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SIMULATION OF THE ELECTRICAL CHARACTERISTICS OF DOUBLE GATE FINFET WITH THE VARIATION OF CHANNEL MATERIALS

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ABSTRACT

In this research work, the electrical characteristics of the double gate FinFET have been simulated for different channel materials. Three materials, Silicon (Si), Germanium (Ge) and Silicon-Germanium (SiGe) has been considered for simulating the drain current VS gate voltage of the FinFET. The characteristics of the threshold voltage of FinFET have also been studied for these three channel materials. The channel length has been considered 50nm. After analyzing the simulations, it has been proposed the smooth increase of drain current with the gate voltage for different values of drain voltage and the less decrease of the threshold voltage for higher drain voltage can be achieved for Silicon-Germanium (SiGe) channel of the FinFET.

KEYWORDS: *Silicon, Germanium, Channel, Material, Threshold, Gate*

Article History

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INTRODUCTION

High performance and high speed chips are being invented, because the intensive downscaling of CMOS has been major driving force behind the aggressive increase in transistor density and performance. As the device dimensions are scaled towards the nanometre regime, conventional single gate MOSFETs experience various short channel effects (SCE's) that deteriorate the drive current and lead to off-state leakages. To address such scaling down issues, alternate multiple gate device structures and materials have been explored and are under continuous study. Multiple-gate Field Effect Transistors (MuGFETS) have been reported [1] to show excellent short channel effect performance to replace their conventional single gate planar device structures. FinFET, [2, 3] a viable implementation of multiple gate MOSFET structure has been reported as the most promising candidate to eliminate such short channel effects while maintaining the downscaling of CMOS to follow the projections of ITRS roadmap [4]. FinFET technology is very attractive that suffices device designers to aggressively look for their efficient structural and process variations, leading to a high end research in such nano-dimensional device structures.

FINFET DEVICE STRUCTURE AND CURRENT-VOLTAGE RELATIONSHIPS

FinFET is basically a fin type FET structure and very frequently named as a double-gate transistor. It consists of a thin body of silicon wrapped by gate electrodes or poly silicon layer and the current flows in the channel from source to drain. FinFET has many advantages such as good scalability and excellent electrostatic control with promising performance for the present day nanoscale technology [5,6]. With scaling limits and the associated SCE's of FinFETs, it seems that additional scaling down of FinFET device structure will be much more complicated because of various practical limitations, such as gate leakage through hot carrier tunnelling, DIBL, SS, and threshold voltage roll-off, which can put a limit on scaling of the FinFET structures. As anticipated, while reducing the device dimensions in order to comply with the Moore's law and the ITRS roadmap further improvement in FinFET speed and performance at low power supply will be possible by using new channel material other than Si [7-9]. In this research work, silicon, germanium and silicon-germanium have been used to simulate the electrical characteristics of the FinFET. The structure of the FinFET device considered for this research work is shown in Figure 1.

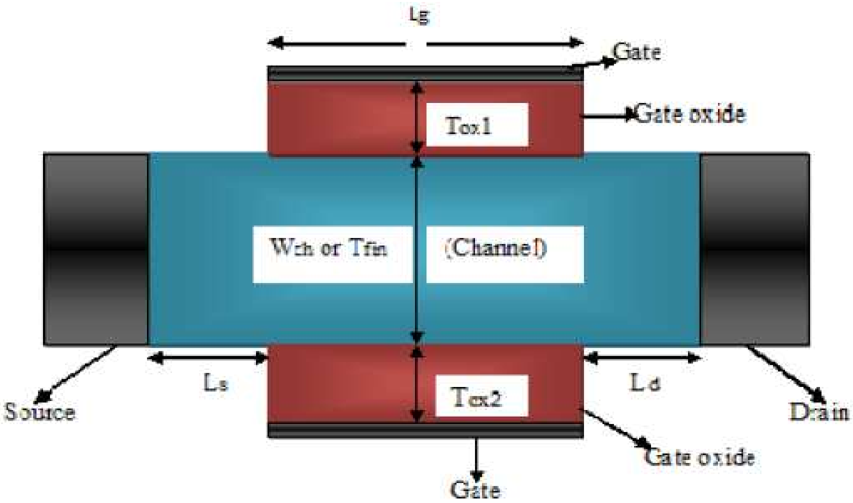

Figure 1: Structure of Double Gate FinFET Structure.

In the linear region of the I-V characteristics of FinFET, the relation of drain to source current I_{ds} with drain to source voltage v_{ds}, for a given gate voltage v_g (> threshold voltage, v_t) is given bellow [10][11]:

$$I_{ds} = 2\,\mu C_{ox}\frac{W}{L}\left(v_g - v_t - \frac{v_{ds}}{2}\right)v_{ds}$$

Here, W / L is the device width to length ratio and $C_{ox}$is the gate oxide capacitance per unit area.

In the saturation region, the relation between I_{ds} with v_{ds} is given here [12]:

$$I_{ds} = \mu C_{ox}\frac{W}{L}\frac{(v_g - v_t)^2}{2m}$$

$$\text{Where, } m = 1 + \frac{3t_{ox}}{X_d}$$

Here, X_d is the depletion layer thickness and t_{ox} is the oxide thickness.

