CHAPTER 7
CONCLUSION

7.1 INTRODUCTION

High speed, ultra dense integration, and less power consumption are considered to be the major issues in future semiconductor technology. As the channel lengths of MOS transistors are being scaled down rapidly into nanometer regime, nanowire transistors open up the possibility for near ballistic operation in MOSFET devices. Carrier scattering is the essential feature of Near ballistic transport. Scattering mechanisms classified mainly into three types: Defect scattering, Carrier –Carrier Scattering and Lattice scattering. Gate All Around (GAA) structures are garnering huge attention as they can provide a high electrostatic integrity, better gate control and scaling potentials. Hence it becomes mandatory to develop physics based models to understand the performance characteristics of Influence of certain Scattering effects in Near Ballistic Silicon Nanowire MOSFETs. In this work, analytically derive and analyse the detailed behavior of Device current and analog parameters of Scattered SiNW MOSFET.

7.2 SALIENT FEATURES OF THE THESIS

This dissertation derives the analytical drain current models for certain Scattered Silicon Nanowire MOSFET. Scattered Silicon Nanowire MOSFET is revealed which includes the effects of elastic scattering, optical phonon emission, surface roughness scattering, Discrete Random dopants and Temperature effects. These analytical models are validated by comparing their results with TCAD simulations.
In chapter 3, the drain current for Discrete Random Dopants (or) Impurity Scattering influenced Near Ballistic Silicon Nanowire MOSFET is derived. An impurity-limited mobility is derived in terms of Impurity resistance (is obtained from “knitting” algorithm) and the Impurity concentration. From impurity-limited mobility, Fermi energy is calculated at source and drain using Femi Dirac distribution function. As Fermi distribution function greatly depends on electron mobility, the Fermi energy of the scattered SiNW MOSFET is varied in accordance with scattered mobility. Then the Transmission parameter has been evaluated by directly solving Boltzmann transport equation (BTE). Finally the drain current for Near ballistic Silicon Nanowire MOSFET considering ImpurityScattering mechanism is evaluated by Landauer formalism from the source to the drain under drain bias $V_D$. Landauer formalism incorporates Fermi energy and transmission parameter which is calculated in previous steps. Analog parameters like Transconductance ($g_m$), Transconductance generation factor ($g_mI_{DS}$) and Early Voltage ($V_a$) is also analysed from derived Drain current. Results obtained with analytical models are verified with TCAD simulation results to validate the accuracy of the present analytical model.

In chapter 4, the drain current for Surface Roughness Scattering influenced Near Ballistic Silicon Nanowire MOSFET is derived. The Surface Roughness scattered mobility is derived in terms of surface roughness resistance, and the cross-sectional charge per unit length. From surface roughness limited mobility, Fermi energy is calculated at source and drain using Femi Dirac distribution function. Then the Transmission parameter has been evaluated by directly solving Boltzmann transport equation (BTE). Finally the drain current for Near ballistic Silicon Nanowire MOSFET considering Surface Roughness Scattering mechanism is evaluated by Landauer formalism from the source to the drain under drain bias $V_D$. Analog parameters like Transconductance ($g_m$), Transconductance generation factor ($g_mI_{DS}$) and Early Voltage ($V_a$) is also analysed from derived Drain current. Results obtained with analytical models are verified with TCAD simulation results.
In chapter 5, the drain current for Combined Scattering influenced Near Ballistic Silicon Nanowire MOSFET is derived. Combined Electron mobility is derived by using Mathiessen’s rule. Various scattering mechanisms limits electron mobility. Scattering limited mobility for each scattering mechanism is derived by its own scattering influencing parameters. The above (chapter 3 & chapter 4) derived certain scattering mobilities are combined using mathiessen’s rule which gives us combined Electron mobility. From Combined Scattering limited mobility, Fermi energy is calculated at source and drain using Femi Dirac distribution function. Then the Transmission parameter has been evaluated by directly solving Boltzmann transport equation (BTE). Finally the drain current for Near ballistic Silicon Nanowire MOSFET considering Combined Scattering mechanism is evaluated by Landauer formalism from the source to the drain under drain bias $V_D$. Analog parameters like Transconductance ($g_m$), Transconductance generation factor ($g_m/I_{DS}$) and Early Voltage ($V_a$) is also analysed from derived Drain current. Results obtained with analytical models are verified with TCAD simulation results.

In chapter 6, the drain current for Temperature influenced Scattered Silicon Nanowire MOSFET is derived. In above chapters (3,4 and 5) analyse the Scattering effects at room temperature. Temperature is a key parameter related to semiconductor devices which can affect their properties even if they are in micro or nano regime. So we analyse Combined Scattering influenced Near Ballistic Silicon Nanowire MOSFET at various temperature. Combined Electron mobility is derived by using Mathiessen’s rule. The temperature influenced scattered mobility has derived using Arora’s mixed scattering rule and Mathiessen’s rule. From temperature influenced scattered mobility, Fermi energy is calculated at source and drain using Femi Dirac distribution function. Then the Transmission parameter has been evaluated by directly solving Boltzmann transport equation (BTE). Finally the drain current for Temperature influenced Scattered Silicon Nanowire MOSFET is evaluated by Landauer
formalism from the source to the drain under drain bias $V_D$. Landauer formalism incorporates Fermi energy and transmission parameter which is calculated in previous steps. Analog parameters like Transconductance ($g_m$), Transconductance generation factor ($g_m I_{DS}$) and Early Voltage ($V_a$) is also analysed from derived Drain current. Results obtained with analytical models are verified with TCAD simulation results to validate the accuracy of the present analytical model.

### 7.3 SUGGESTIONS FOR THE FUTURE WORK

The analytical models presented in this dissertation are good enough to predict the voltage-current performance and analyse some analog parameters characteristics of certain Scattering influenced Near Ballistic Silicon Nanowire MOSFETs, but still, there are some issues that could be addressed to improve the accuracy of these models.

- In addition to this work, High K Metal Gate (HKMG) stacks and additional scattering mechanisms can be included.
- Experimental/Fabrication results can provide further confirmation of the effectiveness of the Surrounding Gate Nanowire MOSFETs.
- In addition to this work, Same Scattering analysis can be incorporated with other device Structures.

### 7.4 SUMMARY

In this dissertation, an attempt has been made to develop the analytical model to explore the impact of certain scattering in Near Ballistic Silicon Nanowire MOSFET. The detailed behavior of analog parameters like transconductance ($g_m$) and early voltage ($V_a$) has been discussed. The Validity of the proposed model has been confirmed by comparing the analytical results with the TCAD simulation results and it shows good agreement. This work can be extended for further research.