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TWO DIMENSIONAL MOBILITY IN GALLIUM NITRIDE (GaN) SINGLE QUANTUM WELL AND GALLIUM ARSENIDE (GaAs) SINGLE QUANTUM WELL: A COMPARATIVE STUDY

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Abstract:
In this paper, the authors have calculated the two dimensional mobility in GaN and GaAs as a function of temperature and donor concentration taking into account the different lattice scattering mechanisms, namely Ionised Impurity scattering and Acoustic phonon scattering. A comparative study of two dimensional mobility of GaN and GaAs has been made.

I . INTRODUCTION

GaN is a wide bandgap semiconductor and has a large breakdown field, so it is extensively used in high power and high frequency devices [1].GaAs is a compound semiconductor used for manufacturing of high frequency microwave and Integrated circuits in LED and semiconductor laser diodes [2].

In order to understand the transport characteristics of these materials it is necessary to know the low field two-dimensional mobility of these materials .In this light, the authors have calculated the two-dimensional mobilities of GaN and GaAs incorporating acoustic phonon and ionized impurity scatterings. A comparative study of the mobilities has also been made and the results agree with the references [3,4].

II . ANALYTICAL MODEL

In the case of calculation of GaN ,the band gaps of AlGaN and GaN are taken as 4.2eV and 3.44 eV respectively [5].We have assumed the bandgap discontinuity in the well and barrier semiconductors to be distributed to about 60% on the conduction band and 40% on the valence band. The conduction band offset for the AlGaN/GaN QWs is much higher than the Fermi energy E_f, so the GaN square well can be assumed to be infinite.

In the case of calculation of GaAs ,the band gaps of AlGaAS and GaAs are taken as 1.56 eV and 1.4 eV respectively [6].Similar to GaN QWs we have assumed the bandgap discontinuity in the well and barrier semiconductors to be distributed to about 60% on the conduction band and 40% on the valence band. The conduction band offset for the AlGaAs/GaAS QWs is much higher than the Fermi energy E_f, so the GaAs square well can also be assumed to be infinite.

We consider a rectangular Cartesian coordinate system with z-axis perpendicular to the interfacial planes so that the 2D transport occurs parallel to the xy plane. The electric field ε is assumed to be along x-axis and the non-quantizing magnetic field B along z-axis. The carrier distribution function can be written as:

$$f(k) = f_0(E) - \left(\frac{e\hbar}{m^*}\varepsilon\right)\frac{\partial f_0}{\partial E}\left[k_x\xi_x(E) - \omega_B k_y \xi_y(E)\right] \quad (1)$$

where k is the 2D wave vector of holes with energy E, $f_0(E)$ is the equilibrium Fermi- Dirac function, e is the carrier charge, is Planck's constant divided by 2π , m* is the electron effective mass, k_x and k_y are the x- and y-components of k, $\omega_B = \frac{eB}{m*}$ is the cyclotron resonance frequency, and ξ_x and ξ_y are the perturbation functions.

The perturbation functions obtained from the Boltzmann transport equation are:

$$\xi_x(E) = \frac{\tau(E)}{1 + \omega_B^2\,\tau^2(E)} \quad (2)$$

$$\xi_y(E) = \frac{\tau^2(E)}{1 + \omega_B^2\,\tau^2(E)} \quad (3)$$

here, $\tau(E)$ is the combined relaxation time for all the scatterings.

$$\tau^{-1}(E) = \tau_{ac}^{-1}(E) + \tau_{Ii}^{-1}(E) + \tau_p^{-1}(E) \quad (4)$$

where $\tau_{ac}(E)$[7] is the relaxation time for acoustic phonon scattering and $\tau_{Ii}(E)$[8] is the relaxation time for ionised impurity scattering and $\tau_p(E)$[9] is the relaxation time for piezoelectric scattering. The Mobility μ is given by the equation:

$$\mu = \frac{e\tau(E)}{m*} \quad (5)$$

III . RESULTS ANALYSIS

Figure 1 and 2 shows the calculated two dimensional mobility in GaN and GaAs as a function of temperature with acceptor concentration (Na) of 2×10^{13} cm^{-3} and donor concentration (Nd) of 5×10^{13} cm^{-3} and acceptor energy(Ea) and donor energy(Ed) as 5.5×10^3 eV.

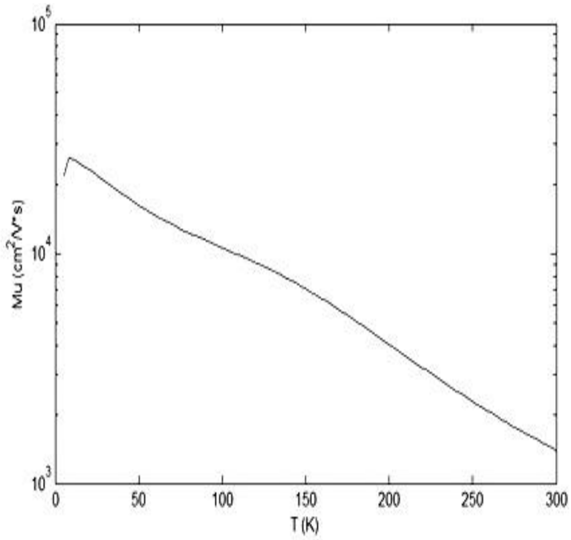

Fig 1: Two dimensional mobility in GaN as a function of temperature.

