# Low-frequency noise in AlGaN/GaN MOS-HFETs

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A comparative study is presented of low-frequency noise in GaN-based metal-oxide-semiconductor heterostructure field effect transistors (MOS-HFETs) and HFETs. The Hooge parameter at zero gate bias was of the order of $10^{-3}$ for both types of device. The AlGaN/GaN MOS-HFETs exhibited extremely low gate leakage current and much lower noise at both positive and negative gate biases.

AlGaN/GaN heterostructure field effect transistors (HFETs) are expected to find applications in microwave and optical communication systems [1, 2]. Low frequency noise is one of the most important parameters for such applications. It was shown that the level of low frequency noise strongly depends on the gate leakage current $I_g$ even at $I_g/I_d < 10^{-4} - 10^{-5}$. ($I_d$ is the drain current) [3, 4]. Recently, novel AlGaN/GaN metal-oxide-semiconductor heterostructure field effect transistors (MOS-HFETs) with high-quality $SiO_2$/AlGaN interfaces have been demonstrated [5]. The devices had output characteristics similar to those of AlGaN/GaN HFETs. However, the introduction of $SiO_2$ reduced the gate leakage by approximately six orders of magnitude, which is extremely important for high-power and low noise applications. In this Letter, we report, for the first time, on the low-frequency noise in AlGaN/GaN MOS-HFETs with $SiO_2$ as a gate insulator.

The AlGaN/GaN heterostructures were grown by low-pressure metal organic chemical vapour deposition (MOCVD) on (0001) sapphire substrates. Both MOS-HFET and HFET devices were fabricated on the same wafer having an electron sheet density and Hall mobility close to $9 \times 10^{12}\,cm^{-2}$ and $1000\,cm^2/Vs$, respectively. For MOS-HFET structures, a 100 nm $SiO_2$ layer was deposited on the AlGaN/GaN heterostructure using plasma enhanced chemical vapour deposition (PECVD) on one half of the wafer. We studied 100 μm wide transistors with 10 μm gate length and 30 μm source-drain spacing. The large gate area and thick $SiO_2$ were chosen in order to study the gate leakage effects on the low frequency noise in both types of device.

The threshold voltages were –11 and –3 V, and subthreshold ideality factors 6.41 and 4.54 for the MOS-HFETs and the HFETs, respectively. The maximum gate current in the MOS-HFET was of the order of 10 pA, which was several orders of magnitude smaller than in the HFET. Maximum transconductances, $g_m$ = 26.5 and 45.5 mS/mm were measured for the MOS-HFET and HFET, respectively.

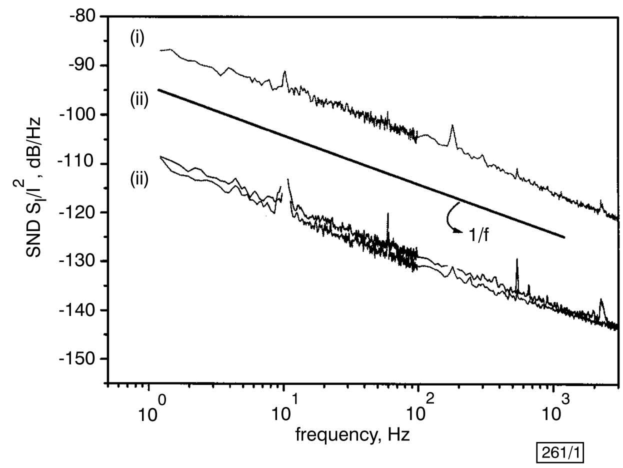


**Fig. 1** *Frequency dependence of spectral noise density (SND) in MOS-HFET and HFET structures on sapphire*

$V_d$ = 0.5 V, S/D = 30 μm
(i) HEMT, $V_g$ = –3 V
(ii) MOS-HFET, $V_g$ = –3 V
(iii) MOS-HFET, $V_g$ = 0 V