SIMULATIONS

In this simulation work, the I-V Characteristics of the FinFET has been studied with varying the channel material of the FinFET. Silicon, Germanium and Silicon-Germanium materials are considered as the channel material of the FinFET and the drain current VS gate voltage characteristics of the FinFET have been studied. The channel length of the FinFET has been considered 50nm for all the simulations of this research. The each I-V characteristics is studied for both drain voltage 0.5 Volt and 1 Volt. The I-V characteristics for Silicon channel has been shown in Figure 2.

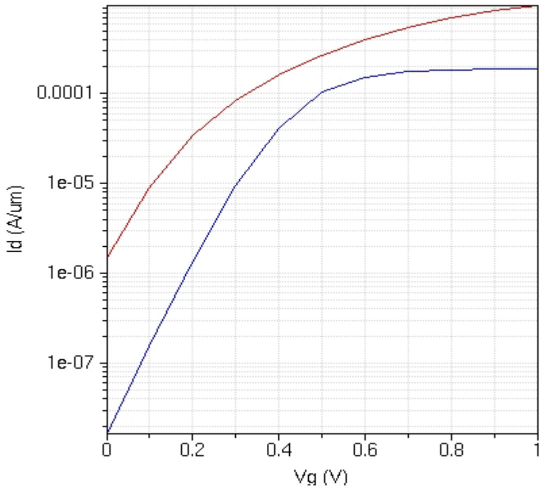

Figure 2: I-V Characteristics for Si Channeled FinFET for 0.5 V (Red Lined) and 1V (Black Lined) Drain Voltage.

The red colored line is for the I-V characteristics for drain voltage 1 Volt and the black colored line is for the I-V characteristics for drain voltage 0.5 Volt. From this figure we see that, for 1 volt drain voltage, the drain current is higher than that for the gate voltage of 0.5 Volt and also the gradual increase of drain current with increasing gate voltage is noticed for the drain voltage of 1 Volt. The I-V characteristics for the Germanium channeled FinFET is shown in Figure 3 where it is seen that, the increase of drain current with gate voltage is more smooth and gradual than that for the Silicon channeled FinFET shown in Figure 2.

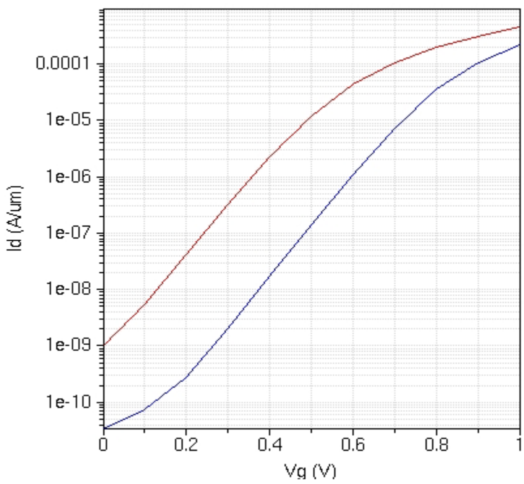

Figure 3: I-V Characteristics for Ge Channeled FinFET for 0.5 V (Red Lined) and 1V (Black Lined) Drain Voltage.

Here, more drain current is found for the drain voltage of 1 Volt and when the gate voltage is increased to higher values, the drain current for 1 volt drain voltage will converge with the drain current for drain voltage of 0.5 Volt. The I-V characteristics for the Silicon-Germanium (SiGe) channeled FinFET is shown in Figure 4.

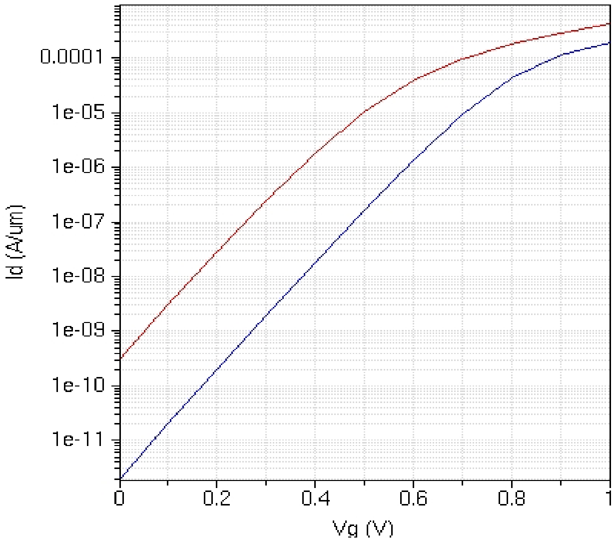

Figure 4: I-V Characteristics for SiGe Channeled FinFET for 0.5 V (Red Lined) and 1V (Black Lined) Drain Voltage.

