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Noise Analysis of AlGaN/GaN MOS-HFETs with Photochemical-Vapor Deposition SiO_2 Layer

Y. Z. Chiou[1], C. K. Wang[2], S. J. Chang[2], Y. K. Su[2], C. S. Chang[2], T. K. Lin[2], T. H. Fang[1] and J. J. Tang[1]

[1]Department of Electronics Engineering,
Southern Taiwan University of Technology, Tainan, Taiwan 710
Email:yzchiou@mail.stut.edu.tw
[2]Institute of Microelectronics & Department of Electrical Engineering
National Cheng Kung University, Tainan, Taiwan 70101

Abstract

The noises of AlGaN/GaN metal-oxide semiconductor heterostructure field-effect transistors (MOS-HFETs) and HFETs were investigated as functions of gate voltage and the drain-source distance in the low-drain bias. The normalized noise-power densities of the two HFETs were both proportional to V_{gs}^{-1} when the devices were biased at -4 V < V_{gs} < 0 V and were independent of the gate voltage when the devices were biased at V_{gs} > 0 V. Moreover, the normalized noise-power densities of both devices were reversely proportional to the drain-source distance when V_{gs} > 0 V. Also, all the experiment data can be well explained by Hooge's Law.

1. Introduction

Previously, we have shown that photochemical-vapor deposition (photo-CVD), using the deuterium (D_2) lamp as the excitation source, can grow high-quality SiO_2 layers used as the gate-oxide layers in nitride-based metal-oxide-semiconductor HFETs (MOS-HFETs)[1-3].

However, the low-frequency noise is one of the most important parameters of microwave devices. In this study, nitride-based metal-oxide-semiconductor heterostructure field-effect transistors (MOS-HFETs) and heterostructure field-effect transistors (HFETs) were both fabricated. The low-frequency noises of the fabricated devices were investigated and reported as functions of gate voltage and drain-source distance in the low drain-bias region.

2. Experiment

The structures of AlGaN/GaN MOS-HFETs and HFETs used in this study were all grown on c-face (0001) 2-inch sapphire (Al_2O_3) substrates by metalorganic chemical-vapor deposition (MOCVD). The structures consist of a 30-nm-thick low-temperature GaN nucleation layer, a 2-μm-thick unintentionally-doped GaN layer, a 5-nm-thick unintentionally-doped $Al_{0.22}Ga_{0.78}N$ spacer layer, a 15-nm-thick Si-doped $Al_{0.22}Ga_{0.78}N$ carrier-supplying layer ($n = 5 \times 10^{18}$ cm^{-3}) and a 4-nm-thick unintentionally doped $Al_{0.22}Ga_{0.78}N$ cap layer. For comparison, AlGaN/GaN HFETs, with exactly the same device structure, but without the photo-CVD oxide layer, were also fabricated.

3. Results and Discussion

A. The Effect of Gate Voltage at V_{ds} = 3 V:

Fig. 1(a) and 1(b) show measured room-temperature-normalized noise spectra of the fabricated MOS-HFETs and HFETs, respectively, in low-drain-bias regions. Figures 2(a) and 2(b) show normalized noise-power densities as functions of gate voltage (V_{gs}) (Fig. 2(a) V_{gs} < 0 V, 2(b) V_{gs} > 0 V) for the fabricated MOS-HFET and HFET biased at low drain voltage. Insert Fig. 2(a) and 2(b) show total channel resistance as functions of gate voltage.

B. The Effect of Drain-Source Distances for $V_{gs} \geq 0$ V

The normalized low frequency noise spectra of our fabricated MOS-HFETs and HFETs can all be reasonably well fitted by the 1/f law up to 1 kHz when devices were biased at linear region (i.e. V_g = 0 V, V_{ds} = 3 V). Fig. 3(a) and 3(b) show measured room temperature normalized noise spectra of the fabricated MOS-HFETs and HFETs, respectively, for different drain-source distance at V_{gs} = 0 V. It was found that the normalized noise-power densities of both devices were reversely proportional to the drain-source distance. Previously, we have demonstrated that the low-frequency noises of our MOS-HFETs and HFETs were dominated by the parasitic series resistance (R_s) when devices were biased before pinch-off region. It can be seen clearly that all these spectra can be fitted reasonably well by the 1/L (L:drain-source distance) curve up to 1 kHz. Moreover, it can also be clearly seen that these theoretical equations agree very well with the experimental results. Such a result again supports the assumption that total resistance (R_{total}) was dominated by series resistance (R_s) before device pinch-off.

