Low frequency noise measurements as a characterization tool for reliability assessment in AlGaN/GaN high-electron-mobility Transistors (HEMTs)

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Abstract

Low frequency noise measurements were performed on AlGaN/GaN high-electron-mobility transistors (HEMTs) under different bias over the entire frequency range of 1Hz-100KHz. The transistor parameters and the drain noise spectra were presented. The noise spectra exhibited frequency dependence on the biasing point, and the drain current noise measurements are performed to analyze the origins of noise in channel or access regions.

INTRODUCTION

AlGaN/GaN High-Electron-Mobility Transistors (HEMTs) have received considerable attention for their potential use in high voltage, high power operations because of the high peak electron velocity, saturation velocity, and breakdown fields [1-2]. Even though some improvements were achieved recently by various approaches, GaN-based devices are still far to be as reliable as other devices[3]. Measurements of low frequency noise (1/f noise) are also an interesting and sensitive diagnostic tool to qualify the active layer and the technological process used to elaborate the structure. 1/f noise is also a non-destructive technique and can reveal the presence of several different noise sources (1/f, thermal noise floor, and also several trapping-detrapping processes).

The failure mechanisms in transistor depend on transistor design, technological processes used in manufacture, electrical working conditions like low and high electric field, low and high current density, static and dynamic regime and so forth, and environment conditions. Accordingly, the choice of the noise indicator for transistor reliability estimation depends on the transistor type and the conditions of its application.

In this paper, low frequency noise measurements were performed on AlGaN/GaN HEMTs under different bias over the entire frequency range of 1Hz-100kHz. The transistor parameters and the drain noise spectra were presented. The noise spectra exhibited frequency dependence on the biasing point, and the drain current noise measurements are performed to analyze the origins of noise in channel or access regions.

EXPERIMENTAL

The GaN epitaxial layers are grown by metal organic chemical vaporize deposition (MOCVD) based on SiC substrates. The layer structure consists of a 2um GaN buffer layer, a 20 nm thick of undoped Al_{0.22}Ga_{0.78}N barrier layer, and a 2nm GaN cap layer. The metallization consists of Ti/Al/Ni/Au with 20/180/55/45nm thicknesses respectively. The contacts are annealed in a rapid thermal annealing (RTA) process at 870°C for 50s in an N\textsubscript{2} atmosphere. A SiN\textsubscript{x} film is deposited by PECVD for surface passivation. A Schottky gate electrode is formed with E-beam evaporated Ni/Au. Prior to the deposition, conventional cleaning using organic solvents and treatment is performed. Gate recessing is performed using ICP-RIE. The device structure is shown in Fig.1.

The I-V characteristics are measured with an Agilent B1500A Semiconductor Device Analyzer. The 9812B Noise Analyzer is used to collect the current noise in a proper frequency range.
RESULTS AND DISCUSSION

A. IV characteristics before and after Light illumination

Figure 2 shows transfer current voltage characteristics of the device. The vertical axis represents the drain current, and the horizontal axis indicates the value of the gate voltage. In order to examine the relation between I and V, the data is plotted on a log scale as shown in the figure. The device has gone through a gate bias from -6V to 5V, while the device has gone through a gate bias from 5V to -6V. And the transfer curves are compared before and after light illumination as shown in the figure 2. During the experiments, we found that the transfer curve significantly changes when source and drain bias exchanged in the same device before light illumination.

B. The drain current noise spectral as a function of frequency at different gate bias voltage

The drain current noise at different gate bias was measured as a function of frequency. Figure 4 shows the drain current noise of the same device before light illumination. In the noise spectrum, several Lorentzians representing generation-recombination (GR) behavior are observed. This may be caused by the moving up of the traps during carrier injection. When the trapping and detrapping appear more frequency, the device becomes noisier. A device becomes less noisy because the filled traps prevent carrier exchange between the conduction bands and trap level.

CONCLUSIONS

The current voltage characteristics of the device are compared before and after light illumination. The drain current noise at different gate bias was measured as a function of frequency. Several Lorentzians representing generation-recombination (GR) behavior are observed. This may be caused by the moving up of the traps during carrier injection.

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REFERENCES

ACRONYMS

HEMT: high-electron-mobility Transistors