Tale of Two Models

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Common Foundation and Limitation

Common Foundation: \[ I_{ds} = \mu_s W Q_I \frac{dV_{ch}}{dy} \]  

Common Limitation: No velocity saturation, retrograde body doping, Halo, inversion layer thickness,….

Common Solution: These realities are added to the “basic model” later.

Example: Effect of velocity saturation on \( I_{dsat} \) vs \( 1/L \)

Moral: Don’t sweat small quantitative differences between “basic models”.

\[ V_{ds} = 1V, \, V_{gs} = 1V, \, V_{bs} = 0V \]
Another Reality – Retrograde Body Doping

- $W_{\text{dep}}$ is approximately fixed.
Charge versus Surface-Potential

\[ I_{ds} = \mu_s W Q_I \frac{dV_{ch}}{dy} \]

\[ I_{ds} = \frac{\mu_{eff} W}{L_{eff}} \int_{V_s}^{V_d} Q_I dV_{ch} \]

Charge-based

Express \( V_{ch} \) in \( Q_I \)

and integrate

\[ I_{ds} (Q_S, Q_D) \]

\[ I_{ds0} = \frac{W \mu_{eff}}{L_{eff}} \left[ \frac{Q_s^2 - Q_d^2}{2nC_{OX}} + kT \left( Q_s - Q_d \right) / q \right] \]

\[ I_{ds0} = \frac{W \mu_{eff} C_{OX}}{L_{eff}} \begin{bmatrix} (V_{GB} - V_{FB})(\phi_d - \phi_s) - \frac{1}{2}(\phi_d^2 - \phi_s^2) \\ -\frac{2}{3} \gamma (\phi_d^{3/2} - \phi_s^{3/2}) + kT (\phi_d - \phi_s) / q \\ +kT \gamma (\phi_d^{1/2} - \phi_s^{1/2}) / q \end{bmatrix} \]

\[ \phi_s \] -based

Express \( Q_I, V_{ch} \) in \( \phi_s \)

and integrate

retrograde/linearization

\[ I_{ds} (\phi_S, \phi_D) \]
CV Model

Charge-based

\[ Q_{CH} = W \int_0^L Q_I \, dy \]

\[ Q_{BULK} = W \int_0^L Q_B(y) \, dy \]

\[ Q_{GATE} = -(Q_{BULK} + Q_{CH}) \]

where

\[ Q_B = \frac{C_{ox}(V_{GB} - V_{FB}) + Q_I / C_{ox}}{1 + \sqrt{\frac{1}{4} + \frac{(V_{GB} - V_{FB}) + Q_I / C_{ox}}{\gamma^2}}} \]

including both depletion charge and accumulation charge in one single equation from accumulation thru inversion

[\[ \text{\phi}_S - \text{based} \]

\[ Q_{GATE} = W \int_0^L (V_{GB} - V_{FB} - \phi_S(y)) \, dy \]

\[ Q_{BULK} = W \int_0^L Q_B(y) \, dy \]

\[ Q_{CH} = W \int_0^L Q_I \, dy \]

where

\[ Q_B = -\text{sign} \left( \phi_S \right) C_{ox} \gamma \sqrt{\phi_S + v_t \left( e^{-\phi_S/v_t} - 1 \right)} \]

Chenming Hu, UCB, WCM 2005
Realities in CV Model
Conclusion: They Are Twins

- Much commonality and little difference.
- One difference: Which is the norm — uniform body or steep retrograde?
- Second difference: Is it easier to add device “realities” to charge or to surface potential?
- Good news: Both can produce very good compact models. Quality is determined mostly by model developer’s skills and resources.