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Research Paper

The Effect of Silicon Film Thickness on the Performance of Electrical Characteristics of Nano-MOSFET

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ABSTRACT:- *Numerical simulations have been performed to investigate the electronic transport through the Silicon (Si) channel of 4 terminal nanomos, namely, drain, source, top gate and bottom gate as shown in Figure 1. In this investigation, the thickness of Silicon film channel is varied from 1.5 nm, 3 nm to 5 nm with other structural dimensions remain unchanged. The simulation is carry out at room temperature (RT). Three models will be presented 1)ballistic transport using Green's function approach; 2) ballistic transport using semiclassical approach; and 3) drift diffusion transport. Electrical properties of Nanomos such as 2D electron density of the subbands, subbands energy profile and drain current- gate voltage* (I_{DS}-V_{GS}) *graphs have been plotted to compare the performance of these three transport models. From the simulation analysis, the drift diffusion transport model shows the worst performance in comparison with the two other models, maybe due to the electron gas scattering encountered during the transport through Si channel. Meanwhile, Green's function approach and semiclassical approach show almost similar results, maybe this explained by less scattering.*

Keywords:- *nanoscale, MOSFET, ballistic transport, semiclassical, drift diffusion transport*

I. INTRODUCTION

Numerical modeling of open quantum devices has become an indispensable tool to understand transport physics of semiconductor devices scaled down to nano-meters regime. Non-equilibrium Green's function (NEGF) method is a comprehensive approach to elaborate the quantum transport under external potential bias. Semiclasical approach applies the techniques of Boltzmann kinetic to explain the electron transport. Both of these models are ballistic in nature. Meanwhile, drift diffusion transport has scattering [1].

II. DEVICE DESIGN

Figure 1 shows the structural dimension of the double-gate (DG) nanomos which is used in this project. The source and drain terminal are heavily n^+ doped at $1x10^{20}$ cm^{-3}. The Si film channel is intrinsic. Its thickness is labeled as T_{Si}. Channel length (L_T) is fixed at 10 nm with no source overlap (U_S) and no drain overlap (U_D). Top gate length (L_{GT}) and bottom gate length (L_{GB}) are fixed at 10 nm. Source and drain length (L_{SD}) is fixed at 7.5 nm. Top insulator thickness (T_{OX1}) and bottom insulator thickness (T_{OX2}) are fixed at 1.5 nm. All the dimension such that the device is in nanometer size. The doping junction is abrupt. The nanomos is fabricated on (001) Si surface wafer [2]. The drain-source potential is fixed at 0.6 V while the gate voltage is swept with step size 0.05 V from 0 V to 0.6V.

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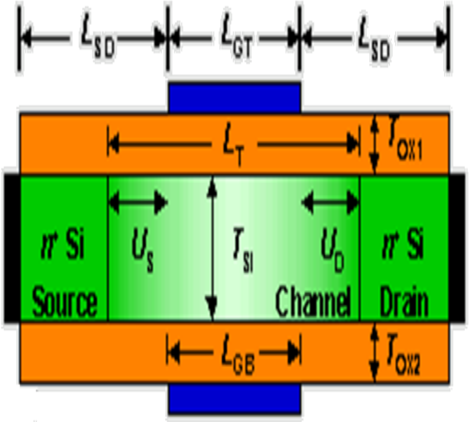

