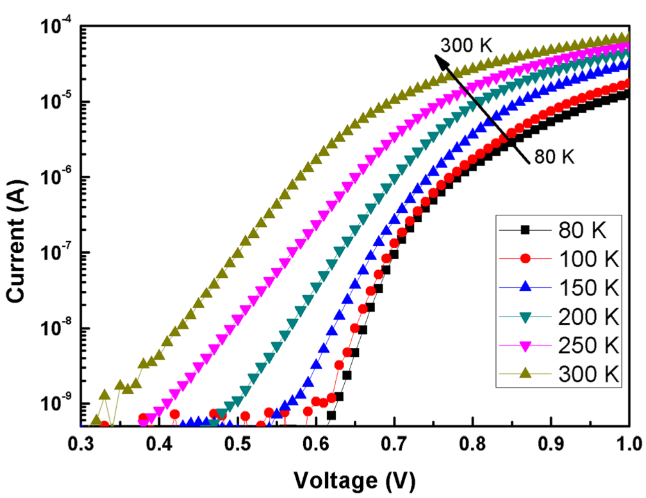

FIG. 2. Current-voltage (*I-V*) characteristics for Ni/n-GaN Schottky barrier diode at different temperatures ranging between 80 and 300 K.

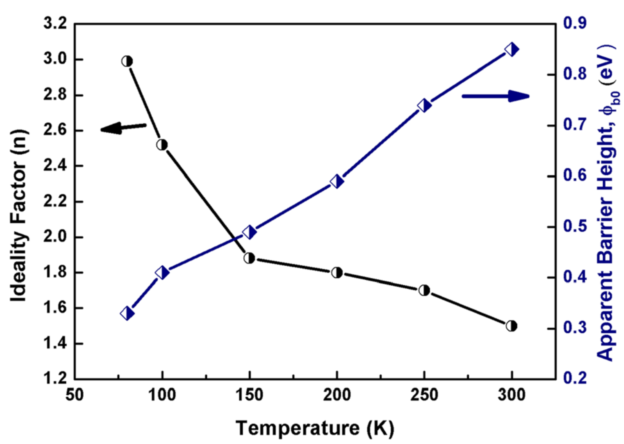

FIG. 3. Variation of ideality factor (n) and barrier height (ϕ_{bo}) calculated by *I-V* characteristics in the temperature range 80–300 K.

$$I(V) = \int_{-\infty}^{\infty} I(\phi_{b0,}V)P(\phi_{b0})d\phi, \tag{6}$$

where ϕ_{b0} is zero bias apparent barrier height. By performing some analytical calculations, I(V) and ϕ_{b0} are given as

$$I(V) = I_s \exp\left(\frac{qV}{nkT}\right)\left[1 - \exp\left(-\frac{qV}{kT}\right)\right], \tag{7}$$

