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RESEARCH ARTICLE

Electrical Characterization of TiO_2 based OMEGA FinFET Compared with Conventional SiO_2 Material

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ABSTRACT

Aim: The aim of the study is to perform the electrical characterization of Innovative TiO2 based Omega FinFET and compare it with SiO2 material by varying the oxide thickness ranging from 1nm to 20nm using nanotechnology. **Materials and Methods:** DFT tool is used to perform the above characterisation. The method was performed for 20 samples per group, TiO_2(n=20) and SiO_2(n=20). Same samples were used for both the control group and experimental group. Different values of drain current were obtained by varying the thickness for both TiO_2 and SiO_2. **Result:** Drain current was obtained for TiO_2 (0.645μA) and found better compared with SiO_2 (0.58μA). **Conclusion:** It is concluded that the TiO2 Omega FinFET appears to be better compared to SiO_2 based omega FinFET.

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Introduction

VI characteristics of TiO_2 based FinFET are being explored with simulation by varying the thickness of the oxide. A FinFET is a multigate device button on a substrate where the gate is placed on a channel with high mobility in channel and reliability (Liu, Lim, and Yeo 2010). VI characteristics of FinFET can be used to determine the current and voltage characteristics of the triple gate FinFET structure in the future and it can also be used for the fabrication of highly efficient FinFET which can be used as an amplifier as well as a switch (Masahara et al. 2005). FinFET is also used as load switches in micromechatronics. This is a basic function in mechatronic applications such as mems, robotics, aeronautics, servo drives (Rajendran and Mary Lourde 2015); (Ha et al. 2017). When rescaling is used, short channel effects have always been a major concern due to the leakage current.

In order to reduce the leakage current TiO_2 can be used for FinFET which is the proposed method (Backhaus 2017).

There are more than 60 articles published in different journals like ieee, google scholar, academia etc., PMOS based FinFET characteristics with design ruled SRAM technology (T. Park et al., n.d.). several reports had proposed body tied FinFET and fabricated on bulk wafer instead of soi (Zhao et al. 2020) wafer. they reduced wafer cost, wafer defect density and relieved floating body effect (T.S. Park, Yoon, and Lee 2003); (Mori and Ida 2013). In some journals they studied about conventional planar mosfet, omega FinFET and nanowire FinFET (Im et al. 2017). When the channel length is reduced, SNM decreases and SNM increases, according to our findings (Idris et al. 2019). The impact of intrinsic fluctuation on the SNM and its efficiency is currently being investigated (Li and Lu 2006); (Kumar et al. 2019). The fin-width dependency was investigated, and the derived data was used to clarify variations in patterns between silicon-on-insulator and body-tied FinFETs. The modelled static lifetime and the measured static lifetime were nearly identical, with only a small root-mean-square

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error (H. Lee et al. 2006), (Sugii 2014). The best study paper had demonstrated soi substrates to overcome problems associated with short channels.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S.R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M.S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Suresh Babu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

It is important to know that the existing method had high leakage current and poor performance in omega FinFET SiO_2 material. TiO_2 is used in purification, disinfection of wastewater, self-cleaning coating for buildings in urban areas and production of greenery energy by splitting water. It has good ultraviolet resistant qualities and acts as ultraviolet absorbent (Farghali, Zaki, and Khedr 2016). These exclusive characteristics and current and voltage properties of TiO_2 inspired us to perform a few simulations based research with respect to TiO_2 by differing some of the parameters of this device. Oxide thickness of the device plays a significant role in the current and voltage properties of TiO_2. The main aim of the study is to analyse the electrical characteristics by variable oxide material thickness in omega FinFET.

Materials and Methods

The research was performed in the department of electronics and communication engineering, saveetha school of engineering. There are two groups with sample size of 20 each. Ethical approval is not needed since the samples were taken from the online sources. A total of 20 values of thickness used for the sample size (Ahmed, Dutta, and Mahmood 2018). Experiment was performed by evaluating the two groups using the same samples. The sample size was estimated to be 20 for each group using G power for 80 with inputs.

In sample preparation for group 1 the drain characteristics of a TiO_2 based Omega FinFET was simulated and analysed by varying the oxide thickness from 1 nm to 20 nm. The DFT based nano tool FinFET was used for simulating the Drain characteristics. Open the DFT tool, select the FinFET module and launch the tool. In the class select the FinFET and the specification 2D (double gate) was chosen for analysis. To obtain the drain characteristics of Tio_2 the device structure like channel width (30nm) was chosen.

