THRESHOLD VOLTAGE FLUCTUATION IN N-MOS DUE TO TRAP POSITION AND DOPING PROFILE

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ABSTRACT

In this paper , the threshold variation due to modification in doping profile and random trap position has been analysed. This analysis has been done on N-MOS with 40 nm channel length and 32 nm effective channel length . The trap position is changing from drain end to source end and results were observed for different doping profiles .The results shows that the fluctuation in $V_{Threshold}$ is not consistent and the standard deviation are dependent on the trap position as well as on the nature of doping profile. As the Gaussian doping profile shows less fluctuation in comparison of Error function doping profile. The threshold voltage standard deviation is highly correlated when the trap is located in between the centre.

***Index Terms*: Doping Profile, Threshold Voltage Fluctuation, Random Telegraph Noise, Erf Doping Profile, Gaussian Doping Profile.**

I INTRODUCTION

Random Telegraph fluctuation (RTF) expose itself the fluctuation in MOS transistor threshold voltage[1,2]. Traditionally the consideration of random telegraph fluctuation was important only in analog design at low frequencies but it cannot be ignored in the digital designs too[1].The charge carrier Degradation has been thought to be due to carrier trapping in the interface- trap generation and/or gate oxide .This script point out the results based on two device models 1) Using Gaussian doping profile for random trap locations, 2) Error function doping profile for random trap location. Traps are electrically active defect located at the interface between oxide and semiconductor; capable of trapping and de-trapping charge carriers, interface traps have an adverse effect on device performance. The interface traps existence disturbs the channel formation during source and drain region which leads to fluctuation in expected threshold voltage and drain current of device. Generation of traps like random variations are unpredictable and are caused by random uncertainties in the fabrication process [7].

In processing of modern semiconductor devices, doping refers to the process of introducing impurity atoms into a pure semiconductor. Doping profile is the spatial (with distance) variation of doping concentration within the structure or A doping profiles a plot of the spatial variation of dopant concentration in a device, usually |NA - ND | on a log scale. In Gaussian doping profile the charge concentration is distributed according to Gaussian function on the other hand distribution is an error function of parameters in Erf doping profile. The random dopant fluctuation and other fluctuations like random telegraph fluctuation makes MOS designing more complicated.

The purpose of this paper is to show NMOS threshold voltage fluctuates due to random doping and random trap interface . The behaviour of above mentioned investigated by means of simulation work using the TCAD software. Technology Computer-Aided Design (TCAD) refers to the use of computer simulations to develop and optimize semiconductor processing technologies and devices. Synopsys TCAD offers a comprehensive suite of products that includes industry leading process and device simulation tools, as well as a powerful GUI-driven simulation environment for managing simulation tasks and analyzing simulation results.

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II MOSFET DEVICE DESIGN

The device model is shown in figure-1. N-MOSFET has been designed using *Genius Deck* in TCAD and design code specifications are given as

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REGION   Label=NSilicon    Material=Si
FACE   Label=NSource   Location=Top       X.min=0.0          X.MAX=0.07
FACE   Label=NDrain    Location=Top X.MIN=.11                X.MAX=.18
FACE   Label=GATE      Location=Top  X.MIN=0.07              X.MAX=.11
FACE   Label=SUB       Location=BOTTOM
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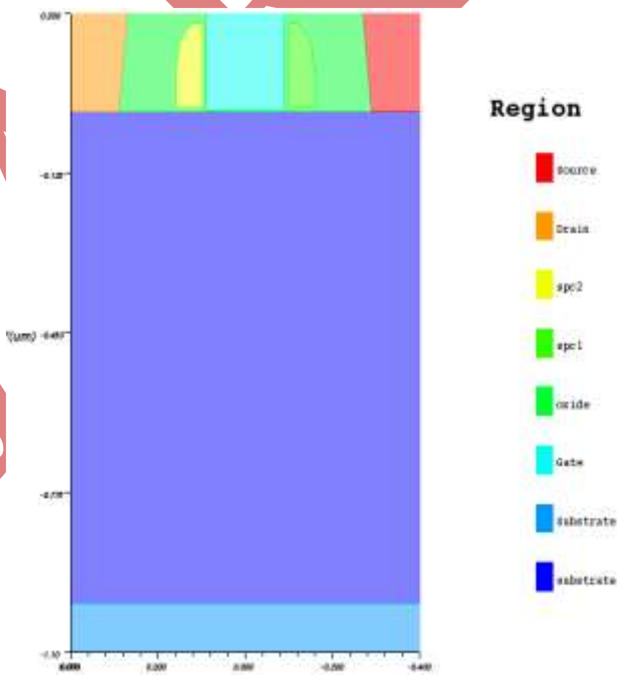
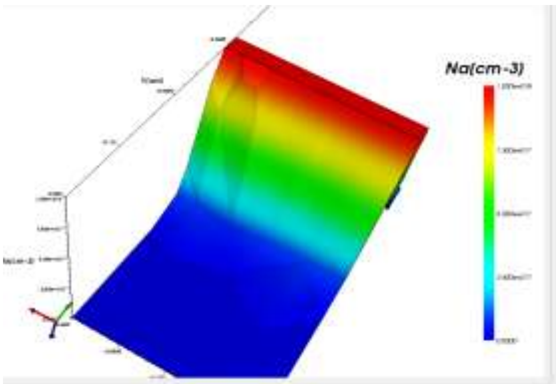