Figure 1

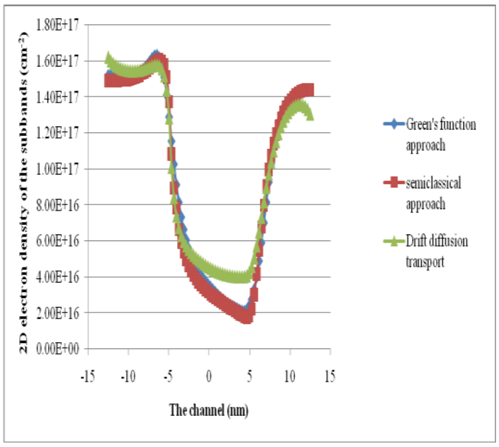

Figure 2: T_{Si} = 1.5 nm

III. RESULTS AND DISCUSSION

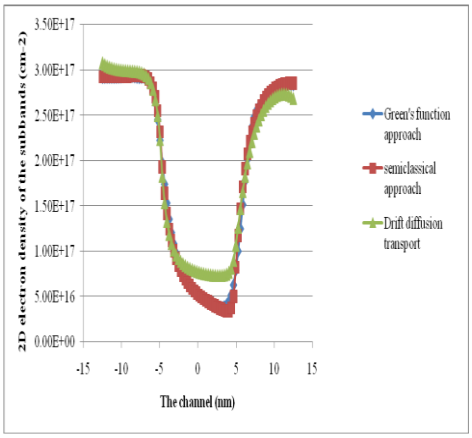

Figure 3: T_{Si} = 3nm

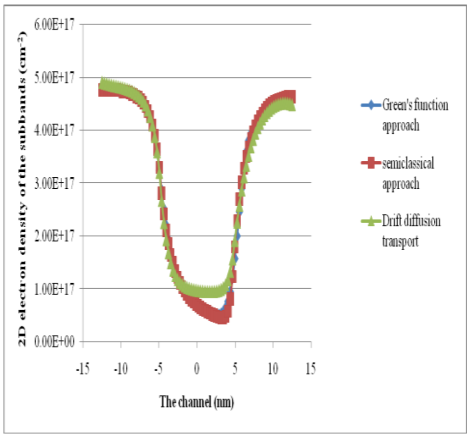

Figure 4: T_{Si} = 5nm

Basically, the 3 transport models curves have roughly the same outline in Figure 2, Figure 3 and Figure 4, except that there are discrepancies in the magnitude of 2D electron density of the subbands in the drain reservoir, channel and source reservoir region. As can be seen in those figures, the magnitude of 2D electron density of the subbands increases as the thickness of the Si film is increased since there are more number of electron quantity. From those graphs, we find that the distribution of electron density are almost the same for ballistic transport using Green's function and semiclassical approach whereas the drift diffusion transport model has more electron density in the channel region since scattering mechanism exists [3,4,5,6,7,8].

Figure 5, Figure 6 and Figure 7 shows the plot of the subbands energy profile along the channel for Si film thickness of 1.5 nm, 3 nm and 5 nm respectively. For each graph, Green's function and semiclassical approach have rough the same potential barrier. On the other hand, the drift diffusion transport shows a moderate higher potential barrier than other models. Generally, as thickness of Si film increased, the potential barriers for all 3 transport models increased [9, 10].

Figure 8, Figure 9 and Figure 10 show the plot of drain current versus gate voltage ($I_{DS} – V_{GS}$) for Si film thickness of 1.5 nm, 3nm and 5 nm respectively. For each graph, Green's function and semiclassical approach have almost the same current at off state as well as on state. On the other hand, drift diffusion transport has the lowest drain current since scattering mechanism prevails; for the other two models, ballistic transport exists. As the thickness of Si film is reduced, the turn on point of the current-voltage curve increase because there is a drop of electron number. By the same reasoning, as the thickness of Si film is reduced, the peak on-state current is reduced for all models.

