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Effect of Gate Dielectric on Ballistic Transport of Cylindrical Carbon Nanotube MOSFET

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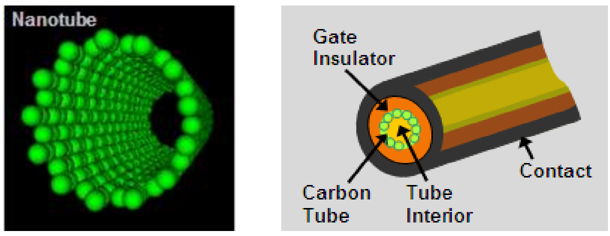
This paper demonstrates the effect of the thickness and dielectric constant of gate dielectric on the ballistic performance of cylindrical Carbon Nanotube (CNT) MOSFET (Fig. 1). A numerical simulator is developed using MATLAB solving Schrodinger and Poisson's equation self-consistently considering wave function penetration and other quantum effects to simulate ballistic transport for semiconducting carbon nanotube with chirality 13 as the channel material. Ballistic transport is simulated using the Non-equilibrium Green's function formalism [1] considering DIBL effect. Firstly, the thickness of the gate oxide layer is varied for SiO_2 and the increase in current is observed with the decrease in thickness (Fig. 2-4). Then, for 1.5nm thickness, different dielectric materials are used as gate oxide to find out the effect of dielectric constant on ballistic performance (Fig. 5-7). High k dielectric is found suitable for high performance [2]. Analytical modeling is done using LMS method for establishing relation of drain saturation current with oxide thickness and dielectric constant. The regions for sharp change in current due to these parameters are identified.



(a) (b)

Fig. 1. Schematic view of (a). Carbon nanotube, (b) Cylindrical CNTFET

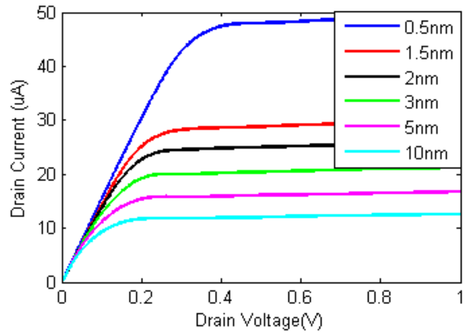


Fig. 2. I_D vs. V_D for for different oxide thickness at V_{GS} = 1V (V_t=0.32V)

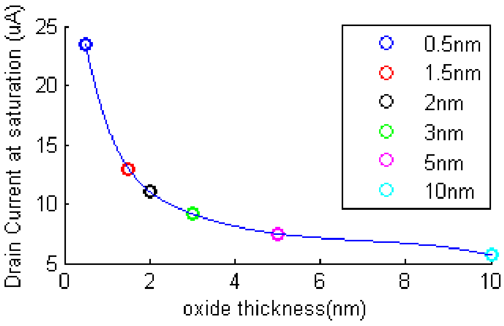


Fig. 3. Saturation drain current vs. oxide thickness

$$I_{Dsat} = 0.01357\times t^4_{ox} - 0.3514\times t^3_{ox} + 3.2671\times t^2_{ox} - 13.2016\times t_{ox} + 27.366 \quad (1)$$

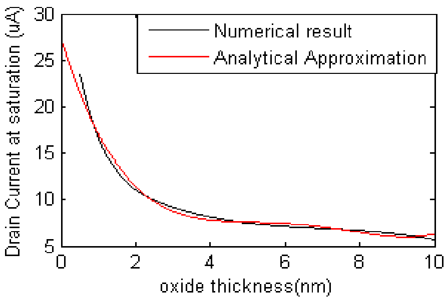


Fig. 4. Saturation drain current vs. oxide thickness from both simulation result and analytic expression

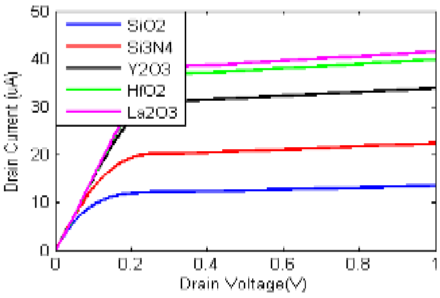


Fig. 5. I_D vs. V_D for for different gate dielectric at V_{GS} = 0.7V

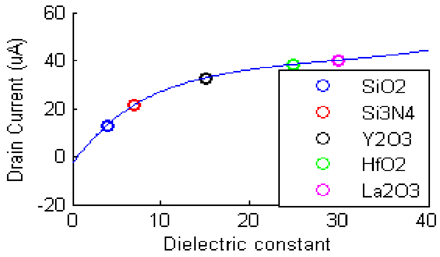


Fig. 6. Saturation drain current vs. dielectric constant for different gate dielectrics at V_{GS} = 0.7V

$$I_{Dsat} = 0.001613\times k^3 - 0.1328\times k^2 + 3.871\times k - 0.512 \quad (2)$$

Where, k is the dielectric constant of the gate oxide.

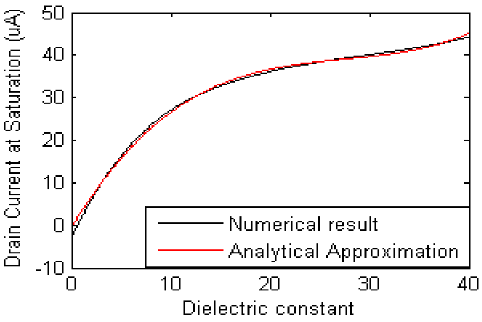


Fig. 7. Saturation drain current vs. dielectric constant for different gate oxides from both simulation result and analytic expression

The thickness and dielectric constant of gate dielectric are closely related to current capability of the device. In this paper, their effects on ballistic transport of cylindrical Carbon nanotube MOSFET are focused. Analytic model is developed using LMS method to predict the change in ballistic performance of CNT MOSFET with the change in gate dielectric parameter. Drain saturation current increases with the decrease in thickness of the dielectric. The increase is accelerated for below 2nm thickness. On the other hand, drain saturation current increases with the increase in dielectric constant of the gate insulator. The rate of change is sharp in the region where the dielectric constant is below 10. These insights are useful for further analysis on CNT MOSFETs.

References

[1]. J. Guo, S. Datta, M.S. Lundstrom and M.P. Anantram, *International J. on Multiscale Computational Engineering*, special issue on multiscale methods for emerging technologies, ed. N. Aluru, 2, 257-276, 2004

[2]. S. Mudanai, Y Y Fang, Q Quyang, IEEE Trans. Electron Dev, vol. 47, Number. 10, pp. 1851–1857, 2000.