Figure 1. N-MOSFET Device Model

P-type doping with uniform throughout all of the body region with doping uniform concentration 2e+16 p.type region-1 direction-y. Initial definitions are Gaussian/Erf doping profile of charge concentration = 1e+20 with n.type in source and drain region, that is marked as region-3 and region- 4respectively in this design.

III SIMULATIONS

For investigation of Threshold Voltage fluctuation two N-MOS devices have been targeted with Gaussian and Erf doping profie to study of random trap position. For MOS with Gaussian doping the device dimensions are; channel length 40nm ,effective channel length 32 nm ,source region and drain region 40 nm. Mesh type triangular (with two times mesh refining), doping profile Gaussian in drain and source region density 1e+20 donor. Doping profile uniform linear in body region with density 2e+16 with accepter. Gate terminal connected via Npolysilicon and metal connections using Aluminium.



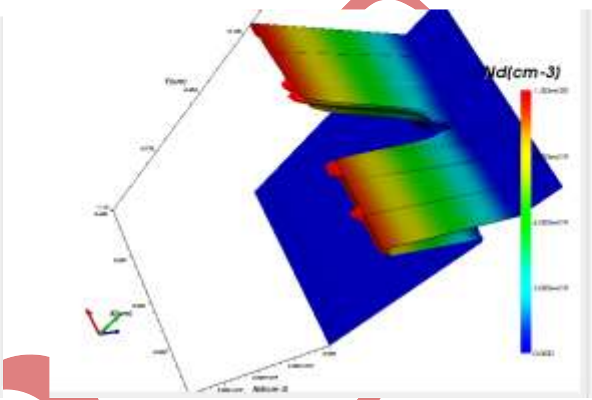
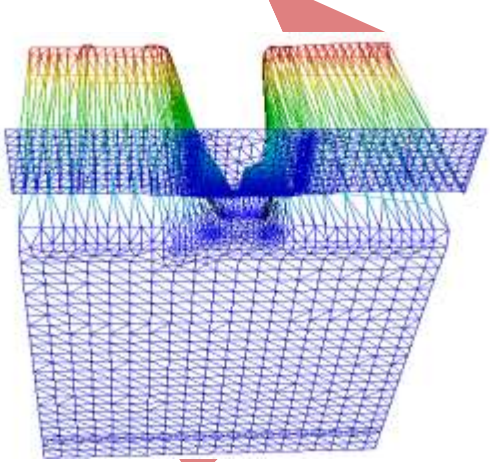


Fig 2. Net body doping with accepter impurity. Fig 3. Net Source /Drain Doping With Donor Impurity.

For designing of N-MOS with Error function doping the other parameters are same except the doping profile has been replace by Erf doping profile.Figure-5



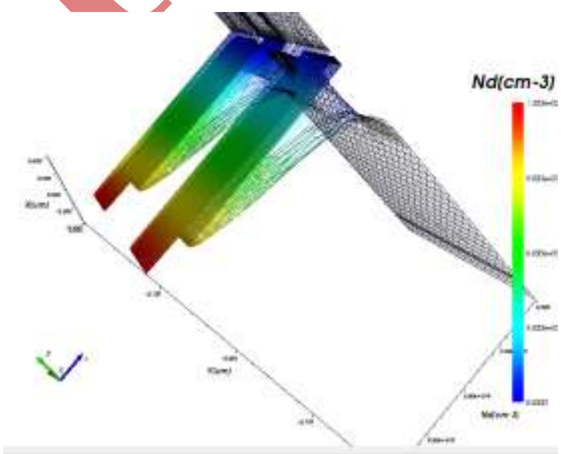
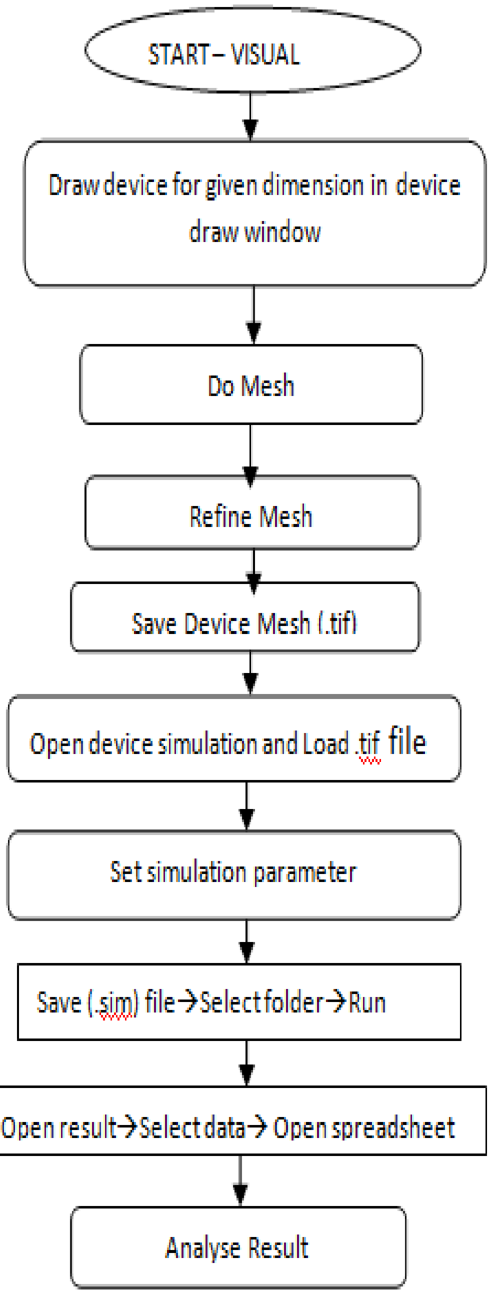


