Modeling Quantum Transport in Nanoscale Vertical SOI nMOSFET

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Abstract: The electron transports in micro-architecture semiconductor are simulated using vertical SOI nMOSFET with different models. Some details in transport can be presented by changing channel length, channel thickness and drain voltage. An interesting phenomenon similar to collimation effect in mesoscopic system is observed. This may suggest the quite intriguing possibility that scattering may open new channel in sufficiently narrow devices.

Key words: semiconductor; MOSFET; transport; mesoscopic system

CLC number: TN 303, TN 301

1 Simulated Device

The transport properties of semiconductors decide directly the performance of semiconductor devices. Hence, in the history of device development, transport properties have been studied widely both experimentally and theoretically. As the characteristic size of devices is lessened to the correlated length determined by inelastic collision (electron-photon), the electronic movements will be determined by the fluctuation and coherence of electronic wave similar to the movement of electromagnetic wave in wave guide. It is defined as the transport in mesoscopic system, which may result in a series of new transport phenomenon. The off equilibrium transport and the quantum mechanical effects occurring in deep submicron/nanometer MOSFET can be studied by quantum simulator with non-equilibrium Green's function formalism. NanoMOS is one of them. The device architecture that we use is a vertical SOI nMOSFET. The ITRS specifications for the year 2016 transistor generation, physical gate length (9 nm), equivalent oxide thickness (0.6 nm) and power supply voltage (0.6 V) have been followed.
appreciated as a new configuration for MOSFET scaling. Fig. 1 is the structural figure of a v-SOI nMOSFET. It arranges vertically from drain to source. The lengths are 7.5, 9, 7.5 nm respectively. The doping concentrations are $N_D = 1.0 \times 10^{20} \text{ cm}^{-3}$, $N_A = 1.0 \times 10^{15} \text{ cm}^{-3}$. The thickness are $t_{si} = 1.5 \text{ nm}$, $t_{ox} = 0.6 \text{ nm}$.

NanoMOS is a 2D-simulator for double-gate MOSFET with thin body (less than 5 nm) made in PURDUE University. Some appropriate remodel and settings are needed to improve the suitability for the simulated device. A series of the results can obtained including the energy profile, carrier concentration and drain current versus voltage characteristics, and so on. Simulations carry out in Sun workstations with four 400 Hz CPU in the Purdue Simulation Hub.

## 2 The Characteristic Simulations and Discussions

There are three simulating models including the classical ballistic transport model (CLBTE), the quantum ballistic transport model (QBTE) and the quantum dissipative transport model (QDTE). The QDTE treats scattering transport in MOSFETs through the Green’s function formalism using a simple B tiker-probe model. The scattering centers are regard as reservoirs similar to the source and drain except that they only change the energy of the carriers and not the total number of carriers in the system. Our simulations prove that electrostatics characteristics from two frameworks, QBTE and QDTE, are nearly no difference, such as energy profile and carrier concentration of subbands.

We simulate the $I_{DS}$ vs. $V_{DS}$ characteristics at different channel lengths $L$ with three transport models. In general, the shortening of channel length means the strengthening of channel electric fields, but there are some differences among the models. So the comparisons between different models may denote the details in transport mechanism. Fig. 2 shows the simulations of $\rho_{DS}$ vs. $V_{DS}$ characteristics of devices at three channel lengths $L$. When the channel lengths decrease, the amplitudes of current increment are the largest in QBTE. The same results also can be seen as the $V_{DS}$ increases. The two statuses will produce higher electric field in channel and result in the shrink of barrier along the channel. Therefore the quantum tunnel current will increase remarkably. The currents from QDTE are less than that from QBTE, and it may be explained that the dissipated transport would not be reachable under ballistic one.