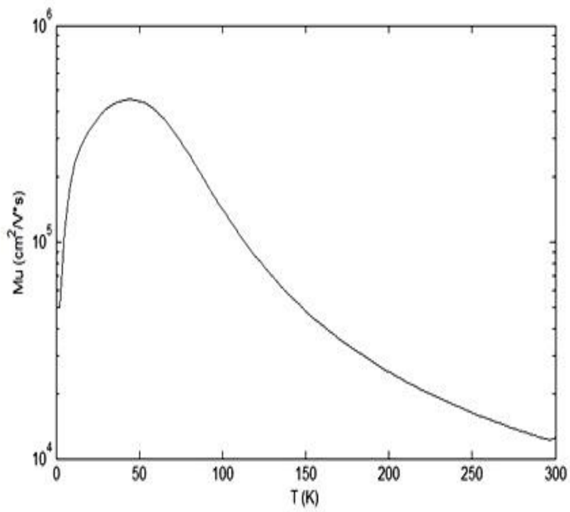

Fig 2: Two dimensional mobility in GaAs as a function of temperature.

It is seen from the figures that the two dimensional mobility of GaN is approximately equal to or greater than 10^5 cm^2/V-s and that the two dimensional mobility of GaAs is greater than 10^4 cm^2/V-s.

Figure 3 and 4 shows the calculated two dimensional mobility in GaN and GaAs as a function of donor concentration(Nd) energy (Ea) and donor energy (Ed) as 5.5×10^{3}eV.

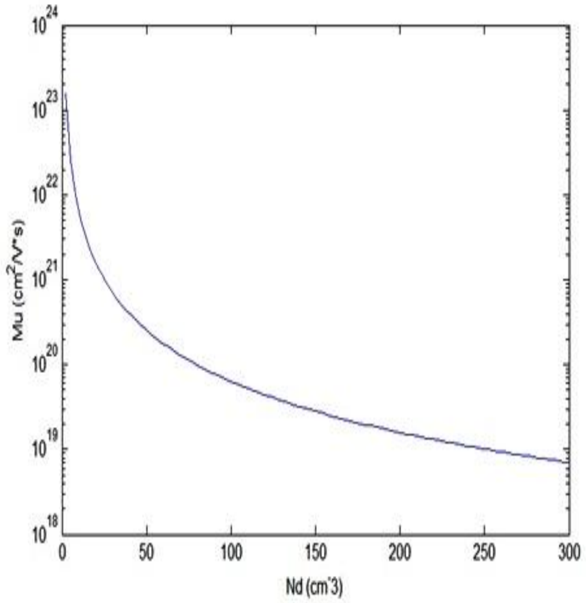

Fig 3: Two dimensional mobility in GaN as a function of donor concentration

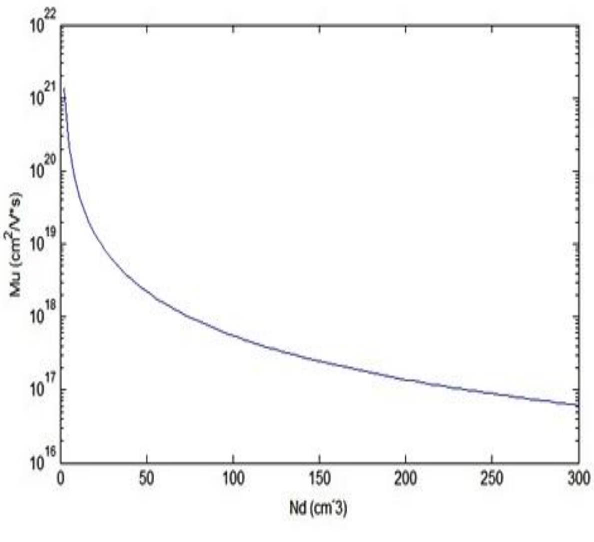

Fig 4: Two dimensional mobility in GaAs as a function of donor concentration

It is seen from the figures that the two dimensional mobility of GaN is higher than that of the two dimensional mobility of GaAs with increase in temperature and donor concentration [10].

considering the ionised impurity scattering with acceptor concentration (Na) of 2×10^{13} m^{-3} , temperature T = 300 K and acceptor

IV . CONCLUSION

We have calculated and presented a comparative study of two dimensional mobility as a function of temperature and donor concentration in GaN and GaAs. We have also given the variations of the mobility with respect to temperature considering the Acoustic deformation and Ionised impurity scatterings mechanisms. The two dimensional mobility of GaN is greater than the two dimensional mobility of GaAs. So, GaN is preferred for high speed and high frequency devices [11] as compared to GaAs.

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