In sample preparation for group 2 the drain characteristics of a SiO_2 based Omega FinFET was simulated and analysed by varying the oxide thickness from 1 nm to 20 nm. The DFT based nano tool FinFET was used for simulating the Drain characteristics. Open the DFT tool, select the FinFET module and launch the tool. In the class select the FinFET and the specification 2D (double gate) was chosen for analysis. To obtain the drain characteristics of SiO_2 the device structure like channel width (30nm) was chosen.

Nano Hub is an open - source software tool. This tool is used for the analysis of drain characteristics of devices with various suitable materials like SiO_2 and TiO_2 by changing the dielectric constant in the channel as per the literature (El-Kareh 2012). The bandgap of a material and the gate contact work function of the material was entered in the tool.

The testing procedure measures the current and voltage characteristics of FinFET and single gate MOSFET. Simulation is done by keeping the voltage as constant and drain current is noted. Drain current for the groups was obtained (Desai, Hunt, and Strachan 2019). In this research work oxide thickness and gate voltage are the independent variables since they are inputs and remain constant even after changing other parameters, whereas the drain current and conductance are dependent variables because they depend on the inputs and vary for every change in the input.

Statistical Analysis

The statistical software used in this research work are origin and SPSS. Origin is used to plot graphs for given values and compare the variables and SPSS is used to calculate the mean, standard deviation and significance difference of the results obtained through simulation. The analysis of the research work is done using Independent T-Test, which is used to compare conductance and drain current of TiO_2 and SiO_2. Oxide thickness is the independent variable and conductance and drain current are the dependent variables.

Results

Drain current of $6.45*10^{-7}$ A was obtained for TiO_2 which appears to be better compared with SiO_2 $5.80*10^{-7}$ A. Current and voltage characteristics of TiO_2 based omega FinFET and SiO_2 for oxide thickness (1nm to 20nm) are shown in Fig.1 and Fig.2 respectively.

