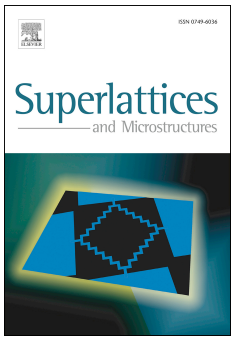
Accepted Manuscript



Effects of trap density on drain current LFN and its model development for E-mode GaN MOS-HEMT

D.K. Panda, T.R. Lenka

PII: S0749-6036(17)31926-2

DOI: 10.1016/j.spmi.2017.09.045

Reference: YSPMI 5281

To appear in: *Superlattices and Microstructures*

Received Date: 13 August 2017

Revised Date: 24 September 2017

Accepted Date: 25 September 2017

Please cite this article as: D.K. Panda, T.R. Lenka, Effects of trap density on drain current LFN and its model development for E-mode GaN MOS-HEMT, *Superlattices and Microstructures* (2017), doi: 10.1016/j.spmi.2017.09.045.

Effects of Trap Density on Drain Current LFN and its Model Development for E-mode GaN MOS-HEMT

D. K. Panda and T. R. Lenka
Microelectronics and VLSI Design Group, Department of Electronics and Communication Engineering,
National Institute of Technology Silchar, Assam, 788010, India
E-mail: d.panda.2016@ieee.org, t.r.lenka@ieee.org

Abstract

In this paper the drain current low-frequency noise (LFN) of E-mode GaN MOS-HEMT is investigated for different gate insulators such as SiO_2, $Al_2O_3/Ga_2O_3/GdO_3$, HfO_2/SiO_2, La_2O_3/SiO_2 and HfO_2 with different trap densities by IFM based TCAD simulation. In order to analyze this an analytical model of drain current low frequency noise is developed. The model is developed by considering 2DEG carrier fluctuations, mobility fluctuations and the effects of 2DEG charge carrier fluctuations on the mobility. In the study of different gate insulators it is observed that carrier fluctuation is the dominant low frequency noise source and the non-uniform exponential distribution is critical to explain LFN behavior, so the analytical model is developed by considering uniform distribution of trap density. The model is validated with available experimental data from literature. The effect of total number of traps and gate length scaling on this low frequency noise due to different gate dielectrics is also investigated.

Keywords: 2DEG; GaN; High –k; MOS-HEMT; TCAD

1. Introduction

Recently GaN HEMTs are emerged as potential candidate for power-electronics, RF and low noise applications [1-5]. Due to its inherent material properties such as large and direct energy band gap, high breakdown field strength, high electron drift velocity and superior thermal and chemical properties, GaN HEMT based MMIC transceivers show superior performances as compared to other devices [1, 6]. On the other hand one of the major disadvantages of these devices is that it has higher gate leakage current which degrades the device performance [7]. In order to avoid this problem different dielectrics and multilayer insulator stacks have been used beneath the gate [8-10]. In order to maintain good channel modulation different high-k insulators are used as oxide layer [11]. Due to the inherent material properties of GaN, these devices are generally normally-on [1]. But normally-off (E-mode) devices have added advantage in simpler circuit design and low power consumption due to the elimination of negative power supply [3]. In order to obtain normally-off operation of GaN MOS-HEMT, gate recess technique is proposed in various literatures [13-14].

Different oxides such as SiO_2, Al_2O_3 have been reported as gate dielectrics for GaN MOS-HEMTs [11]. In order to enhance the device performance other high-k dielectrics such as HfO_2 and La_2O_3 and composite dielectrics such as $Al_2O_3/Ga_2O_3/GdO_3$, HfO_2/SiO_2, La_2O_3/SiO_2 also have been reported in literatures [11, 15]. Although these high-k dielectric based gate-stack materials enhance the DC characteristics of the device, it has major impact on low frequency noise performance and reliability of the device [15]. So in this paper the different issues of low frequency noise in GaN MOS-HEMT with different trap densities are investigated using commercially available ATLAS TCAD tool [16]. Additionally, the effects of gate length scaling trends, number of traps and its energy distribution on drain current LFN of GaN MOS-HEMT is also investigated.

Low frequency noise is one of the most important noise sources in any semiconductor device as these are up converted to microwave frequencies which may degrade the circuit performance [17]. But the origin of this noise is still in infant stage of research. These 1/f noises are mainly classified into two types *i.e*. drain current 1/f noise and gate current 1/f noise. There are mainly two models available in literature which explain the origin of drain current 1/f noise. The first one is the McWhorter model [18] which is based on electrons fluctuation whereas the second one is the Hooge's model [19] which is based on mobility fluctuations due to the random phonon scattering.