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Ballistic and scattering limited mobility in GaN Single quantum well and Al0.25Ga0.75N/GaN superlattice MOSFET: A Comparative Study.

[1]Palasri Dhar , [2]Antara Ghosal, , [3]Anurima Majumdar, , [4]Dr. Sunipa Roy, [5]Hridika Saha
[1,2,3,4,5]Guru Nanak Institute of Technology, Nilgunj Rd, Sodepur,Kolkata- 700115

Abstract:
In this paper, the authors have calculated the two dimensional mobility in GaN single quantum well and ballastic mobility of Al0.25GaN0.75/GaN Superlattice MOSFET as a function of gate length .In the case of two dimensional mobility in GaN single quantum well the different lattice scattering mechanisms, namely ionised impurity scattering and acoustic phonon scattering are taken into account. A comparative study of two dimensional mobility of GaN single quantum well and ballastic mobility Al0.25GaN0.75/GaN Superlattice MOSFET 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]. In order to understand the transport characteristics of these materials it is necessary to know the low field two-dimensional mobility of these materials . Terahertz (THz) plasmonic devices such as AlGaN/GaN heterostructures are getting close to being commercialized. In this light, the authors have calculated the two-dimensional mobilities of GaN incorporating acoustic phonon and ionized impurity scatterings.The ballastic Mobility of AlGaN/GaN heterostructure as a function of gate length is also calculated.A comparative study of the mobilities has also been made and the ballistic mobility is higher than the scattering limited mobility .The results agree with the references [2,3].

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 [4].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 Al0.25GaN0.75/GaN Superlattice MOSFET is much higher than the Fermi energy E_f , so the GaN square well can be assumed to be infinite[5].

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:

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

where k is the 2D wave vector of holes with energy E, f0(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, kx and ky are the x- and y-components of k, is the cyclotron resonance frequency, and ξx and ξy are the perturbation functions.

The perturbation functions obtained from the Boltzmann transport equation are:

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

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

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

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

where τac(E)[6] is the relaxation time for acoustic phonon scattering and τIi(E)[7] is the relaxation time for ionised impurity scattering and τp(E)[8] is the relaxation time for piezoelectric scattering. The Mobility is given by the equation:

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

In the case of calculation of Al0.25GaN0.75/GaN Superlattice MOSFET ballistic mobility [9],[10] (i.e. the electron mobility limited by the device contacts given (for the degenerate 2DEG) by :

$$\mu_{bal} = \frac{2}{\pi}\frac{qL}{m_n v_F}$$

Here **q** is the electronic charge**, L** is the gate length, **m$_n$** is the electron effective mass, √ is the Fermi velocity, and n_s is the electron sheet density.

III . RESULTS ANALYSIS:

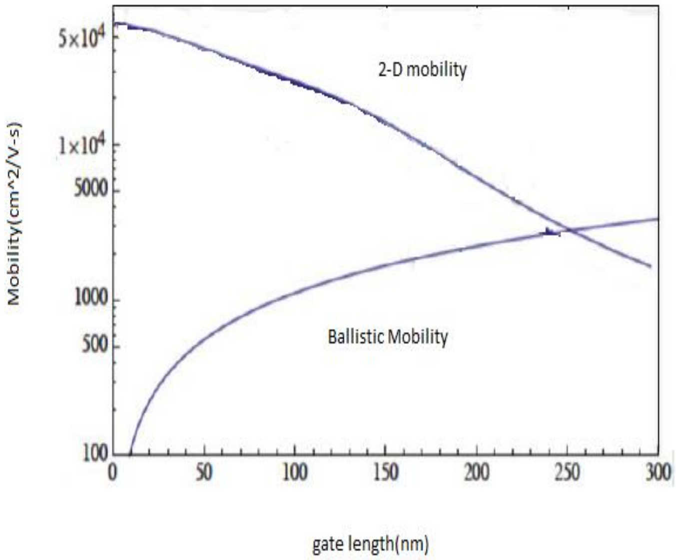

Fig 1: Two dimensional mobility in GaAs and Ballastic Mobility of Al0.25GaN0.75/GaN Superlattice MOSFET as a function of gate length.

Figure 1 shows the calculated two dimensional mobility in GaN and Ballastic Mobility of Al0.25GaN0.75/GaN Superlattice MOSFET as a function of gate length.[11]

Conclusion:

In the present paper,the authors have made a comparative study of the two dimentional mobility in single GaN quantum well with the Al0.25GaN0.75/GaN Superlattice MOSFET.The results show that the ballistic mobility is quite higher than the scattering limited mobility for 270 nm .So high mobility transistors and the devices can be made with the ballistic channels.

References:

[1] A Dyson, B.K.Rideley, "High field transport and tetrahertz generation in GaN", J. of Appl. Phys. **104**, 113709 (2008).

[2] H. Arabshahi , Z. Moodi and A. Pourhasan "Numerical calculation of the electron mobility in GaAs semiconductor under weak electric field application", International Journal of Science Environment and Technology **2**, 80-87 (2012)

[3] S M Sze "Physics of Semiconductor Devices" ,New York:Wiley (1981).

[4] D. C. Look and J.R Sizelove, "Dislocation Scattering in GaN", Physical Review Letters **82**, 1237-1240 (1999).

[5] A.Ghosal, D.Chattopadhyay and A.Bhattacharyya, “One-dimensional hot electron transport in quantum-well wires of polar semiconductors”, J. Appl. Phys. **59**, 2511 (1986).

[6] D Chattopadhay, "Piezoelectric and deformation potential acoustic scattering mobility of a two-dimensional electron gas in quantum wells", Phys. Status Solidi (b), **135**, 409-413 (1986).

[7] S.S Kubakaddi, B.G. Mulimani, V M Jali, “Hot ElectronTransport in Semiconductor Quantum Well Wires”, J. Phys. C, Solid State Phys., **19**, 5453-5457 (1986)

[8] D I Rode , “Low Field Electron Transport” Semiconductors and Semimetals, 10, 189-193 (1975).

[9] Kastalsky A A and Shur M S ,”Conductance of Small Semiconductor Devices” Solid State Commun. **39**(6) 715-718 (1981)

[10] Dmitriev A P and Shur M S Ballistic admittance: Periodic variation with frequency *Appl. Phys. Lett.* **89** 142102 (2006)

[11] Michael Shur, “AlGaN/GaN plasmonic terahertz electronic devices” Journal of Physics,**486** ,(2014)