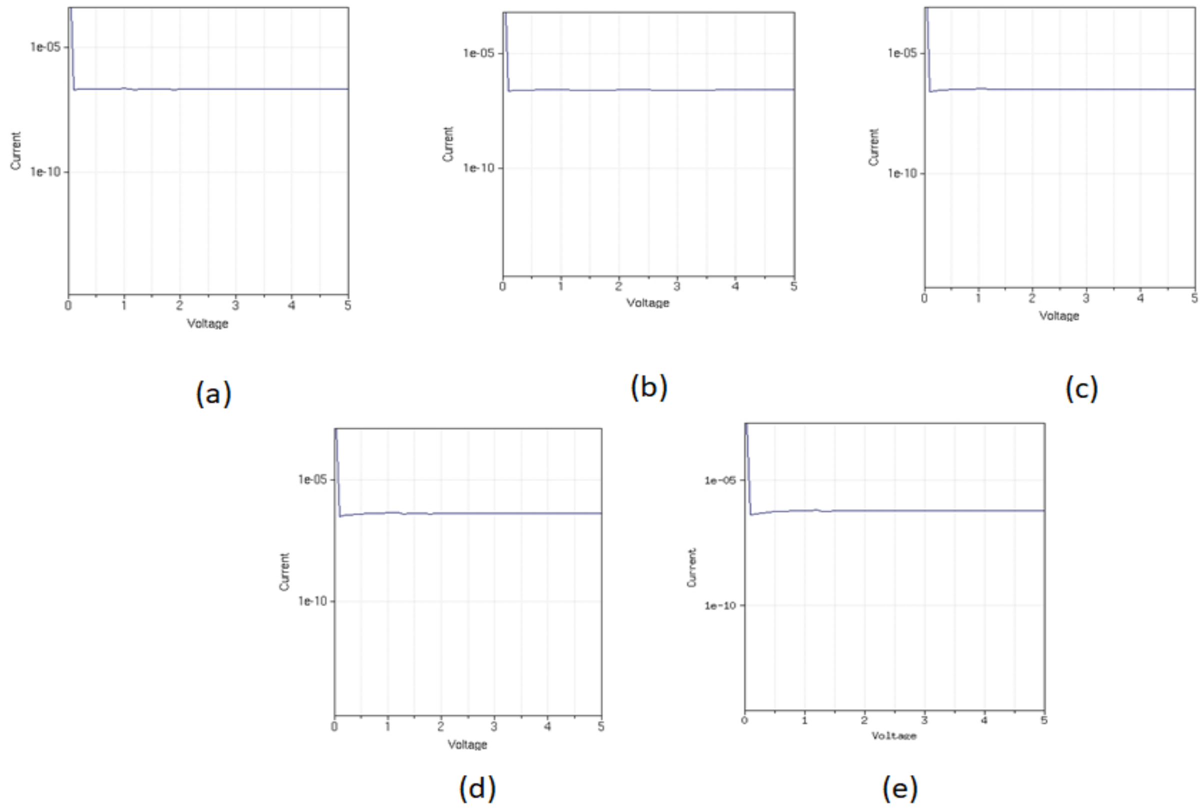

Fig. 1. Simulated IV characteristics of FinFET for an oxide thickness of two gates. (a)1nm (b)2nm (c)3nm (d)4nm (e)5nm. The line represents the IV curve with drain current on x axis and voltage on y axis

