Tale of Two Models

Chenming Hu

Univ. of Calif., Berkeley

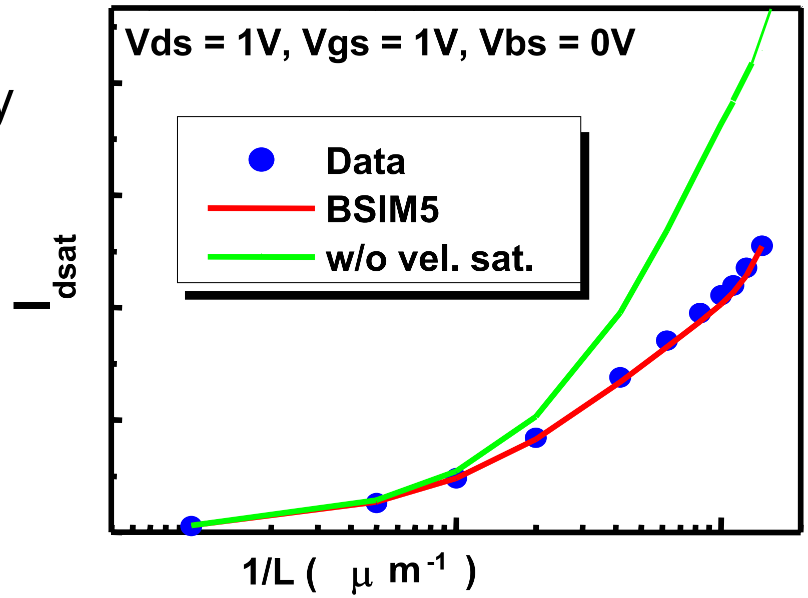
Common Foundation and Limitation

Common Foundation: $I_{ds} = \mu_s W Q_I \frac{dV_{ch}}{dy}$ ← quasi-Fermi level

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

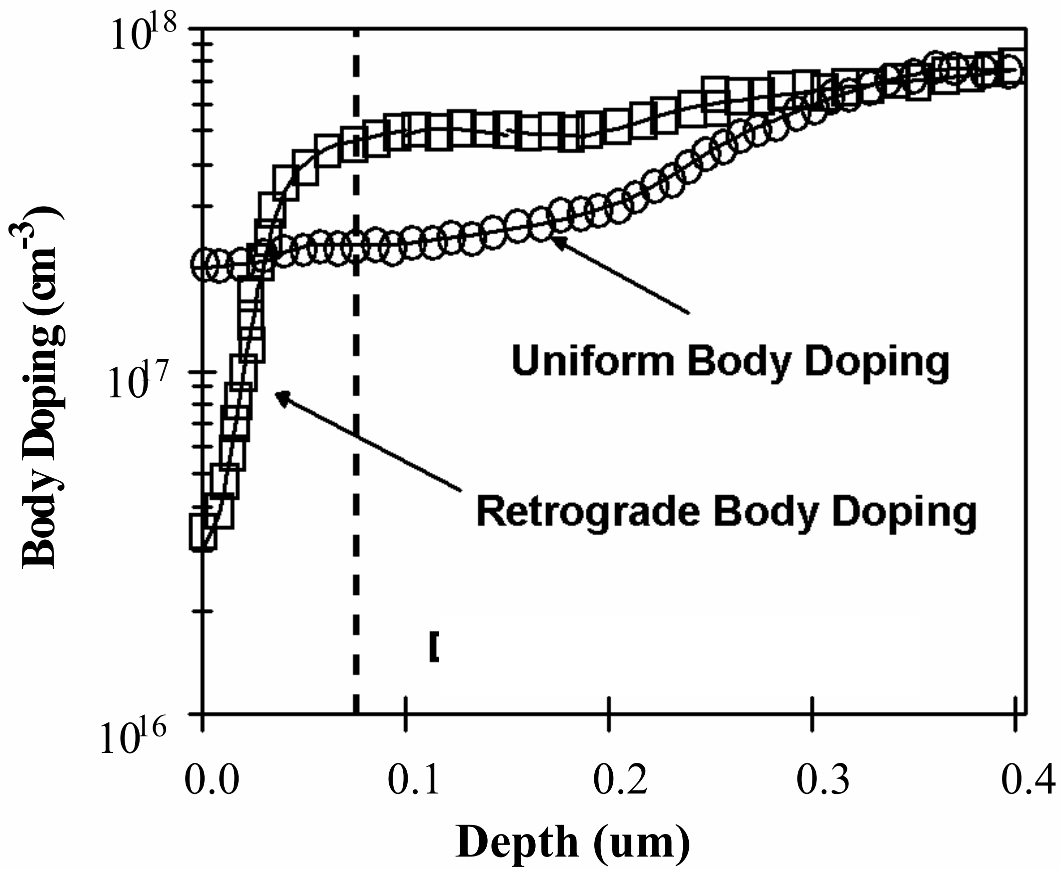
Common Solution: These realities are added to the "basic model" later.

