Sub-Threshold Slope and ON/OFF Current variation in Nano-Scale MOSFETs

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***Abstract*— The Multi Gate transistors (MGT) have been used to improve the transistor device performance at the nanometer scales. MGTs alleviate many problems in the planar devices due to tighter control of the gate on the channel. In this paper the change in the Fin Architecture and Gate Length of the MOS device, is correlated with the Subthreshold Slope (SS) and ON/OFF current ratio. The study is done by conducting experiments and three-dimensional simulations.**

Keywords— **MGT, SS, Leakage, ON/OFF Current, MOSFET, NANO, Ivy Bridge, Short Channel Effect.**

I. INTRODUCTION

For many decades now the Moore's Law has been predicting the features of Metal Oxide Semiconductor (MOS) transistor becoming smaller and smaller. Many different variations in the transistor structure and composition have been tried to sustain scaling. Over the past decade the main way of scaling the transistor has been using the three-dimensional structure of the gate along with other innovations in materials technology. Promising results have been achieved by using this methodology. The FinFet, Trigate and other gate all-around transistors have received much industrial and academic attention.[1-3,16] This paper describes the simulation of the Trigate transistor in Transistor Computer Aided Design (TCAD)[15] software and also some experimental studies which were conducted. More details on the simulations can be found in related papers [4-13] and full quantum mechanical formulation approaches can be used to determine electron distribution as well [13-14]. Herein mainly special attention has been paid to the subthreshold behaviour as a function of channel dimensions. Planar, Silicon on Insulator (SOI), Trigate MOSFETS have been compared. Poor ION/IOFF ratio and bad SS characteristics can lead to rendering the transistor performance unacceptable. It has been shown how the innovations in MGTs result in improvement in SS behaviour of the MOSFETS.

II. SIMULATION SETUP

TCAD based tools are widely used to simulate electrical characteristics of MOS transistors, e.g:- Vth, SS, Ion, Ioff , gm, gds etc. These characteristics are very important metrics of device behavior and are used to compare and contrast different devices. Within the framework of TCAD they are determined by first doing the process simulation then doing a device simulation and finally an extraction from the the results of the device simulation. We compared the behavior of four devices: planar MOSFET , triangular bulk 3D-MOSFET, rectangular bulk 3D-MOSFET and rectangular SOI 3D-MOSFET. These analyses will indicate the superiority of the 3D-MOSFET over the planar device. The 3D-MOSFET height is equal to 24 nm, the base width is 10.7 nm. The angle of the fin in the triangular 3D-MOSFET is equal to 84 degrees. These devices have the same underlying process. The planar device is obtained by modifying the 3D-MOSFET, by reducing the fin height(H) and stretching the fin width(W) equal to the $(2 * H + W)$. The doping concentration in the source and the drain is 1020 cm3 and that in the channel region is 1018 cm3. We have closely tried to follow Intel Ivy Bridge [1,16] device dimensions.

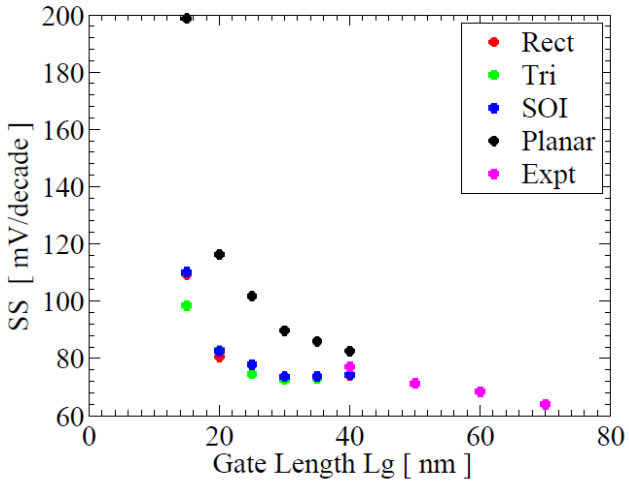

Figure 1 Subthreshold slope variation with respect to Lg

III. RESULTS

In the Figure 1, we observe that the SS in case of the 3D-MOSFET's is lower than the planar devices for all the gate lengths, so these devices can switch better and as we go down the gate length. The Figure 2, illustrates comparison of the ON-current to OFF-current, log(ION/IOFF), we can clearly see that the ratio of the ON-state to the OFF-state currents degrades in all the devices as we scale them. In case of the planar device it degrades faster than the 3D-MOSFET'S.

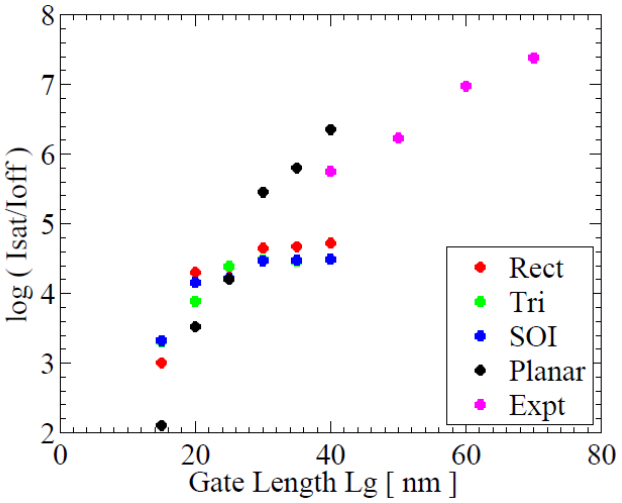

Figure 2: ION/IOFF with respect to Lg

IV. CONCLUSION

It is clearly seen that the Subthreshold Slope and ION/IOFF current characteristics of the 3D-MOSFETs are better than the planar counterparts. Especially as we approach the device lengths below 20 nano meters the performance is dramatically improved.

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