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International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 3 March 2013 Page No. 777-780

# A CHARGE CONTROL MODEL OF SURROUNDING GATE MOSFET

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Abstract----*In this paper total charge of multigate MOSFET is calculated by using centroid model. Analytical modeling of total inversion charge is computed using self consistent model. The total Charge is analyzed for various value of gate to source voltage and results are discussed. The model is based on charge quantisation within the channel and it includes overshoot velocity effects*

Keywords
*Charge control, centroid model, quantum charge, total charge, Surrounding Gate MOSFET.*

## I. INTRODUCTION

One of the promising SOI devices for the nanoscale range is the surrounding gate (SGT) or Gate-All Around MOSFET (GAA). Gate-all-around FETs are similar in concept to Fin FETs except that the gate material surrounds the channel region on all sides. Depending on design, gate-all-around FETs can have two or four effective gates. This advanced structure can be scaled more aggressively than the bulk-Si structures. We have proposed a compact RF model for SGTs, based on a charge control model obtained from 2D device simulations where transistor parameters are taken into account. The charge control model can be applied both to the classical and quantum cases [1].

The charge sheet approach and using an approximate unified expression for the inversion charge density, we have derived explicit Continuous DC and charge-conserving models for fully-depleted SOI MOSFET's. The effects like Mobility degradation and short-channel effects- channel length modulation, velocity saturation, DIBL have also been included [2]. In previous work**,** they have presented an analytical dc model for cylindrical undoped SGT MOSFETs. The model is based on a new unified charge control model developed for this device, from which we derived a channel current expression in terms of the channel charge densities at the source and drain ends of the channel. The model becomes explicit by using appropriate expressions for the channel charge densities in terms of the applied voltages. The channel charge distribution in the silicon film is adequately accounted for in the charge control model. Besides, the channel current expression presents an infinite order of continuity for overall operating regimes, which makes the model very promising for circuit simulation. Examining the new charge control model, the dependencies of the channel charge density on the applied voltages in each operating regime, we propose approximate explicit expressions of the channel charge densities in terms of the applied bias and infinitely continuous through all operating regimes. Due to its infinite order of continuity, the new model provides smooth transitions through all operating regimes.

## II. PROPOSED WORK

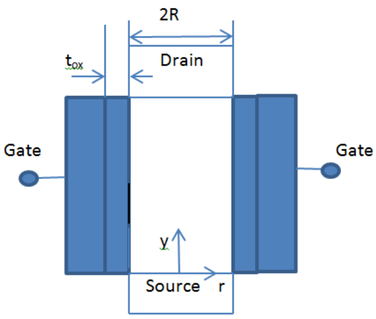


Fig 1: cross section of the Gate All around MOSFET

In the existing work, using the centroid the noise figure of SG MOSFET. But in our paper, we have proposed a charge model and analyzed the total charge throughout the device.

In this centroid model we derive the expression for the total charge

$$(V_{gs} - \Delta\vartheta - V) - \frac{KT}{q}\log\left(\frac{8}{\delta R^2}\right) = \frac{Q}{C_{ox}} + \frac{KT}{q}\log\left(\frac{Q}{Q_0}\right) + \frac{KT}{q}\log\left(\frac{Q+Q_0}{Q_0}\right) \qquad (1)$$

Where $Q_0 = (4\varepsilon_{si}/R)(KT/q)$, $C_{ox}$=Channel Capacitance, R=Constant

This charge control model, without the third term in the right hand side (RHS), is very similar to the Unified Charge Control Model (UCCM) derivedpreviously for bulk and single-gate fully-depleted SOI MOSFET [3]. For films thinner than 10 nm, quantum confinement should be considered; it leads to a reduction of the channel charge density and an increase of the threshold voltage.

We can take(1) into below threshold since $Q << Q_0$

$$Q = Q_0 \exp\left(\frac{V_{gs} - V_0 - V}{V_{th}}\right) \qquad (2)$$

Where $V_{th}$=KT/q

To calculate the approximate equation of total charge in previous works explicit solutions of UCCM in bulk and single-gate SOI MOSFETs were proposed and tested [3].

Using this centroid model, a classical inversion charge model has been improved, in order to include quantum effects. In the new model, the classical oxide capacitance was replaced by one where the capacitance of the oxide layer is in series with the capacitance of the silicon layer, its thickness corresponding to the value of the inversion charge centroid. The new total capacitance is calculated as [4].

$$\frac{1}{C_{TOTAL}} = \frac{1}{C_{ox}} + \frac{1}{C_{sem}} \qquad (3)$$

Where $C_{ox}$ is the value of a cylindrical capacitor with the external radius.

$$C_{ox} = \frac{\varepsilon_{ox}}{R.\ln\left(1 + \frac{t_{ox}}{R}\right)} \qquad (4)$$

Where $\varepsilon_{ox}$ is the oxide permittivity.$C_{sem}$ is calculated as:

$$C_{sem} = \frac{\varepsilon_{si}}{(R - z_I)\ln\left(1 + \frac{z_I}{R - z_I}\right)} \qquad (5)$$

