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Modelling Of Future Nano Transistor

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Abstract— The study is to focus on different scattering effects in Silicon NanoWire (SiNW) MOSFET. The proposed system shows the impact on Gate All Around (GAA) Silicon NanoWire (SiNW) MOSFET with precisely positioned dopants. I-V characteristics of my proposed model are compared with various other Si nanowire transistor scattering models using the MATLAB simulation tool. The result of this analysis gives the study on the current variability of the device, which shows decrease in electric current. From this it provides the guidance for future development of Si nanowire transistor.

Keywords: Silicon NanoWire MOSFET, Gate All Around, MATLAB

I. INTRODUCTION

Great deal of improvement in performance and the density have been achieved since the invention of integrated circuit(IC) technology. For more than four decades, Dennard's rules of scaling have dominated the evolution of complementary metal oxide semiconductor design, fulfilling the notation of Moore's law. The development in nanofabrication has made it possible to considerably shrink the channel length of the devices and also move towards ballistic transport. However, the last technology do have some additional problems for scaling, which in turn relates to several issues like Short Channel Effects (SCE), Drain Induced Barrier Lowering (DIBL), large static power consumption, increased access resistance and also more pronounced variability and reliability.

Today's solid state research tries to counterbalance these effects by means of such multi-gate configurations with silicon nanowire technology, since it has low carrier mobility in silicon when compared with other semiconductors. The Silicon NanoWire Transistor (SiNWT) has its unique merits like low noise intensity, low cost and are compatible with current. Small size of silicon nanowire makes their electronic and electrical properties strongly dependent on the growth of direction, size, surface and reconstruction.

The aim of this paper is to study the impact of various scattering models by comparing the I-V characteristics using the MATLAB simulation tool.

SiNW MOSFET STRUCTURE

Silicon NanoWire transistors with various types of cross-sections are being extensively explored by a number of experimental groups. The various cross sections are the cylindrical wire (CW), triangular wire (TW) and rectangular wire (RW) nanowire FET. Here we consider the n-channel cylindrical SiNW MOSFET of 2 nm thick SiO_2 gate oxide. Current flow along the direction of source to drain. Continuously the random discrete dopants are added in the 4nm region of Source and Drain leads.

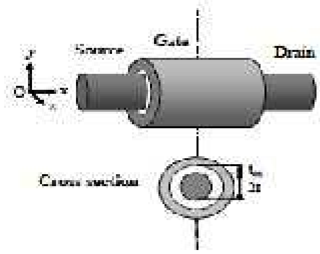

Fig.1.SiNW MOSFET Structure

II. BLOCK DIAGRAM

The above block diagram show the overall work of the project. The first block shows the landauer formalism which yields an expression of electric current I_D from the urce to drain under drain bias V_D.

Second block is the ballistic which means there is no scattering effect. Here the transmission coefficient $T_i(\varepsilon)$ is always one.

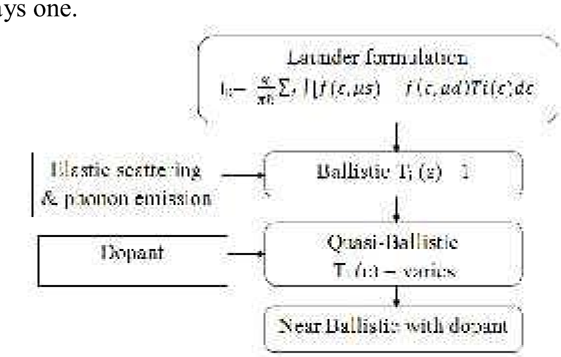

Fig.2.Block Diagram

When the elastic and phonon emission scattering combine with the ballistic which form the quasi-ballistic, and here the transmission coefficient $T_i(\varepsilon)$ varies based on the condition of sub band.

When dopants effect added with the quasi ballistic transport then it is the near ballistic, which means the impurity scattering. By impurities we mean foreign atoms in the solid which are efficient scattering centres especially when they have a net charge. Ionized donors and acceptors in a semiconductor are a common example of such impurities. The amount of scattering due to electrostatic forces between the carrier and the ionized impurity depends on the interaction

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time and the number of impurities. Larger impurity concentrations result in a lower mobility.

NUMERICAL ANALYSIS

Using semi-analytical Fourier- Bessel series, the potential of single charged impurities randomly distributed in the cross section of the NW is first calculated. This potential is further screened by the free carriers in the conduction or valence band of the NWs within a self-consistent linear response approximation. Then the impurity-limited mobility μ_{imp} being calculated. Hence a drain current equation based on the *kT*-layer theory has been proposed by Lundstrom's group. Introduction of scattering effects into the ballistic modelling of MOSFET has been discussed so called *kT*-layer theory. But is limited to the saturation current of the device. Natori's scattering model is employed in the model, considering the elastic scattering and the energy relaxation due to optical phonon emission. The drain current is readily evaluated by Landauer formalism from the source to the drain

μ_{iS} and μ_{iD} - Fermi levels associated with the source and drain electrodes respectively.

$\mu_{iD} = \mu_{iS} - qV_D$, where V_D is the drain bias.

$\square_i$ - Summation of contributions from various subbands.

