Comparison of High Field Electron Transport in Wurtzite Phase of GaN and AlGaN

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Abstract— **The results of an ensemble Monte Carlo simulation of the steady-state and transient electron drift velocity as a function of applied electric field in GaN and AlGaN are presented. The effect of temperature and doping dependencies of electron drift velocity in these structures have been calculated. The following scattering mechanisms, i.e, impurity, polar optical phonon and acoustic phonon are included in the calculation. The maximum electron drift velocity that is obtained at room temperature for 10^{23} m^{-3} donor concentration is 2.2×10^{7}cm/s for both GaN and AlGaN materials. For high applied electric field, transient electron drift velocity shows a significant overshoot in two semiconductors.**

Keywords-: *Ensemble Monte Carlo, transient, Overshoot, drift velocity.*

I. INTRODUCTION

In recent years, nearly all electronic and optoelectronic devices have been realized using alloys of III-V materials, like group III-nitrides, GaN, AlN, and InN [1-4]. While GaN has been extensively studied [5-6], AlGaN has yet to examined to the same extent. It is considered reasonably well established that the electron drift velocity dependence on electric field in group III-nitrides have a region of negative differential (NDR) conductivity. The mechanism which provides for bulk negative differential resistance is a field induced hot electron transfer from a low energy, high mobility conduction band minimum to a higher energy, low mobility satellite valley. In addition, to observe NDR in bulk semiconductors, a well-defined threshold field as well as sufficiently large intervalley separation energy must exist. Different separation energies are predicted to give different NDR characteristics, thus providing a degree of engineering freedom in the design of real-space microwave oscillators [5-9]. The experimental determination of the peak electron velocity in a device which exhibits NDR is difficult since dipole domain formation disturbs the uniform carrier concentration needed to determine the carrier velocities. Consequently much of the information available on the peak electron velocity and threshold field is obtained using theoretical methods, particularly those based on Monte Carlo calculations. The Monte Carlo results are only as reliable as the input material parameters used in the simulation which are typically not all known with sharp precision. In order to use Monte Carlo techniques for semiconductor device simulation, it is of principle importance to determine a reliable set of input parameters for each material system studied. In general, one adjusts the lesser known parameters, those not directly measurable, in order to agree with experimental measurements of the velocity-field characteristic. The comparison to experimental measurements, when available, serves as a control on the Monte Carlo calculations. The effects of a particular device geometry on the calculations can then be completely isolated since any difference between the calculated bulk and device quantities must be due solely to the device geometry.

The Monte Carlo method provides an additional advantage in that it can be used as a theoretical laboratory in that parameters can be varied at will and their effects on observables assessed. The method provides a very powerful present herein a series of computer experiments in which the effects of variations in the polar optical phonon energy, dielectric constants, effective masses and central to satellite valley separation energy on the steady-state electron velocity-field relatioship for AlGaN are determined [8-11].

The present work studies the high-field transport properties for electrons in bulk GaN and AlGaN in both steady-state and transient situations using ensemble Monte Carlo. It's organized as follows. Details of the simulation model which is used in this work are presented in Sec. II, and results for simulation are interpreted in Sec. III-1 for steady-state and Sec. III-2 for transient situation.

II. SIMULATION MODEL

The ensemble Monte Carlo method used as the basis for this work was developed in Sabzevar and has been used extensively in the study of the electronic properties of many semiconductors and device structures.
At the start of each simulation, ten thousand electron particles are distributed in momentum space according to a 300 K