

Mobility Model

$$V_{bseff} = V_{bc} + 0.5[V_{bs} - V_{bc} - \delta_1 + \sqrt{(V_{bs} - V_{bc} - \delta_1)^2 - 4\delta_1 V_{bc}}] \quad (2.1.26)$$

where $\delta_1 = 0.001$. The parameter V_{bc} is the maximum allowable V_{bs} value and is calculated from the condition of $dV_{th}/dV_{bs}=0$ for the V_{th} expression of 2.1.4, 2.1.5, and 2.1.6, and is equal to:

$$V_{bc} = 0.9 \left(\Phi_s - \frac{K_1^2}{4K_2^2} \right)$$

2.2 Mobility Model

A good mobility model is critical to the accuracy of a MOSFET model. The scattering mechanisms responsible for surface mobility basically include phonons, coulombic scattering, and surface roughness [11, 12]. 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 [13] proposed an empirical unified formulation based on the concept of an effective field E_{eff} which lumps many process parameters and bias conditions together. E_{eff} is defined by

$$E_{eff} = \frac{Q_B + (Q_n/2)}{\epsilon_{Si}} \quad (2.2.1)$$

The physical meaning of E_{eff} can be interpreted as the average electrical field experienced by the carriers in the inversion layer [14]. The unified formulation of mobility is then given by

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$$\mu_{eff} = \frac{\mu_0}{1 + (E_{eff}/E_0)^v} \quad (2.2.2)$$

Values for μ_0 , E_0 , and v were reported by Liang *et al.* [15] and Toh *et al.* [16] to be the following for electrons and holes

Parameter	Electron (surface)	Hole (surface)
μ_0 (cm^2/V)	670	160
E_0 (MV/cm)	0.67	0.7
v	1.6	1.0

Table 2-1. Typical mobility values for electrons and holes.

For an NMOS transistor with n-type poly-silicon gate, Eq. (2.2.1) can be rewritten in a more useful form that explicitly relates E_{eff} to the device parameters [14]

$$E_{eff} \cong \frac{V_{gs} + V_{th}}{6T_{ox}} \quad (2.2.3)$$

Eq. (2.2.2) fits experimental data very well [15], but it involves a very time consuming power function in SPICE simulation. Taylor expansion Eq. (2.2.2) 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

Carrier Drift Velocity

$$(mobMod=1) \quad (2.2.4)$$

$$\mu_{eff} = \frac{\mu_o}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gst} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gst} + 2V_{th}}{T_{ox}} \right)^2}$$

where $V_{gst} = V_{gs} - V_{th}$. To account for depletion mode devices, another mobility model option is given by the following

$$(mobMod=2) \quad (2.2.5)$$

$$\mu_{eff} = \frac{\mu_o}{1 + (U_a + U_c V_{bseff}) \left(\frac{V_{gst}}{T_{ox}} \right) + U_b \left(\frac{V_{gst}}{T_{ox}} \right)^2}$$

The unified mobility expressions in subthreshold and strong inversion regions will be discussed in Section 3.2.

To consider the body bias dependence of Eq. 2.2.4 further, we have introduced the following expression:

$$(For\ mobMod=3) \quad (2.2.6)$$

$$\mu_{eff} = \frac{\mu_o}{1 + [U_a \left(\frac{V_{gst} + 2V_{th}}{T_{ox}} \right) + U_b \left(\frac{V_{gst} + 2V_{th}}{T_{ox}} \right)^2] (1 + U_c V_{bseff})}$$

2.3 Carrier Drift Velocity

Carrier drift velocity is also one of the most important parameters. The following velocity saturation equation [17] is used in the model