Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 86 (2016) 128 – 131

Procedia
Computer Science

2016 International Electrical Engineering Congress, iEECON2016, 2-4 March 2016, Chiang Mai, Thailand

Effects of Temperature and Channel Doping on the BSIM3 Threshold Voltage Model of NMOSFET form Substrate Bias Dependent Methodology

Rangson Muanghlua[a], Surasak Niemcharoen[a], Amporn Poyai[b], Anucha Ruangphanit[b,*]

[a]*Department of Electronics Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*
[b]*National Eelectronics and Computer Technology Center, 112 Thailand Science park, Patumthani 12120, Thailand*

Abstract

The effects of channel doping and temperature dependence on the BSIM3 threshold voltage model of NMOSFET form substrate bias dependent methodology is proposed. The I_{DS} -V_{GS} in linear region with different substrate bias condition of a big size of NMOSFET was used. The threshold voltage parameters extraction procedure is based on the measurement of the transconductance characteristics of MOSFET in linear region. The electrical parameters γ, N_{CH} and N_{SUB} also the BSIM3 model parameter K_1 and K_2 at different channel implanted dose and different operating temperature are extracted. The model can be implemented in simulation tools with the error is less than 5% .

Peer-review under responsibility of the Organizing Committee of iEECON2016

Keywords: NMOSFET; Threshold voltage; BSIM3

---

1. Introduction

The threshold voltage (V_{TH}) is the one important parameters of MOSFET. The adjustment of threshold voltage was done by the implantation in a channel. In modern CMOS technology fabrication, the use of two implants is done in controlling the threshold voltage and controlling the punch -through effect. In threshold voltage controlling, the implant ions very closed to the surface, then the substrate doping concentration is not increased. To prevent punch –through, the implant ions is much closed to the point of source-drain junction depth, the depletion region

---

* Corresponding author. Tel.:+66 -3885-7100; fax: +66-3885-7175.
E-mail address: cmoslee517@gmail.com, anucha.ruangphanit@nectec.or.th

Peer-review under responsibility of the Organizing Committee of iEECON2016
doi:10.1016/j.procs.2016.05.032

widths should be contained at the point between source and drain end where the punch-through current flow [1]. In NMOS with non uniform channel doping concentration, the implant ions and the substrate doping is the same type. The channel doping concentration is defined by [1]

$$N_{CH} = N_{SUB} + N_I \tag{1}$$

$$\gamma_1 = \frac{\sqrt{2q\varepsilon_{SI} N_{CH}}}{C_{OX}} \tag{2}$$

$$\gamma_2 = \frac{\sqrt{2q\varepsilon_{SI} N_{SUB}}}{C_{OX}} \tag{3}$$

$$\frac{qN_{CH}X_t^2}{2\varepsilon_{SI}} = \Phi_S - V_{BX} \tag{4}$$

Where N_{CH} is an implanted channel doping, N_{SUB} is substrate concentration, N_I is an implanted concentration, γ_1 and γ_2 are a body-bias coefficient when the doping concentration is N_{CH} and N_{SUB} respectively, V_{BX} is the body bias voltage when the depletion width in a channel is equal X_t. In BSIM 3 level, the threshold voltage include non uniform substrate doping is proposed [3]

$$V_{TH} = V_{THO} + K_1\left(\sqrt{\Phi_S - V_{BS}} - \sqrt{\Phi_S}\right) - K_2 V_{BS} \tag{5}$$

$$K_1 = \gamma_2 - 2K_2\sqrt{\Phi_S - V_{BM}} \tag{6}$$

$$K_2 = \frac{(\gamma_1 - \gamma_2)\left(\sqrt{\Phi_S - V_{BX}} - \sqrt{\Phi_S}\right)}{2\sqrt{\Phi_S}\left(\sqrt{\Phi_S - V_{BM}} - \sqrt{\Phi_S}\right) + V_{BM}} \tag{7}$$

Where the parameter K_1 and K_2 are the first -order body effect coefficient and the second -order body effect coefficient in the non uniform doping MOSFET with the unit of $V^{1/2}$ and none of unit respectively. In this paper, the effects of channel doping and temperature dependence on the BSIM3 threshold voltage model and the extraction methodology are proposed also. The electrical parameters such as γ, N_{CH} and N_{SUB} also the BSIM3 model parameter K_1 and K_2 at different channel implanted dose and different operating temperature are extracted and proposed .

2. Materials and Methods

The testing devices in this paper were fabricated by Twin-Well 0.8 CMOS technology (TMCN08) from Thai Micro Electronics Center (TMEC). The testing devices using a precision semiconductor parameter analyzer B-1500A. From Sentaurus process simulation data, the X_t is approximately 0.15μm [3], the N_{CH} is around 1×10^{17} cm^{-3}, the calculated V_{BX} is approximately -0.37V to -0.6 V which is depended on the surface doping concentration. The threshold voltage measurement method is the linear extrapolation method [5]. The reverse substrate biases start from 0 to 10 V, V_{BS} from 0 to 0.1V with 0.02 V per step, V_{BS} from 0.1 to 1V with 0.1 V per step and V_{BS} from 1 to 10V with 1.0 V per step. Fig.1 shows the simulated step profile concentration in channel. Fig.2 shows the V_{TH} versus $(\Phi_S - V_{BS})^{1/2}$ with the channel doping dose (M) is 1.3×10^{12} cm^{-2}