$$\phi_{b0} = \overline{\phi_{b0}} - \frac{\sigma_s^2}{2kT}. \tag{8}$$

According to Eq. (8), a plot between ϕ_{b0} (in eV) and $(2kT)^{-1}$(in eV^{-1}) should yield a straight line with slope giving the value of σ_s, zero bias standard deviation, and y-intercept giving the value of $\overline{\phi_{b0}}$, zero bias mean barrier height. Fig. 4 shows theϕ_{b0} (in eV) versus $(2kT)^{-1}$(in eV^{-1}) for Ni/n-GaN SBD in the temperature range 80–300 K. Fig. 4 shows two straight line regions (80–150 K and 150–300 K) instead of one with transition somewhere in between 150 and 200 K. Both regions have different slopes and different intercepts. The value of $\overline{\phi_{b0}}$ and σ_s were found to be 0.67 eV and 68.5 meV in the temperature range 80–150 K and 1.36 eV and 161.2 meV in the temperature range 150–300 K, respectively. The values of σ_s (68.5 meV and 161.2 meV) cannot be neglected as compared to $\overline{\phi_{b0}}$ (0.67 eV and 1.36 eV) so MS interface is spatially inhomogeneous. The width of Gaussian distribution, σ_s gives the strength of barrier inhomogeneities. The magnitude of width of Gaussian distribution (σ_s) is 161.2 meV in 150–300 K which is around 2.4 times as compared to 68.5 meV in 80–150 K. This shows that diode is more homogenous in temperature range 80–150 K and less homogenous in the temperature range 150–300 K. The existence of a double Gaussian distribution in Schottky diode was already experimentally observed by ballastic electron emission microscopy (BEEM).[29,30] Moreover, our experimental findings of double distribution for Ni/n-GaN Schottky diodes in temperature range 80–300 K are experimentally supported by studies of Yildirim *et al.*,[15] Mamor,[16] Ravinandan *et al.*,[17] and Dogan *et al.*[18] Our experimental values of the zero bias mean barrier height, $\overline{\phi_{b0}}$, and zero bias standard deviation, σ_s, are in agreement with the studies of Yildirim *et al.*[15] on Ni/n-GaN Schottky diode. Yildrim *et al.*[15] found $\overline{\phi_{b0}}$ and σ_s as 0.72 eV and 82 meV in the temperature range 100–200 K, respectively, and 1.41 eV and 173 meV in the temperature range of 200–400 K, respectively.

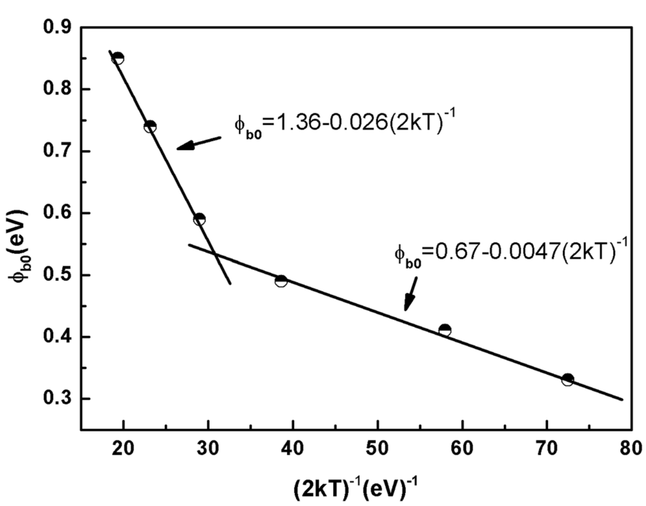

FIG. 4. Variation of ϕ_{b0} versus $(2\,kT)^{-1}$. The graph clearly shows the existence of two linear regions in the temperature range 80–150 K and 150–300 K.

B. Effect of Schottky barrier inhomogeneities on 1/f noise

In the previous Sec. III A, it was shown that Ni/n-GaN Schottky diode is spatially inhomogeneous in the temperature range 80–300 K. However, it was also demonstrated that the level of barrier inhomogeneities is more in the temperature range 150–300 K then in temperature range 80–150 K.

The spectral power density of voltage fluctuations, S_V, was investigated using the experimental set up as described earlier. Forward current across the diode was 50 μA and frequency was varied between 1 and 100 Hz. The temperature was varied between 80 and 300 K. At different temperatures between 80 and 300 K, spectral power density of voltage fluctuations, S_V, exhibited $1/f^{\gamma}$ dependence with γ ranging between 0.8 and 1.1. The spectral power density of current fluctuations, S_I was obtained from spectral power density of voltage fluctuations, S_V, using the relation,[24]

$$S_I = \frac{S_V}{\left(\frac{dV}{dI} - R_S\right)^2} = \frac{S_V}{\left[\frac{nkT}{q(I+I_S)}\right]^2}, \tag{9}$$

where R_S is the series resistance and I_S is the saturation current. The variation of spectral power density of current fluctuations, S_I, with frequency at different temperatures between 80 and 300 K is shown in Fig. 5. The variation of S_I with temperature at $f = 10$ Hz is shown in Fig. 6. In the temperature range 80–300 K, S_I was found to be decreasing with increase in temperature.