Where $\varepsilon_{si}$ is the silicon permittivity, $z_I$=constant

We vary $t_{ox}$ and calculate the total charge of Gate All Around MOSFET.

$$D = -\frac{2C_{ox}V_{th}{}^2}{Q_0} \qquad (6)$$

Equation (6) substitute in (7)

$$Q = C_{total}\left(D + \sqrt{D^2 + 4V_{th}{}^2 \ln^2\left(1 + \exp\left(\frac{V_{GS} - V_t + \Delta V_t - V}{2V_{th}}\right)\right)}\right) \qquad (7)$$

This new unified compact model has the same explicit expression for classical and quantum-effect model but using different threshold voltages and effective oxide capacitance. We substitute total capacitance for oxide capacitance. The threshold voltage ($V_{th}$) is that value of the gate source voltage ($V_{GS}$) at which a conducting channel is induced under the gate oxide at the surface of Surrounding Gate MOSFET.

Due to scaling, the silicon thickness is ultra-thin and quantum confinement must be included in the models.

Quantum mechanical effects have not been consideredin this model; anyway, they are negligible for silicon films thicker than 10 nm (i.e.,R>5 nm). For films thinner than10 nm, quantum confinement should be considered.

## III. RESULTS AND DISCUSSION

In this section calculated total charge is varied for various gate to source voltage and also with respect to oxide thickness. We calculate the output of various parameter of Gate All Around MOSFET. In previous method they calculate drift current model and temperature model.

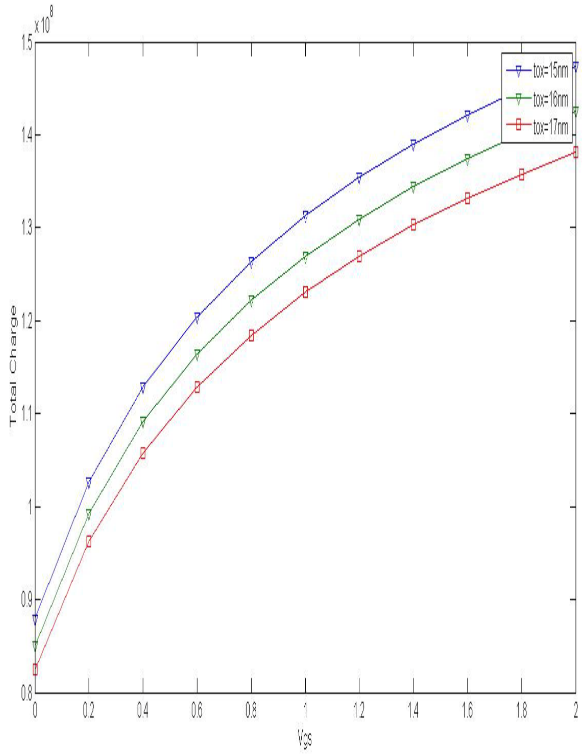


Fig 2: Gate source voltage VS Total charge $t_{ox}$=15nm, 16nm, 17nm

If the thickness of the MOSFET increase, the total charge and gain to source voltage has increased. We vary various value of thickness of the MOSFET. According to this result we reduce the thickness then total charge increased. So thickness of MOSFET is inversely proportional to the capacitance and also inversely proportional to gain source voltage.

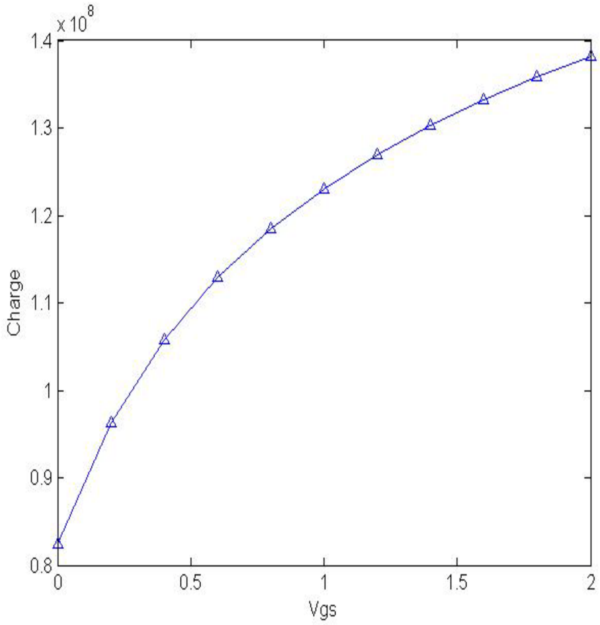


Fig 2: Gate to source voltage VS Total charge with oxide thickness $t_{ox}$=100nm, R=6.25nm

## IV. CONCLUSIONS

In this paper we calculated the total charge and it is varied between the various gate to source voltage and also respect to oxide thickness. The various parameters are calculated for different gate to source voltage and compared with the MOSFET.

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