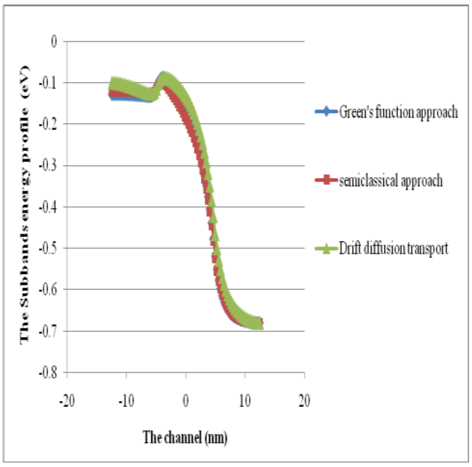

Figure 5. T_{Si} = 1.5 nm

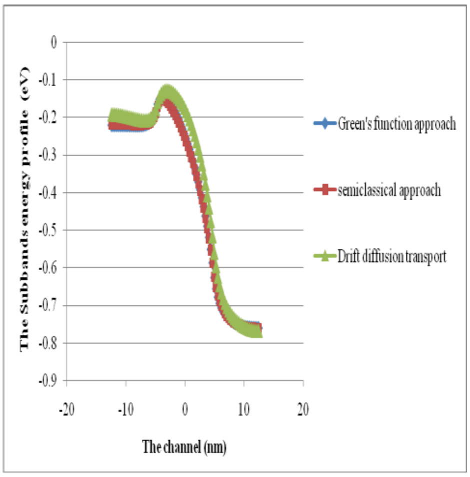

Figure 6. T_{Si} = 3 nm

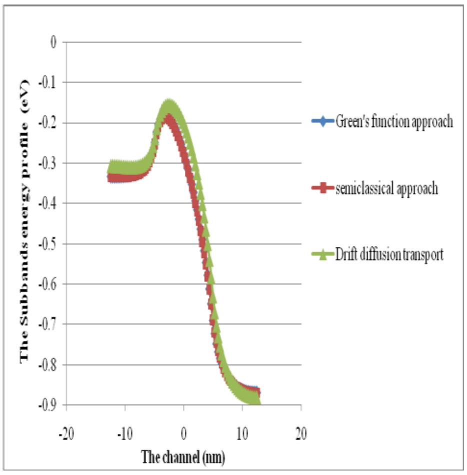

Figure 7. T_{Si} = 5 nm

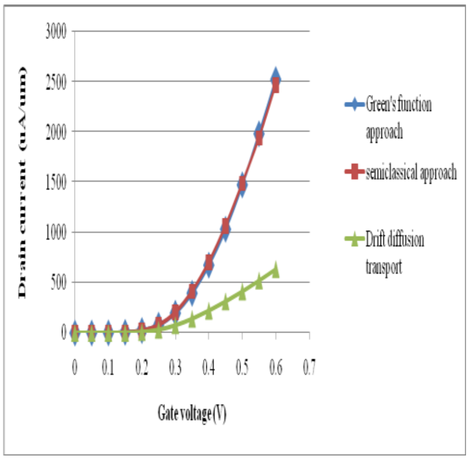

Figure 8. T_{Si} = 1.5 nm

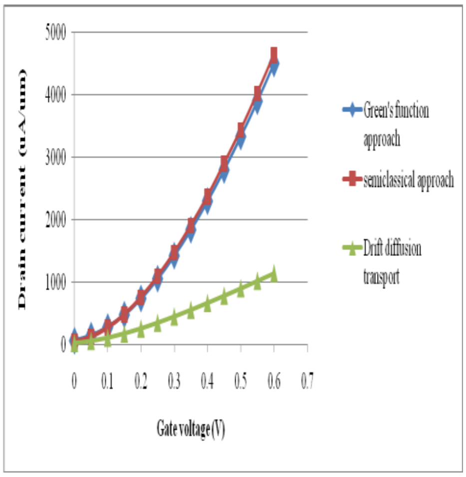

Figure 9. T_{Si} = 3 nm

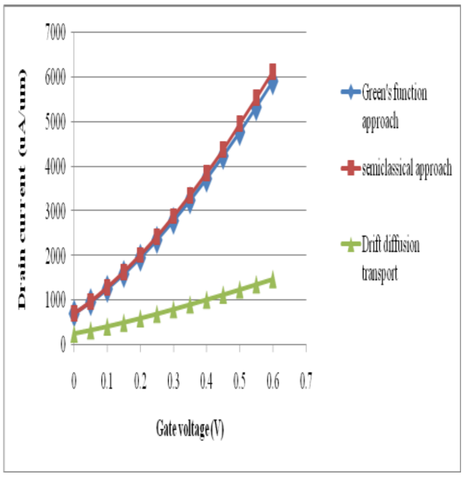

Figure 10. T_{Si} = 5 nm

IV. CONCLUSION

Among the here transport model studied, Green's function and semiclassical approach produce roughly the same characteristics since both of them deal with ballistic transport. Meanwhile, drift diffusion transport has the lowest performance due to existence of scattering. When all other structural design of a nanomos are fixed, increment in Si film thickness will result in more number of electron in the channel region. Thus, it's seem that thick-body nanomos can performance better than thin-body nanomos.

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