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Analysis & Validation of a MOSFET Mobility Model using BSIM3v3.2.2

Sanjay Kumar Singh and Subhanshu Kumar Verma***

ABSTRACT

This paper presents a mobility model for MOSFET comprising some of the vital areas such as, mobility. A comparison is done between BSIM3v3.2.2 and BSIM3v3.1 emphasizing the domain of mobility.

***Keywords:** Mosfet; Bsim; Threshold Voltage; Gate Oxide Thickness.*

1.0 Introduction

A good mobility model is critical to the accuracy of a MOSFET model. The scattering mechanisms responsible for surface mobility basically include phonons, columbic scattering, and surface roughness. For good quality interfaces, phonon scattering is generally the dominant scattering mechanism at room temperature. In general, mobility depends on many process parameters and bias conditions. For example, mobility depends on the gate oxide thickness, substrate doping concentration, threshold voltage, gate and substrate voltages, etc. Sabnis and Clemens proposed an empirical unified formulation based on the concept of an effective field Eeffwhich lumps many process parameters and bias conditions together. Eeffis defined by

$$E_{eff} = \left(\frac{(Q_B + Q_n/2)}{2}\right)$$

The physical meaning of *Eeffcan* be interpreted as the average electrical field experienced by the carriers in the inversion layer. The unified formulation of mobility is then given by

$$\mu_{eff} = \frac{\mu o}{1 + (E_{eff}/Eo)^{v}} \qquad (1)$$

For an NMOS transistor with n-type poly-silicon gate, Eq. (1) can be rewritten in a more useful form that explicitly relates *EefHo* the device parameters

$$E_{eff} = \frac{(Vgs + Vth)}{6Tox} \qquad (2)$$

This equation (1) fits experimental data very well, but it involves a very time consuming power function in SPICE simulation.

Taylor expansion Eq. (1) is used, and the coefficients are left to be determined by experimental data or to be obtained by fitting the unified formulation. Thus, we have

- **(mobmod=l)**

$$\mu_{eff} = \frac{\mu o}{(1 + (U_a + U_b.V_{bseff})\left(\frac{Vgst + 2Vth}{Tox}\right) + Ub\left(\frac{Vgst + 2Vth}{Tox}\right)^2} \qquad (3)$$

Where V_{gst}=(V_{gs}-V_t)

- U_a = First order mobility Degradation coefficient;
- U_b = Second order mobility Degradation coefficient;
- U_c = Body Effect of mobility Degradation coefficient;
- μ_o= Mobility at normal temperature

To account for depletion devices another model is given by the following:

- (**for mobmod=2**)

$$\mu_{eff} = \frac{\mu o}{(1 + (U_a + U_b.V_{bseff})\left(\frac{Vgst}{Tox}\right) + U_b\left(\frac{Vgst}{Tox}\right)^2} \qquad (4)$$

To consider the body bias dependence of equation (3) further it can be modified as:

- (**for mobmod=3**)

$$\mu_{eff} = \frac{\mu o}{(1 + [U_a\left(\frac{Vgst + 2Vth}{Tox}\right) + U_b\left(\frac{Vgst + 2Vth}{Tox}\right)^2](1 + U_c.V_{bseff})} \qquad (5)$$

Sarncethe entire three mobility model occupy mobility degradation coefficient, hence an investigation will be essential to study the mobility variation by varying these coefficient.

**Corresponding Author: Department of Electronics and Communication Engineering Engineering, BPRCE, Gohana, Haryana, India (E-mail: singhsanjaykumar234@gmail.com)*
***Department of Electronics and Communication Engineering, YMCA University, Faridabad, Haryana, India*

2.0 Mobility Calculation Results

Now the calculation is done by using the mobility model 1 as stated in equation (3) and the parameters extracted from BSIM3v3.1 model file. The results are as follows

Table 1: Mobility Utilizing Mobility Model 1

μ_o (cm^2/Vs)	U_a(m/V)	U_b (m/V)^2	U_c (m/V2)	MOBILITY μ (cm^2/VSec)
269.0634518	- 1.188565E-9	1.930877E-18	2.224818E-11	290.5172

Another calculation is done by using the mobility model 2 as stated in equation (4) and the parameters extracted from BSIM3v3.1 model file. The results are as follow

Table 2: Mobility Utilizing Mobility Model 2

μo (cm2/Vs)	U_a (m/V)	U_b (m/V)2	U_c (m/V2)	MOBILITY μ (cm^2/VSec)
269.0634518	- 1.188565E-9	1.930877E-18	2.224818E-11	328.8146

3.0 Validation and Comparison of Calculated Mobility of BSIM3v3.2.2 with BSIM3v3.1

Since $gm=\mu_{eff}C_{ox}(W/L)(V_{gs}-V_t)$

- ***for mobility model 1***(Calculatedμ_{eff}= 290.5172 cm^2/Vsec inBSIM3v3.2.2)

Practical result (BSIM3V3.1): **gm=196.811**μA/V^2
The calculated value of Transconductance (**gm**) = **226.38**μA/V^2

- ***for mobility model 2*** (Calculatedμ_{eff}=328.8146cm^2/Vsec in BSIM3V3.2.2)

Practical result (BSIM3V3.1): **gm=219.790** μA/V^2
calculated value of Transconductance (**gm**) = **251.70**μA/V^2

4.0 Conclusion for Mobility Model

It is observed that BSIM3v3.1 is designed with mobility model 1 and mobility model 2 (It gives the similar results for mobility model 3 as for mobility model or the default) The Tran conductance thus calculated for BSIM3v3.2.2 is comparatively high hence the mobility model presented in BSIM3v3.2.2 could be used to implement more efficient and result oriented Trans conductance amplifier.

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