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AlGaN/GaN Heterostructure Field-Effect Transistors (HFETs) Model Including Impact Ionization Rates

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Abstract: Hot carrier effects in semiconductors are crucial phenomena or electron devices, since they play an important role in the device. One of the most powerful tools to describe hot carrier effects is ensemble Monte Carlo (EMC) simulation. This article reports the development and application of a Two-dimensional self-consistent Monte Carlo simulator for electron transport in wurtzite phase AlGaN/GaN heterostructure (HFETs). The properties of AlGaN/GaN HFETs at the higher ambient temperature and doping concentration are described and evaluated. It is shown that the saturation drain current and peak transconductance of the devices investigated decrease similarly with increased temperature with respect to their room temperature values. On the other hand, the higher acceptor and donor concentration are favourable for restraining the shifts of threshold voltage in the AlGaN/GaN HFET.

Key word: AlGaN/GaN heterostructure field-effect transistors; high ambient temperatures; donor concentration; acceptor concentration.

I. INTRODUCTION

Group III-V nitrides semiconductors have been a great interest for researchers since the invention of high electron mobility transistors by Mimura and Yokoyama in 1980 [1-2]. Even though silicon is the most widely used material in today's electronics, compound electronics exhibits functions beyond the physical limits of the electronic properties of silicon [3]. The great interest raised by AlGaN/GaN (HFETs) in the international semiconductor scientific community in general, for high power, high temperature, and high frequency operation, mainly because of their wider band gap, high breakdown field and saturated drift velocity. One fundamental cause of breakdown in devices operatingat high voltages is impact ionization, where in, under the influence of an applied electric field, free electrons traveling with sufficient kinetic energy can cause transitions of bound electrons from the valence band to the conduction band, generating additional electron-hole pairs. With a wider energy gap, a higher magnitude of electric field would be required to initiate an impact ionization event. High break down fields also make it possible to design devices with thinner layers. Higher saturated drift velocities allow for higher current drive, and large thermal conductivities translate into more efficient heat dissipation in the devices.This paper provides the first Two-dimensional self-consistent Monte Carlo simulation for electron transport in the wurtzite phase AlGaN/GaN heterojunction (HFET) in the presence of the impact ionization effect, which is expected to be a crucial factor at large drain voltages causing a breakdown of the device. In next section, results of the homogeneous transport simulation are presented. Section III describes procedure of the device simulation. The results of the device simulation are presented in Sections IV and V.

II. MODEL DESCRIPTION

Fig. 1 shows the simulated $Al_{0.2}Ga_{0.8}N$/GaN HFET structure. The device consists of a $30\ nm$ top $Al_{0.2}Ga_{0.8}N$ layer with doping density of $1x10^{16}cm^{-3}$. An electron concentration of $3x10^{18}cm^{-3}$ is assumed for the source and darincontact regions. The overall device length is $3\ \mu m$ in the $direction$ x and the device has a $0.2\ \mu m$ gate length and $0.25\ \mu m$ source and drain length. The GaN is p type with a net hole density of $2x10^{17}cm^{-3}$ and the substrate is

p-GaN ( ). The effective source to gateand gate to drain separation are 0.8 and