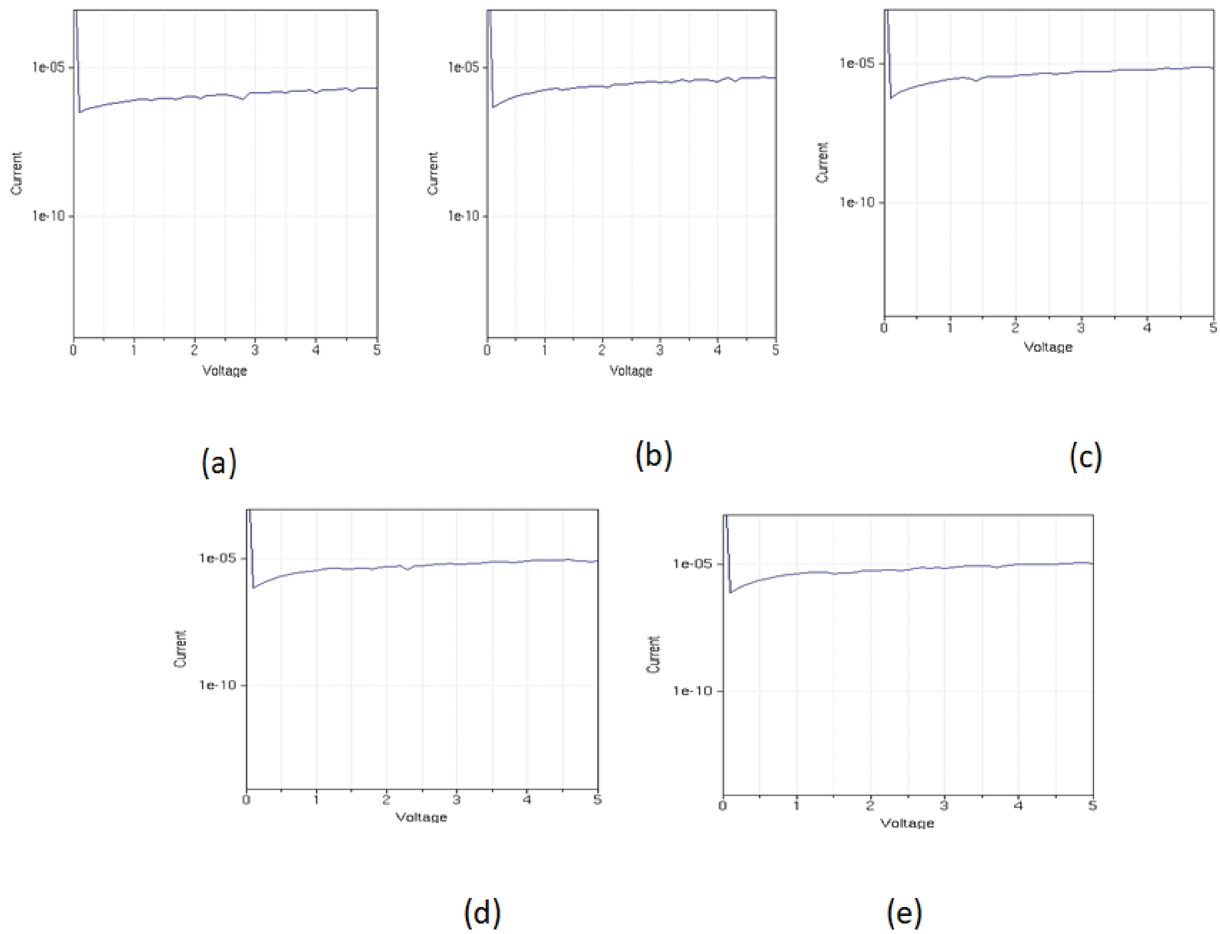

Fig. 2. Simulated IV characteristics of drain current for SiO_2 for an oxide thickness (a)1nm (b)2nm (c)3nm (d)4nm (e)5nm. The line represents the IV curve with drain current in SiO_2

Table 1. Drain current values of TiO_2 for different values of oxide thickness

S. No	Thickness(nm)	Drain Current (amp)TiO_2
1	1nm	1.95e-07
2	2nm	2.28e-07
3	3nm	2.68e-07
4	4nm	3.10e-07
5	5nm	3.60e-07
6	6nm	3.95e-07
7	7nm	4.37e-07
8	8nm	4.78e-07
9	9nm	5.19e-07
10	10nm	5.60e-07
11	11nm	6.01e-07
12	12nm	6.42e-07
13	13nm	6.83e-07
14	14nm	7.24e-07
15	15nm	7.65e-07
16	16nm	8.06e-07
17	17nm	8.48e-07
18	18nm	8.89e-07
19	19nm	9.30e-07
20	20nm	9.71e-07

Table 1 shows that the drain current of TiO_2 which appeared to be maximum when the oxide thickness was 1nm which is $6.45*10^{-7}$ A.

Table 2. Drain current values of SiO_2 for different values of oxide thickness

S. NO	Thickness(nm)	Drain current (amp)SiO_2
1	1nm	2.21e-07
2	2nm	2.64e-07
3	3nm	3.02e-07
4	4nm	3.58e-07
5	5nm	3.98e-07
6	6nm	4.43e-07
7	7nm	4.83e-07
8	8nm	5.32e-07
9	9nm	5.78e-07
10	10nm	6.23e-07
11	11nm	6.67e-07
12	12nm	7.12e-07
13	13nm	7.57e-07
14	14nm	8.02e-07
15	15nm	8.47e-07
16	16nm	8.92e-07
17	17nm	9.37e-07
18	18nm	9.82e-07
19	19nm	10.27e-07
20	20nm	10.72e-07

Table 2 shows that the drain current of SiO_2 which appeared to be maximum when the oxide thickness was 1nm which is $5.80*10^{-7}$A.

According to Table 3 there is a statistically insignificant difference between the TiO_2 and SiO_2 since the value of p is less than 0.05 ($p<0.05$).

Table 3. T-test comparison of TiO_2 and SiO_2 by varying the oxide thickness from 1nm to 20nm. Statistically significant difference of TiO_2 and SiO_2. TIO_2 has the highest mean (6.45) over the SiO_2 (5.80)

V2	Group	N	Mean	std. Deviation	std. error mean
	Tio_2	20	6.45450	2.656388	.593986
	SiO_2	20	5.80450	2.431790	.543765

Table 4 shows that TiO_2 has the highest mean 6.45 and SiO_2 has the lowest mean 5.80. It had 95% confidence interval of difference.

Table 4. Confidence interval of the difference has 95%. There is an insignificance difference between the two groups since p = 0.638. (Independent Sample T Test)

		Levene's Test for Equality of variances					T-test for Equality of Means		95% Confidence Interval of the Difference	
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std.Error Difference	Lower	Upper
V2	Equal variances assumed	.225	.638	.807	38	.425	.650000	.805295	-.980235	2.280235
	Equal variances not assumed			.807	37.707	.425	.650000	.805295	-.980650	2.280650

Fig. 3 shows the comparison of the mean of (+/-1 SD) TiO_2 and SiO_2 drain current by varying oxide thickness.