The decreasing trend of noise with increase in temperature for Ni/n-GaN Schottky diode in above experiment cannot be explained on the basis of Hsu's model and Luo's

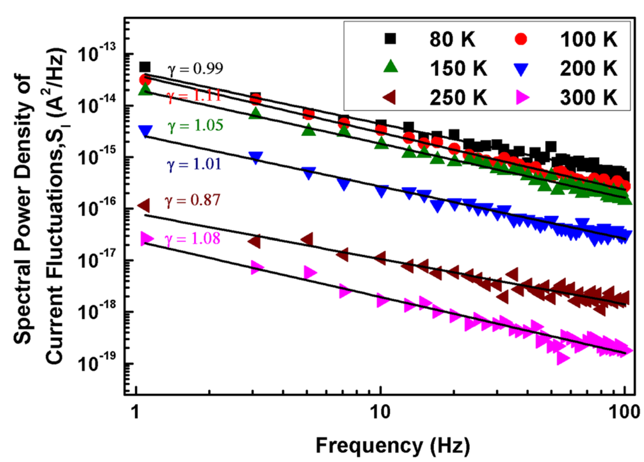

FIG. 5. Variation of spectral power density of current fluctuations S_I with frequency at different temperatures for the Ni/n-GaN Schottky diode at fixed forward bias current $I = 50\,\mu$A.

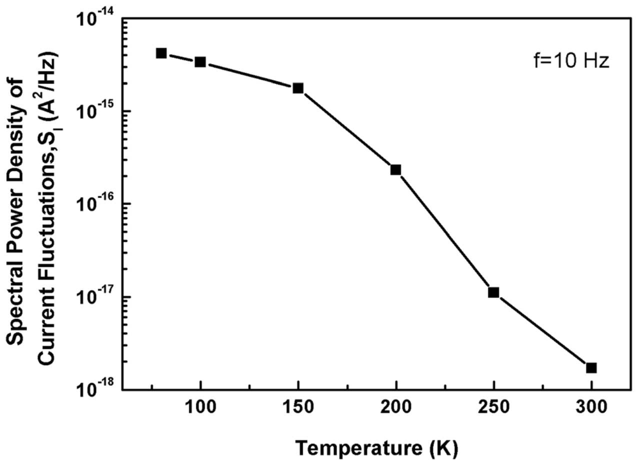

FIG. 6. Variation of spectral power density of current fluctuations S_I as a function of temperature T for Ni/n-GaN Schottky diode at fixed forward bias current $I = 50\,\mu$A and $f = 10$ Hz.

model. Both of these models assumed that the MS interface is spatially homogeneous. Hsu's model predicts noise to be independent of temperature while Luo's model predicts an increase of noise with temperature. Hsu's model is based upon assumption that trap states are uniformly distributed in space as well as in energy. This assumption might hold good in case of silicon (Hsu model is based on metal-silicon SBDs) but not in metal/GaN SBDs due to structural defects, threading dislocations, metal induced gap states, etc. Experimentally Hall *et al.*[31] on basis of their work on M/GaN SBDs found that current flow is modified due to presence of deep level centres acting as traps and these trap states are non-uniformly distributed in space as well as in energy (0.27–0.43 eV below conduction band edge). Luo's model also does not consider the role of interface states as well as Schottky barrier inhomogeneities in explaining the noise behaviour. However, role of interface states should be considered as these interface states are charged states, capture and emission of charge carries at these states (according to Shockley-Read-Hall statistics) yield a wide distribution of time constants and hence affect the noise properties.

