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Subthreshold Swing for Top and Bottom Gate Oxide Thickness of Asymmetric Double Gate MOSFET

Hakkee Jung[1]

[1] Department of Electronic Eng., Kunsan National University,
558 Daehangno, Gunsan, Chonbuk, Rep. of Korea
hkjung@kunsan.ac.kr

Abstract. The subthreshold swing of asymmetric double gate(DG) MOSFET has been analyzed for top and bottom gate oxide thickness. The asymmetric DGMOSFET has the advantages to be able to fabricate differently thickness of top and bottom gate oxide. The analytical subthreshold swing model has been derived from analytical potential model for asymmetric DGMOSFET. The subthreshold swing for asymmetric DGMOSFET has been investigated using our analytical subthreshold swing model for the change of top and bottom gate thickness. As a result, we know the subthreshold swings have greatly changed for top and bottom gate thickness, and those have been especially influenced on top gate thickness.

Keywords: subthreshold swing, asymmetric double gate MOSFET, Poisson equation, potential distribution

1 Introduction

To reduce the SCEs(Short Channel Effects), the many works for novel structure of transistor are in progress[1]. The multiple gate FET(MugFET) is the candidate to be able to eventually replace CMOSFET for reducing the SCEs to happen for the conventional MOSFET of sub-20 nm channel length. The double gate(DG) MOSFET is the representative MugFET, having simple processing and structure

Since the symmetric DGMOSFET is the simplest structure among these MugFETs, many researchers are studying for analytical transport models[2]. However the study for asymmetric DGMOSFET is not much. Z. Ding et al. had analyzed the asymmetric DGMOSFET using simple 2D potential model using constant doping in channel[3]. However, doping profile in channel follows Gaussian distribution in the case of asymmetric DGMOSFET. Tiwari et al. had successfully analyzed threshold voltage and surface potential using 2D analytical potential model based on Gaussian doping profile in channel[4], but they obtained surface potential for only symmetric DGMOSFET. Therefore the subthreshold swing for the asymmetric DGMOSFET has been analyzed in this paper, using 2D analytical potential model based on Gaussian doping profile in channel, differently with Ding's model.

This paper is arranged as follows. The method to obtain the subthreshold swing for the asymmetric DGMOSFET using Gaussian doping profile based on Ding's potential model is described in Section 2. In Section 3, the subthreshold swings changed by top and bottom gate oxide thickness and biasing, and doping profile have been presented,

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and deviation of subthreshold swings for these device parameters has been well explained for asymmetric DGMOSFET. The summary and discussion are described in Section 4.

2 The analytical subthreshold swing model

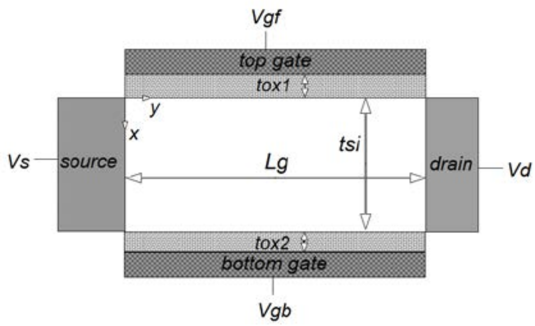

Fig. 1. The schematic diagram of a asymmetric DGMOSFET.

The schematic overview diagram of a asymmetric DGMOSFET is shown in Fig. 1, where L_g, t_{Si}, t_{ox1}, t_{ox2} are channel length, channel thickness and top gate oxide thickness, bottom gate oxide thickness, respectively. The 2D potential distribution $\phi(x, y)$ has been obtained by solving the following Poisson's equation

$$\frac{\partial^2 \phi(x,y)}{\partial x^2} + \frac{\partial^2 \phi(x,y)}{\partial y^2} = \frac{qn(x)}{\varepsilon_{Si}} \tag{1}$$

where ε_{Si} is the permittivity of silicon and $n(x)$ is the Gaussian doping distribution. By the definition of subthreshold swing and Ding's methods[3],