4. Summary

The low-frequency noises of AlGaN/GaN metal-oxide semiconductor heterostructure field-effect transistors (MOS-HFETs) and heterostructure field-effect transistors (HFETs) were investigated as functions of the gate voltage and drain-source distance at low drain bias. At low drain bias, it was found that the measured noise spectra can fit well by the 1/f law up to 10 kHz. At 100 Hz, the normalized noise-power densities of the two HFETs were both proportional to V_{gs}^{-1} when the devices were biased at -4 V < V_{gs} < 0 V, and were independent of the gate voltage when the devices were biased at V_{gs} > 0 V. For the effect of each drain-source distance, it was found that the normalized noise-power densities of both devices were reversely proportional to the drain-source distance. Moreover, all the experiment data of the above two bias conditions can be explained well by noise theory and Hooge's law.

References

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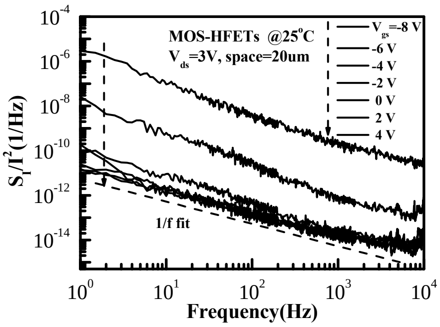

Fig. 1(a) Normalized-noise spectra of the fabricated MOS-HFETs.

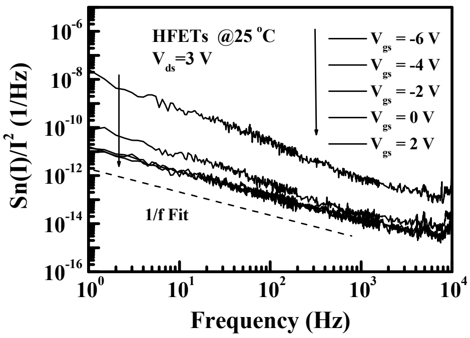

Fig. 1(b) Normalized-noise spectra of the fabricated HFETs.

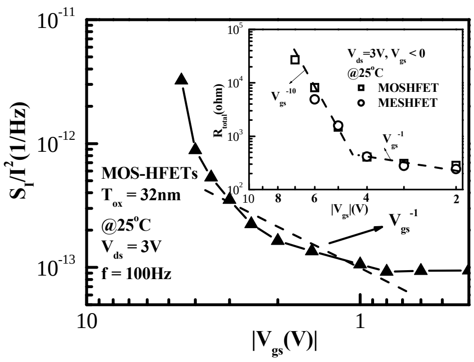

Fig. 2(a) Normalized noise-power densities as functions of gate voltage (V_{gs}) biased at low drain voltage, $V_{gs} < 0$ V.

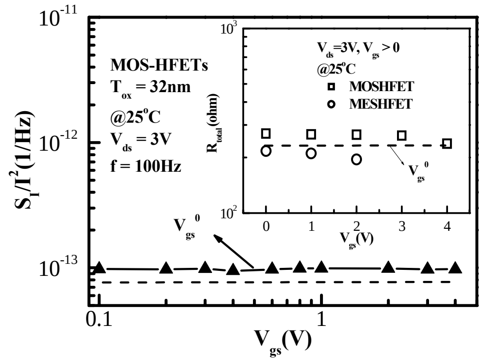

Fig. 2(b) Normalized noise-power densities as functions of gate voltage (V_{gs}) biased at low drain voltage, $V_{gs} > 0$ V.

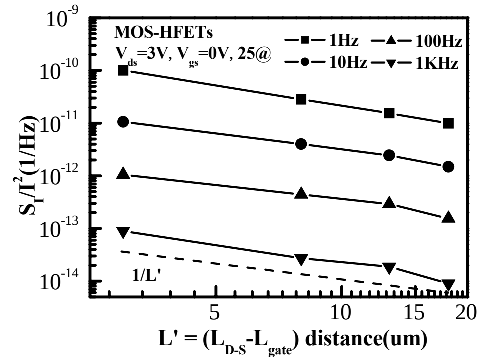

Fig. 3(a) Normalized-noise spectra of the MOS-HFETs for different drain-source distance at different frequencies.

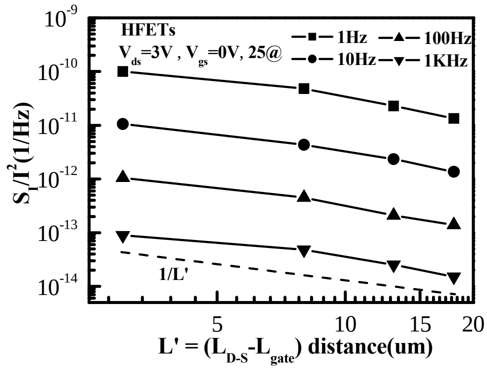

Fig. 3(b) Normalized-noise spectra of the HFETs for different drain-source distance at different frequencies.