According to thermionic emission theory,[8] current across metal-semiconductor interface depends exponentially on barrier height. Any small variation in SBH results in strong variation in the current. So, we can say that the noise behaviour of Ni/n-GaN Schottky diodes is correlated with the spatial inhomogeneities at the metal-semiconductor interface. The current fluctuations arise because of random capture and emission process of electrons at trapping states close to MS interface. This random process results in the fluctuations of the instantaneous interface charge Q by an amount δQ. The barrier height ϕ_{b0} is determined by the interface charge Q and any fluctuations in Q will lead to fluctuations in barrier height ϕ_{b0}. The fluctuations in the barrier height ϕ_{b0} cause strong fluctuations in the current due to the exponential dependence of barrier height on current.

If all the interface states are monoenergetic, then noise contribution due to capture and emission of electrons at interface states was given by Madenach and Werner[32] as

$$S_V^{mono}(f) = \alpha_{mono} N_T (1-F) \frac{\tau_{mono}}{1 + (2\pi f \tau_{mono})^2}, \tag{10}$$

$$\alpha_{mono} = \frac{4e^2 n_{i0} v_{th} S_e}{A C_R^2}, \tag{11}$$

$$\tau_{mono} = \frac{F}{v_{th} S_e n_{i0}}, \tag{12}$$

where N_T is the density of the monoenergetic interface states, F is the occupation of interface states by electrons, S_e is the capture cross section for electrons, v_{th} is the thermal velocity of the electrons, C_R is the capacitance of the depletion region, and $n_{i0}\left(= n_i \exp\left(\frac{-e\phi_{b0}}{kT}\right)\right)$ is the concentration of electrons at MS interface where n_i is the concentration of the electrons in the bulk.

According to Eq. (10), the noise spectra due to capture and emission of electron at monoenergetic interface state should follow Lorentzian curve. At lower frequency $(f \ll {}^1/_{\tau_{mono}})$, $2\pi f \tau_{mono} \to 0$ which gives $S_V = \alpha_{mono} N_T (1 - F)\tau_{mono}^2 =$ constant and at high frequency $(f \gg {}^1/_{\tau_{mono}})$, $S_V \propto {}^1/_{f^2}$.

However, it seems quite unpractical to consider that interface states available for the capture and emission of electrons are monoenergetic. A more realistic approach should consider that noise arises from the capture and emission of electrons at the interface states which are continuously distributed over energy. Madenach and Werner[32] recalculated the noise contribution with approximation given by Lee *et al.*[33] that integration of Lorentzian noise spectra of monoenergetic interface can be done over the energy E if number of interface states is much smaller than the number of electrons available for capture. Noise spectra due to capture and emission of electrons at the interface states which are continuously distributed over energy is given by[32]

$$S_V^{cont}(f) = \alpha_{cont} \frac{N_{SS}}{(2\pi f)^2 \tau_n} \ln[1 + (2\pi f \tau_n)^2], \tag{13}$$

$$\alpha_{cont} = \frac{2kTe^2}{A C_R^2}, \tag{14}$$

$$\tau_n = \frac{1}{v_{th} S_e n_{i0}}, \tag{15}$$

where N_{SS} is the continuous density of interface states, τ_n is the time constant for capture and emission of electrons, and integration is performed over occupation number F.

$S_V^{cont}(f)$ differs slightly from the $S_V^{mono}(f)$ and yields Lorentzian noise spectra. However, noise spectra in our case are not Lorenzian and it is described neither by Eq. (10) nor by Eq. (13). The reason for this discrepancy is that both of these equations have been derived by considering the fact that MS interface is electrically homogenous. From Eq. (15), it is clear that the capture time constant depends τ_n upon n_{i0}, the steady state electron concentration at MS interface which depends exponentially upon local barrier height ϕ_{b0}. Spatial fluctuation in the barrier height ϕ_{b0} yields spatial fluctuations in the capture time constant τ_n and this will change the noise behaviour. MS interface is already found to be electrically inhomogeneous for Ni/n-GaN Schottky barrier diodes, and spatial inhomogeneities are described by considering that SBH follows a Gaussian distribution given by Eq. (5). The noise contribution due to capture and emission of charge carriers at different barrier heights is considered as independent. The total noise spectrum is obtained by integrating all the noise contributions. Each contribution has to be weighed by probability distribution $P(\phi_{b0})$ and integrating over $\phi_{b0} - \overline{\phi_{b0}}$ resulting in noise spectra[32]

