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ORIGINAL PAPER

# Charge Density Based Small Signal Modeling for InSb/AlInSb Asymmetric Double Gate Silicon Substrate HEMT for High Frequency Applications

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## Abstract

This paper proposes the Asymmetric Double Gate Silicon Substrate HEMT (ADG-Si-HEMT) to study the carrier concentration and intrinsic small signal parameters of the InSb/AlInSb silicon wafer DG-HEMT device. The HEMTs work as a three-port system and the device is named Asymmetric Double Gate HEMT when the top and bottom gates are biased with different gate voltages. The position of quasi-Fermi energy levels ($E_f$) is used to investigate the modulation of back-channel charge density caused by the front gate voltage. Also, the small signal model is obtained for a various parameters such as cut off frequency, gate to source capacitance and transconductance. To enhance device operation, the effects of the following factors are being investigated delta doping, drain current for various top and bottom gate voltages. The transconductance 2390 Sm/mm for $V_{fg} = 0.2$ V and cut off frequency around 197 GHz for $V_{bg} = 0.3$ are obtained. The analytical results are compared to the results of the Sentaurus 3-D TCAD simulation. Because of the variation in threshold voltage and modifying carrier density in dual channels, the asymmetric biassing approach has a wide range of mixed applications.

**Keywords** Indium Antimonide · TCAD · Double gate HEMT · Semiconductor · Capacitance

## 1 Introduction

In this article, InSb based asymmetric HEMTs are presented to enhance the performance of the HEMT. The Indium Antimonide (InSb) based High Electron Mobility Transistors (HEMTs) are the most suitable for high-speed applications due to their highest electron mobility (30,000 cm2 $V^{-1}S^{-1}$) and high saturation velocity ($5 \times 10^7$ cm/s) than the other known compound semiconductors [1–3]. HEMTs are symmetric or asymmetric, depending on how the top and bottom gates are biased [4, 5].

As asymmetric DG-HEMT, the potential well is formed perpendicular to the interface between layers AlInSb and InSb because of their bandgap differences, and charged electrons are transferred from the doped (delta doping- δ) layer to the InSb layer [6]. The accumulation of transferred electrons in the narrow bandgap material (InSb) is referred to as a potential well or a two-dimensional electron gas(2DEG) [7]. The Coulomb scattering is reduced in the high electron mobility transistor because the electrons are separated from the donor atoms. The electrons are permitted to move in the vertical direction of an interface and the concentration of electrons depends on the gate bias and delta doping of the barrier layer [8–12].

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