Example: Effect of velocity saturation on Idsat vs 1/L



Moral: Don't sweat small quantitative differences between "basic models".

Another Reality – Retrograde Body Doping



- W_{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

ϕ_s -based

Express V_{ch} in Q_I and integrate

$I_{ds}(Q_S, Q_D)$

$$V_{GB} = V_{FB} + \phi_s + \frac{Q_I + Q_B}{C_{OX}}$$

$$\frac{dQ_I}{Q_I} = \frac{d(\phi_s - V_{ch})}{kT/q}$$

retrograde/linearization

Express Q_I, V_{ch} in ϕ_s and integrate

$I_{ds}(\phi_S, \phi_D)$

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

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

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

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

ϕ_s- based

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

$$Q_{BULK} = W\int_0^L Q_B(y)dy$$

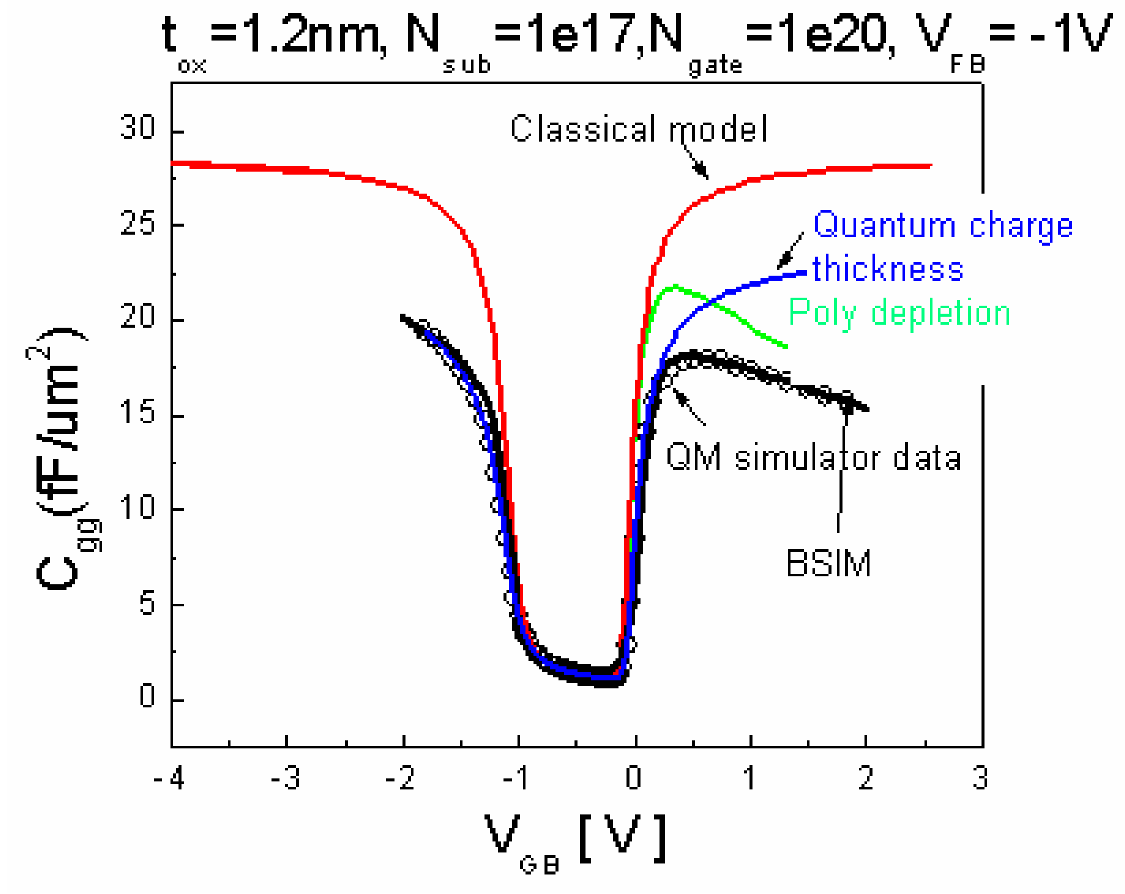
$$Q_{CH} = W\int_0^L Q_I dy$$

where

$$Q_B = -sign(\phi_S) c_{ox} \gamma \sqrt{\phi_S + v_t\left(e^{-\phi_S / v_t} - 1\right)}$$

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

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.