Fig4: N-MOSFET Device TCAD Mesh structure Fig 5: N-MOSFET Device with Erf doping profile

This simulation model design is based on percolation theory[8].It computes the conductivity of cellular array structure from the source to drain end of a MOSFET with a particular random trap is present in a cell statistically distributed across the channel width. The interface trap considered in this model is located at the Gate oxide and channel interface with charge density 1e+15 and accepter in nature. For simulation Gate voltage selected as voltage sweep: initial voltage 0, final voltage 2V step size .01. Drain voltage kept constant 0.5 V . To perform statistical analysis trap is not included in first MOSFET modelling for calculation of desired threshold voltage.

The simulation procedure to perform simulation is shown in flow diagram



IV RESULTS AND DISCUSSION

For every trap position the threshold voltage was calculated as mean of 10 different doping concentrations in both the cases for Gaussian and Erf profiles and fluctuation has been calculated with respect to threshold voltage neglecting the trap behaviour of device at interface. The calculated result shown in Table no-1

Trap position(nm) Drain-to-Source	Mean V_T fluctuation (Gaussian)	Mean V_T fluctuation (Erf)
0	0.018	0.016
5	0.014	0.012
10	0.02	0.017
15	0.016	0.015
20	0.015	0.014
25	0.013	0.019
30	0.017	0.014
35	0.018	0.019
40	0.025	0.027
Std. Deviation	0.003605551	0.004359

Table No. 1: Result analysis

The trap near to drain making less influence on threshold voltage in comparison of source end since they are major obstacle for electrons in N-MOS channel because the high input barrier experienced in the source region. Effect of this obstruction offered by trap is less effective for Gaussian doping profile in respect of Erf doping. The threshold voltage fluctuation with respect to trap position along the channel has been displayed in figure-6. The results are giving the clear reflection that, the threshold voltage fluctuation is inconsistent with random trap location for both the doping profiles.

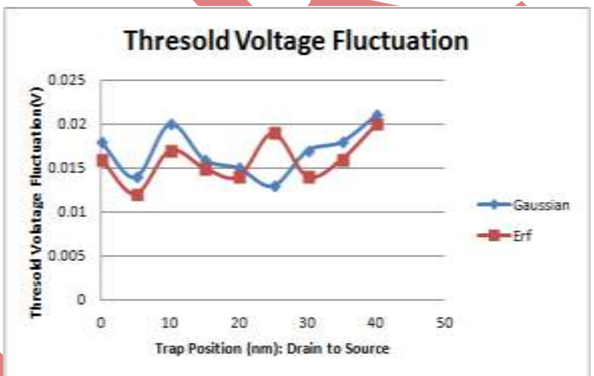


Fig 6: Threshold Voltage fluctuation with trap location for Gaussian and Erf doping profiles

V CONCLUSION

The Threshold voltage fluctuation and its standard deviation are extracted by our simulation results, the explanation holds and since a trap near to drain region is causing less resistance in comparison of trap location near to source side and in graphical analysis it is showing peak of the threshold fluctuation due to source side of trap. The Gaussian doping profile shows less fluctuation than Erf doping profile. From the statistical analysis of result obtained from simulation giving clear evidence, that due to random nature of threshold voltage fluctuation for various trap location make mathematical modelling of device challenging which introduce complication in device deign. Another conclusion can be draw from the standard deviation for Gaussian and Erf doping profiles ,the fluctuation in threshold voltage is also dependent on the nature of doping functions .

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