$$\begin{aligned} SS &= \frac{\partial V_{gf}}{\partial(\log_{10} I_d)} = 2.3V_t \left[\frac{\partial \phi(x,y)}{\partial V_{gf}}\right]^{-1} \\ &= 2.3V_t \left[\begin{array}{l} \displaystyle\sum_{n=1}^{\infty} \frac{2}{n\pi}(1-(-1)^n) \left(\frac{(e^{-k_n t_{si}} - k_n \varepsilon_{si} e^{-k_n t_{si}} / C_{ox2}) e^{k_n x} - (e^{k_n t_{si}} + k_n \varepsilon_{si} e^{k_n t_{si}} / C_{ox2}) e^{-k_n x}}{(1 - k_n \varepsilon_{si} / C_{ox1})(e^{-k_n t_{si}} - k_n \varepsilon_{si} e^{-k_n t_{si}} / C_{ox2}) - (1 + k_n \varepsilon_{si} / C_{ox1})(e^{k_n t_{si}} + k_n \varepsilon_{si} e^{k_n t_{si}} / C_{ox2})} \right) \\ \bullet \sin \dfrac{n\pi y}{L_g} \end{array} \right]^{-1} \end{aligned} \tag{2}$$

where $V_t = kT/q$, C_{ox1} and C_{ox1} are the capacitances of top gate and bottom gate oxide, respectively .

3 Results and discussion for subthreshold swing

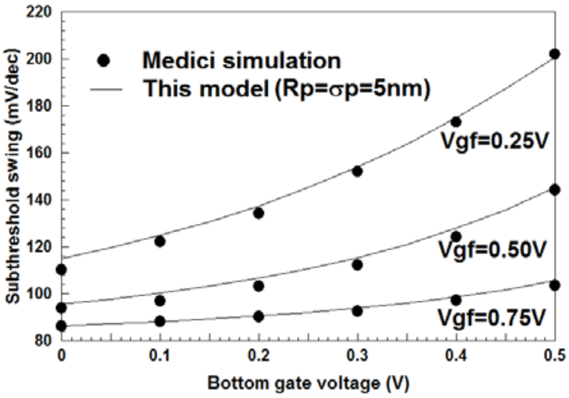

Fig. 2. The subthreshold swings for bottom gate voltage with a parameters of top gate voltage under the conditions of $L_g = 25nm, t_{si} = 10nm, t_{ox1} = 1nm, t_{ox2} = 1nm$ and $N_p = 10^{16} / cm^3$. The line describes the subthreshold swings of this model and dots are those for Medici simulation.

To verify the validity of this model, subthreshold swings of this model compares with those of 2D numerical simulation[3], and results agree with each other as shown in Fig. 2. As shown in Fig. 2, the changing rate for top gate voltage is very low in the region of low bottom voltage, but that is higher in the region of high bottom gate voltage. Note the subthreshold swing is equal if top gate voltage is the same as bottom gate voltage.

Figure 3 shows the contours of subthreshold swings for top and bottom gate oxide thickness in the case of biasing the same voltage at top and bottom gate. There is a proportional relation between top and bottom gate oxide thickness to sustain equal subthreshold swings as shown in Fig. 3.

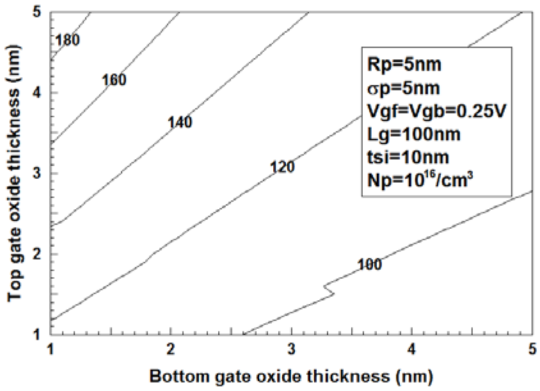

Fig. 3. The contours of subthreshold swings for top and bottom gate oxide thickness under the conditions of $L_g = 100nm, t_{si} = 10nm, V_{gf} = V_{gb} = 0.25V$ and $N_p = 10^{16} / cm^3$.

We know the subthreshold swings are decreasing with the increase of bottom gate oxide thickness and the decrease of top gate oxide thickness. The increasing rate of subthreshold swing is high in the region of high top gate and low bottom gate oxide thickness. On the other hand, the increasing rate of subthreshold swing is lower in the region of low top gate and high bottom gate oxide thickness.

4 Conclusions

The subthreshold swing for asymmetric DGMOSFET has been investigated for the change of top and bottom gate thickness. As a result, we know the subthreshold swings have greatly changed for top and bottom gate thickness, and those have been especially influenced on top gate thickness. We know the subthreshold swings are decreasing with the increase of bottom gate oxide thickness and the decrease of top gate oxide thickness, and the change of top gate oxide thickness influences more than the change of bottom gate oxide thickness for the deviation of subthreshold swing.

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