Fig. 1 presents the frequency dependence of the relative spectral noise density (SND) in the MOS-HFET and HFET structures under a drain bias $V_d$ = 0.5 V at different gate biases $V_g$. The measurements revealed that the low-frequency noise in both the MOS-HFET and HFET is typical $1/f$ noise under all bias conditions. To characterise the noise level the Hooge parameter α was calculated [6]:

$$\alpha = \frac{S_I}{I^2} f N \tag{1}$$

where $f$ is the frequency, and $N$ is the total number of carriers in the channel between the source and drain. The devices exhibited the same noise level at a gate bias of $V_g$ = 0 V resulting in a Hooge parameter of $\alpha = 8.7 \times 10^{-4}$. This value of α is somewhat less than the reported values in [4, 7, 8] for HFETs grown on sapphire. Lower values for α were also reported [9, 10].

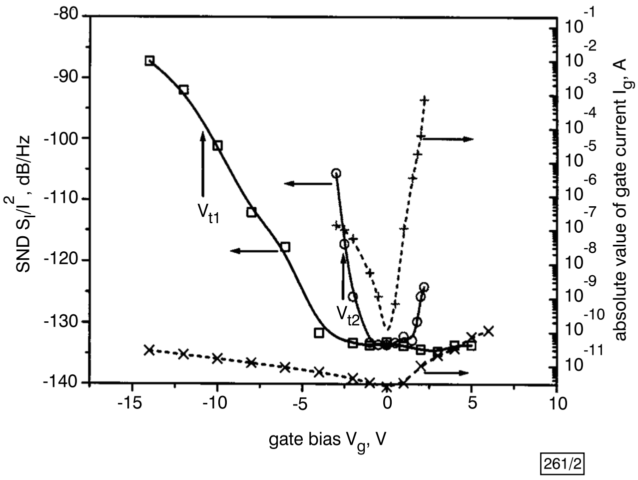


**Fig. 2** *Gate bias dependence of noise density at f = 200 Hz and gate current in MOS-HFET and HFET*

$V_d$ = 0.5 V
Also shown are threshold voltages $V_{t1}$ and $V_{t2}$ for MOS-HFET and HFET, respectively
○ SND in HFET
□ SND in MOS-HFET
+ $I_g$ in HFET
× $I_g$ in MOS-HFET

The gate bias dependence of the SND at frequency $f$ = 200 Hz and the gate current in MOS-HFET and HFET are compared in Fig. 2. A similar level of low-frequency noise at zero gate bias in both types of structure indicates that no traps or defects, which might degrade the device performance, were introduced by oxidation. In contrast MOS-HFETs and HFETs demonstrated rather different noise characteristics under applied gate bias. As in our previous publications [3, 4, 7], we attribute the sharp increase in noise density in the HFET to the high gate leakage current at high gate biases. It should be pointed out that another explanation for gate bias dependence of the noise is also possible [9]: the screening effect can govern the gate bias dependence of the noise. However, the noise in an HFET increases not only for negative gate voltage $V_g$ but also for positive $V_g$. That increase cannot be explained by the screening effect. It should be also mentioned that HFETs on the same substrate with identical current voltage characteristics but with a higher level of gate leakage current $I_g$ had a higher noise.

MOS-HFET structures had an extremely low gate leakage current and practically no gate voltage dependence for small values of gate bias $V_g$ (see Fig. 2). However for $V_g$ < –5 V the noise in the MOS-HFET increases sharply. Further experiments are needed in order to establish the nature of the noise dependence on the gate bias and/or on the drain current.

In conclusion, the low frequency noise properties of MOS-HFETs have been studied for the first time. It has been shown that the low frequency noise in MOS-HFETs with extremely low gate leakage current is less than in HFETs at both positive and negative gate biases. That makes the novel MOS-HFET structure a promising device for high frequency and high temperature low noise applications.

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