DRAIN CURRENT MODEL

The channel under the gate oxide can be divided into two regions . In the linear region , lateral electric field is negligible . and the other , saturation region where the 2D effects are serious and lateral field cannot be neglected . The two regions are modelled separately .

The Linear Region

The current model is based on the hydrodynamic model .

From the previous chapter ,

$$\mu = \mu 0 \frac{1}{1 + \beta E y \exp \frac{-y}{L_v} + \alpha E (1 - \exp \frac{-y}{L_v})}$$

mobility is phenomenologically expressed as :

In the channel region ,

Free surface charge density Q(y) is given as

$$Q(y) = -C_{ox} \left[V_{gs} - (V_t - \Delta V_t) - (1 + \delta) V(y) \right]$$

where V(y) is the channel potential and
δ is explained later .

The Current is given as

$$I_{ds} = Q(y)\mu_n(y)E_y$$

$$I_{ds} = C_{ox}\left[V_{gs} - (V_t - \Delta V_t) - V(y)\right]\mu_n(y)\frac{\partial V}{\partial y}$$

Putting the expression for mobility ,

$$I_{ds} = C_{ox}\left[V_{gs} - (V_t - \Delta V_t) - V(y)\right]\mu_n{}^0 \frac{\partial V}{\partial y} \frac{1}{1 + \beta E_y y \exp\frac{-y}{L_v} + \alpha E_y (1 - \exp\frac{-y}{L_v})}$$

Bringing denominator of RHS to LHS and multiplying with current gives,

$$\int_0^L I_{ds}\left[\ 1 + \beta E_y y \exp(\frac{-y}{L_v}) + \alpha\frac{\partial V}{\partial y} + \alpha \exp(\frac{-y}{L_v})\ \right]dy$$

$$= I_{ds}\left[\ L + \alpha\int_0^{V_{ds}} dV + \int_0^L\left[\ \beta E_y y \exp\frac{-y}{L_v} + \alpha E_y \exp(\frac{-y}{L_v})\ \right]dy\ \right]$$

Approximately the expression becomes by assuming electric field to be constant and equal to the electric field as source end,

$$= I_{ds}\left[L + V_{ds} + E(0)\int_0^L \beta y \exp(\frac{-y}{L_v})dy - E(0)\int_0^L \alpha \exp(\frac{-y}{L_v})dy\right]$$

$$= I_{ds}[L + V_{ds} + \alpha E(0)L_v\{\exp(\frac{-L}{L_v}) - 1\} + \beta E(0)\{L^2{}_v - LL_v \exp(\frac{-L}{L_v}) - L^2{}_v \exp(\frac{-L}{L_v})\}]$$

$$= I_{ds}\,[L + V_{ds} - \alpha E(0) L_v + \beta E(0) L^2{}_v]$$

Carrying out the RHS integral and equating with LHS ,

$$I_{ds} = \frac{W\mu^0{}_n C_{ox}\{V_{gst}V_{ds} - \frac{(1+\delta)V_{ds}{}^2}{2}\}}{L + \alpha V_{ds} + E_y(0)\{\beta\ L^2{}_v - \alpha L_v\}}$$

To calculate the electric field at source end we note that,

at y=0

$$I_{ds} = WC_{ox}\,\mu^0{}_n [V_{gs} - V_t + \Delta V_t] E_y(0)$$

Also from previous equation, current may be calculated as ,

$$I_{ds} = \frac{W\mu^0{}_n C_{ox}\{V_{gst}V_{ds} - \frac{(1+\delta)V_{ds}{}^2}{2}\}}{L + \alpha V_{ds} + E_y(0)\{\beta\ L^2{}_v - \alpha L_v\}}$$

Which by inserting the expression for E_y (0) reduces to ,

$$I_{ds} = \frac{W\mu^0{}_n C_{ox}\{V_{gst}V_{ds} - \frac{(1+\delta)V_{ds}{}^2}{2}\}}{L + \alpha V_{ds} + \{\beta\ L^2{}_v - \alpha L_v\}\frac{I_{ds}}{WC_{ox}\,\mu^0{}_n[V_{gs} - V_t + \Delta V_t]}}$$

We may write the expression for drain current as,

$$I_{ds} = \frac{-A_2 + \sqrt{A_2{}^2 - 4A_1A_3}}{2A_1}$$

$$A_1 = \frac{\{\beta \ L^2{}_v - \alpha L_v\}}{W\mu^0{}_n C_{ox} V_{gst}}$$

$$A_2 = L + \alpha V_{ds}$$

$$A_3 = -W\mu_n{}^0 C_{ox}[V_{gst}V_{ds} - \frac{(1+\delta)V_{ds}{}^2}{2}]$$