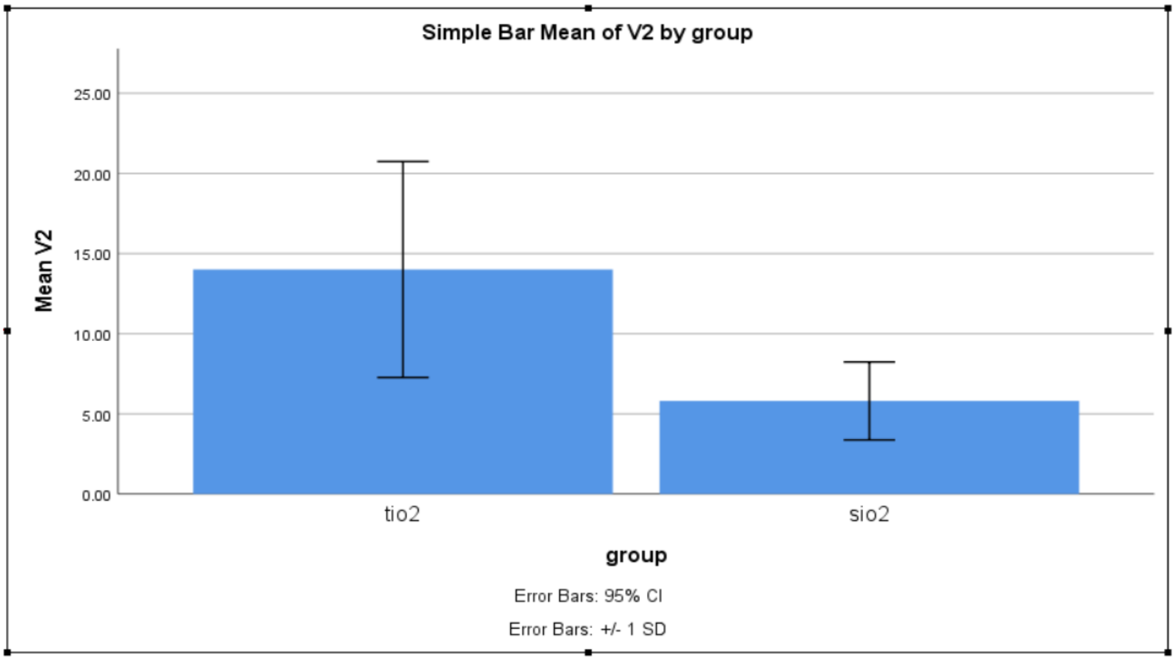

Fig. 3. Bar chart comparing the mean of (+/-1 SD) drain current of TiO_2 and SiO_2 by varying the oxide thickness. X axis represents the two groups. Y axis gives the mean with =/-1SD.

Discussion

In this study, drain current was obtained for TiO_2 based innovative FinFET current obtained as ($6.45*10^{-7}$ A) and found better compared with SiO_2 ($5.80*10^{-7}$ A). The factors that affect the drain current for TiO_2 and SiO_2 in this research work are oxide thickness, channel dimension and substrate thickness. The other factors are kept constant and simulations are carried out by varying oxide thickness. In SiO2 dielectric constant increases, band gap decreases because both are inversely proportional to each other (Wang, Liu, and Zhang 2017). The dielectric constant increases the peak of the conductance characteristics shift towards left corner. (C.W. Lee et al. 2007). The low dielectric constant of SiO_2 because of absence modulation at SiO_2/GaN devices (Gila et al., n.d.). By increasing dielectric constant the natural length reaches its scaling limit (Gupta, Raghav, and Patel 2015). Due to the presence of high k gate dielectric beneath the gate, it helps in reducing the gate fringing field. (Das and Baishya 2017). The drain current of TiO_2 improves compared to SiO_2. Limitations such as short channel effects and channel length modulation the power dissipation increases which decreases because of which decrease the performance of SiO_2 based FinFET. There is still leakage of current leakage in TiO_2 based FinFET but it is minimum when compared to SiO_2 based FinFET. In future this could be tried physically.

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

Conclusion

Drain current was obtained for TiO_2 ($6.45*10^{-7}$ A) and found better compared with SiO_2 ($5.80*10^{-7}$ A) The Drain current of TiO_2 omega FinFET appears to be higher compared to SiO_2 based omega FinFET.

Declarations

Conflict of Interests

No conflict of interest in this manuscript.

Authors Contributions

Author JSK was involved in simulation, analysis, manuscript writing. Author JM was involved in conceptualization, data validation, and review of manuscript.

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