The current consists of separate contributions from each subband. T_i (ε) denotes the transmission coefficient of a carrier injected into the *i*th subband (i = 0, 1, 2, . . .), which represents the probability that the *i*th subband carrier injected from the source with energy ε is eventually absorbed by the drain without returning to the source, after suffering elastic scattering and energy relaxation within the channel. various intra and intersubband carrier scattering. The intersubband transition probability of a carrier in scattering depends on the matrix element of the scattering potential between the initial subband state and the final subband state. Then, the intrasubband scattering may constitute a dominant part. In the analysis, the intersubband elastic scattering was emulated by the expedient intrasubband scattering, as mentioned later. The source electrode is assumed to be an ideal one that supplies the sufficient carriers to the channel.Transmission coefficient is eventually transferred to drain suffering from the intervening elastic scattering or energy relaxation. Evaluation of the transmission coefficient is required for estimation of the device current.

III. I-V CHARACTERISTICS

The study is to focus on the scattering effects that modify the I-V characteristics of the SiNW MOSFET. Considered Channel length (L) = 20 nm. Scattering parameters are directly related to carrier mobility.

The values B_0= 1.54×10^{12} (eV)$^{1/2}$s^{-1}

and D_0=1.46×10^{12} (eV)$^{1/2}$ s^{-1} are assumed approximately .Since these values represent the scattering parameters at room temperature, the subsequent discussion is limited to the device characteristics at room temperature and the model itself is related to temperature variation. The accuracy of the proposed model is demonstrated using the MATLAB simulation tool.

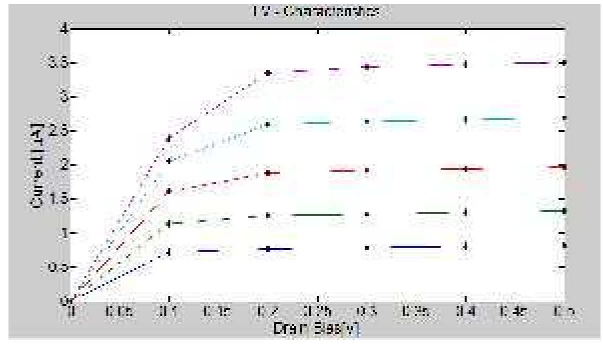

Fig.3. I–V_D characteristics of near Ballistic SiNW MOSFET with Random discrete dopants.

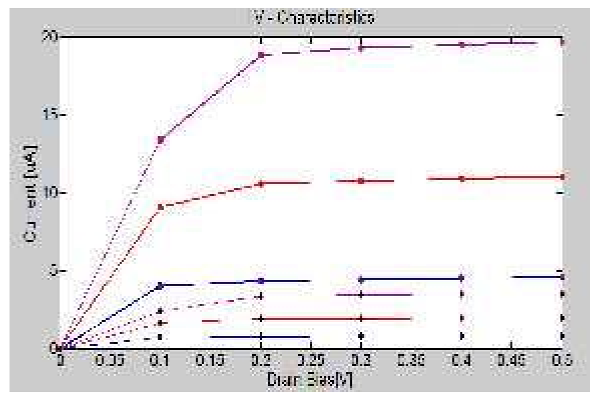

Fig.4. I–V_D characteristics of Near Ballistic SiNW MOSFET with Random discrete dopants are compared with ballistic.

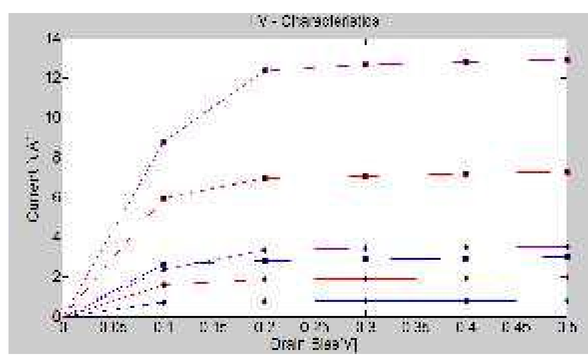

Fig.5. I–V_D characteristics of Near Ballistic SiNW MOSFET with Random discrete dopants are compared with quasi-ballistic.

Fig.2 shows the I-V characteristics near ballistic SiNW MOSFET for various gate over drive. Fig.3 and 4 shows the compared IV characteristics of Near ballistic SiNW MOSFET with Natori's ballistic and quasi ballistic models. The curve with different colour represents the different gate overdrive voltage. The magnitude of the near ballistic current is decreased because the discrete Random dopants.

Current saturation is absolute in ballistic and Quasi ballistic transport where it is imperfect in our proposed model, because of the increased width of the inelastic zone by the applied gate over drive and the backscattered flux within the zone gradually decreases, which results in increase of current at saturation region.

IV. CONCLUSION

The I–V characteristics of a Near Ballistic SiNW MOSFET with Random discrete dopants has been proposed. The value of mobility for this device depends upon impurity scattering which decreases the field mobility. Random discrete dopants cause reduction of device current. Impurity scattering in proposed Near Ballistic SiNW MOSFET with Random Discrete Dopants makes a steady decrease in drain current with lower magnitude when compared with Quasi Ballistic device and ballistic model. The all device characteristics are achieved through the simulation in MATLAB. My proposed approach is appropriate for the modelling of Near Ballistic SiNW MOSFET in the presence of Random Discrete dopants.

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