From this figure, it is noticed that, The increase of drain current with gate voltage is more smooth than that for the Si and Ge channeled FinFET shown in Figure 2 and 3. The I-V characteristics for the SiGe channeled FinFET is shown for both 1 volt and 0.5 volt drain voltage and for both the voltages, smooth and converging I-V characteristics have been studied from this simulation. The threshold voltage characteristics of Si, Ge and SiGe channeled FinFET has also been simulated in this research works and the simulated characteristic curves are shown in Figure 5, 6 and 7.

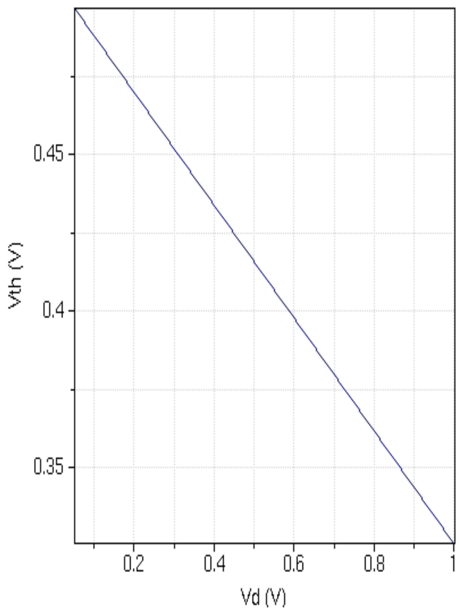

Figure 5: Threshold Voltage for Si Channeled FinFET.

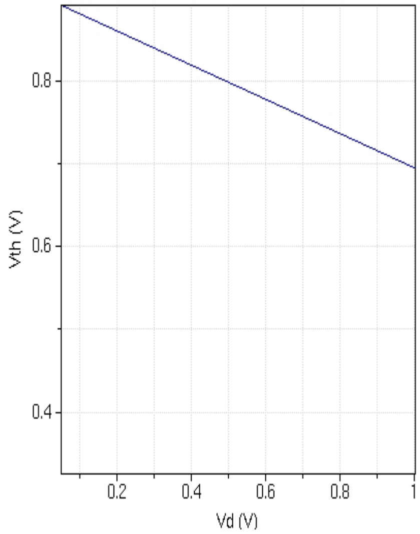

Figure 6: Threshold Voltage for Ge Channeled FinFET.

From the figure 5, it is seen that, for Si channel, the threshold voltage for the FinFET decreases gradually with increasing the drain voltage. Bur from the Figure 6 and 7, it is seen that, for Ge and SiGe channeled FinFET, the threshold decreases to certain values with increasing the drain current. The highly decreasing threshold voltage of Silicon channeled FinFET (shown in Figure 5) may result quick breakdown for the FinFET for high values of drain voltage and drain current. So, for the Ge and SiGe channeled FinFET, the possibility of breakdown for the FinFET will become lower and also smooth drain current VS gate voltage characteristics can be obtained.

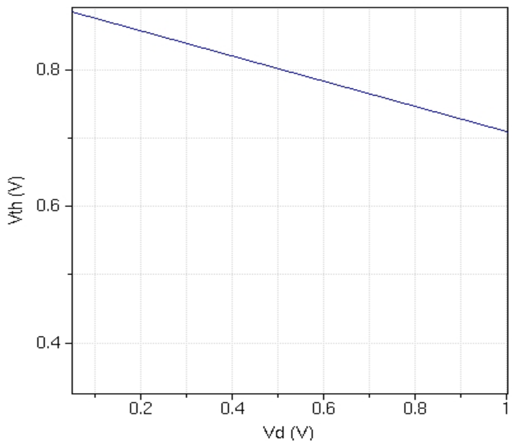

Figure 7: Threshold Voltage for SiGe Channeled FinFET.

RESULTS

The three different channel materials have been considered for the FinFET here, Si, Ge and SiGe and the electrical characteristics of the FinFET has been simulated for these three materials. The smooth I-V characteristics for the SiGe channeled FinFET has been studied from the simulation of the drain current VS gate voltage characteristics of the FinFET. After that, the characteristics of the threshold voltage for the Si, Ge and SiGe channeled FinFET are studied in this research work and highly decreasing threshold voltage characteristics for Silicon channeled FinFET has been found from the simulation. The FinFET with Ge and SiGe channel are less quickly to be reached to the breakdown for their moderate threshold voltage decreasing characteristics with increasing drain voltage, which has been studied from the simulation. So, SiGe can be a suitable channel material for the FinFET than the Silicon and Germanium.

CONCLUSIONS

The electrical characteristics of double gate FinFET has been simulated in this research work for three different channel materials. The I-V characteristics of the FinFET has been studied for Si,Ge and SiGe channel materials. Also the characteristics of the threashold voltage have been studied for the FinFET with these three materials. From the simulations, the SiGe has been found as the most suitable channel material for the FinFET for its smooth current-voltage characteristics at different drain voltages and for the tendency to be slowly reached to its breakdown. In future, the analysis of this simulation can be used to determine the electrical characteristics for trigate FinFET structure and it can also be applied for the fabrication purpose of highly electrically efficient FinFET with these three materials. [10].

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