$$S_V(f) = \int_{-\infty}^{\infty} P(\phi_{b0}) S_V^{cont}(f) d(\phi_{b0} - \overline{\phi_{b0}}). \tag{16}$$

This noise spectra deviates from the Lorentzian noise towards 1/*f* noise with σ_s as the dominant parameter. Strength of the barrier inhomogeneities is correlated with σ_s. Higher the value of σ_s, higher the barrier inhomogeneities, higher is the deviation from Lorentzian to 1/*f* noise. The transition from Lorentzian to 1/*f* noise can be understood by defining a distribution function $g(\tau)$ of time constants for capture and emission process. This distribution function is calculated by changing $\phi_{b0} - \overline{\phi_{b0}}$ to τ

$$S_V(f) = \int_{0}^{\infty} S_V^{cont}(f) g(\tau) d\tau, \tag{17}$$

and $g(\tau)$ is given by[32]

$$g(\tau) = \frac{1}{\tau(2\pi\sigma_T)^{\frac{1}{2}}} \exp\left[-\ln^2\left(\frac{\tau/\tau_n}{2\sigma_T^2}\right)\right], \tag{18}$$

where $\sigma_T (= q\sigma_s/kT)$ is dimensionless equivalent to σ_s. As σ_s increases, the distribution of time constants broadens which results in an increase range of time constants for capture and emission process contributes to the noise spectrum. This will cause the deviation of Lorentzian spectra to 1/*f* noise spectra and hence spectral power density of current fluctuations decreases. So for Ni/n-GaN Schottky diodes, Schottky barrier inhomogeneities are more (higher value of σ_S) in the temperature range 150–300 K; hence, spectra deviate more and more from Lorentzian to 1/*f* which results in decrease of noise with temperature.

The noise behaviour in Ni/n-GaN Schottky diodes is also in agreement with qualitative studies of Güttler and Werner.[13] Güttler and Werner[13] attributed decrease in noise with temperature to Schottky barrier inhomogeneities at MS interface. According to their model, noise increases as long as $\sigma_S > 2$kT. In our case, we observe a drastic increase in noise from 300 to 150 K as $\sigma_S = 161.2$ meV which is much greater than 2 kT.

IV. CONCLUSIONS

The temperature dependence of 1/*f* noise in Ni/n-GaN SBD has been studied in the temperature range 80–300 K with frequency varying between 1 and 100 Hz. The existence of two linear regions in ϕ_{b0}versus$(2kT)^{-1}$ clearly indicates that the strength of Schottky barrier inhomogeneities is different in two temperature ranges (80–150 K and 150–300 K). At all temperatures, spectral power density of current fluctuations S_I varies as $1/f^{\gamma}$. The value of frequency exponent γ lies between 0.8 and 1.1. It is found that S_I decreases with increases in temperature. This behaviour is understood in the framework of spatial inhomogeneities model which attributes decrease in noise with increase in temperature to the spatial inhomogeneities in the SBH at MS interface. The decrease in noise with increase is temperature is due to higher level of Schottky barrier inhomogeneities at MS interface which deviates Lorentzian noise to 1/*f* noise. So, this study correlates the barrier inhomogeneities to the temperature dependent noise properties in Ni/n-GaN SBDs. Also, this experimental study suggests that low frequency noise characterization can be used as a tool for studying barrier inhomogeneities at metal-semiconductor interface in SBDs.

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