Three-Valley Model For The Study Of Electron Transport Properties At Very High Electric Field In Bulk GaSb, $Ga_{0.5}Sb_{0.5}As$ and GaAs Materials

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Abstract— **Electron drift velocity simulation results are presented for bulk GaSb, $Ga_{0.5}Sb_{0.5}As$ and GaAs based on a three-valley Monte Carlo model. Our velocity-field results at 300 K are in good agreement with available experimental data. It is found that GaSb exhibits an extremely low peak drift velocity at room temperature 0.25×10^5 ms^{-1}, at a doping concentration of 10^{17} cm^{-3} in comparison to GaAs. All dominant scattering mechanisms in the structure considered have been taken into account. For all materials, it is found that electron velocity overshoot only occurs when the electric field is increased to a value above a certain critical filed, unique to each material. This critical field is strongly dependent on the material parameters.**

Keywords-: *Velocity overshoot; critical field; doping concentration; drift velocity.*

I. INTRODUCTION

GaSb and related compounds have begun to generate a great deal of interest for a range of electronic and optical applications in recent years [1-3]. The growth of GaSb by metal organic chemical vapor deposition [4-5], and molecular beam epitaxy [4] has led to the development of resonant tunneling devices [6-9], infrared lasers [10], photo diodes [11], long wavelength infrared detectors [12], electro optic modulators[13], and second-harmonic generators [14]. A rather unique feature of GaSb is that the L valley lies only about 85 meV above the Γ valley. Hence, it barely qualifies as a direct-gap semiconductor. It, therefore, becomes possible to easily convert the material into an indirect band structure either by applying suitably large magnetic fields [15], static pressure [16], or through novel quantization effects [17]. For instance, quantum confinement or the growth of a few mono layers of AlSb within a GaSb quantum well has been shown to push the Γ valley above the L valley energy minima. This is useful, since the selection rule forbids inter subband absorption of normally incident light for a spherical constant-energy surface. However, with an ellipsoidal constant-energy surface, such as the L band of GaSb, inter subband transitions become allowed. This feature opens up possibilities for long-wavelength optical direction. Another advantage of GaSb is that it provides for type II band alignment in super lattices and quantum wells when used in conjunction with the InAs system. Such structures are being recognized as promising candidates for mid-infrared lasers due to the inherent suppression of internal electron-hole recombination. The Auger rates have also been shown to be greatly reduced in the GaSb based super lattices [18-19]. Furthermore, as the GaSb/InAs share no common cation or anion, one can fabricate either an InSb-like or a GaAs-like interface simply by changing the growth sequence. Different vibrational properties are expected to result [20], and the electronic properties of the confined carrier gas are correspondingly affected [21-23].

GaSb and GaAs are not used in the semiconductor industry for their mechanical characteristics. While sharing many of the same mechanical properties of silicon, it is significantly weaker, with its Young's modulus only %54 that of silicon. It, like silicon, is also very brittle and thus offers no advantages in terms of mechanical performance. GaAs contains more crystal defects than high quality silicon and, of these, arsenic precipitates are of paramount importance in determining fracture strength. For a normal distribution of arsenic precipitates in a large sample, such as a wafer, there will always be at least one defect large enough to cause small load fracturing. However, for small samples of materials, it is quite common to have limited defect size, which allow the manufacture of high stress structures out of macroscopically low stress materials. Due to the fact that GaAs is not an elemental structure, it exhibits some mechanical properties that would not be expected from other materials. In GaAs, the electron cloud tends to shift towards the arsenide atoms, which creates a dipole moment along the [111] axis. This causes the eight [111] surfaces to have differing concentrations of Ga and As atoms. As a result, the [111] planes are much tougher than expected. This toughening causes the [110] planes to be the primary fracture points. GaAs and GaSb also have a thermal conductivity that is less than one-third that of silicon and one-tenth that of copper, which makes it a poor conductor. The