BSIM4.5.0 Enhancements

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BSIM4.5.0 New Features

- A mobility model which accounts for Coulomb scattering effect as well as the channel length dependence of mobility due to heavy halo-doping
- A scalable substrate resistance model (rbodyMod = 2) that is scalable with channel length, channel width and number of fingers
- Gate resistance parameters XGW, NGCON that can now be specified as instance parameters(XGL still model parameter)
- Additional temperature dependence of model parameters VOFF, VFBSDOFF
- Enhanced tempMod = 2, where Vth(DITS) and gate tunneling models are functions of nominal temperature and the temperature dependence of zero-bias flat-band voltage is added
- A new instance parameter DELVTO that may be used to represent threshold voltage variation
- A new well-proximity effect model developed by CMC companies
- Igc Vbs dependence improvement with the full BSIM4 Vth model implemented

Mobility Model for BSIM4.5.0

Mobility Coulomb Scattering Model and L_{eff} dependence

- mobMod = 0

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UCV_{bseff})\left(\frac{V_{gsteff} + 2V_{th}}{TOXE}\right) + UB\left(\frac{V_{gsteff} + 2V_{th}}{TOXE}\right)^2 + UD\left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2V_{th}}\right)^2}$$

- mobMod = 1

$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + \left[UA\left(\frac{V_{gsteff} + 2V_{th}}{TOXE}\right) + UB\left(\frac{V_{gsteff} + 2V_{th}}{TOXE}\right)^2\right](1 + UC \cdot V_{bseff}) + UD\left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2V_{th}}\right)^2}$$

- mobMod = 2

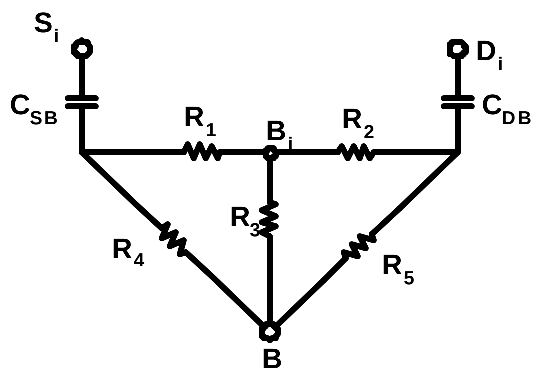
$$\mu_{eff} = \frac{U0 \cdot f(L_{eff})}{1 + (UA + UC \cdot V_{bseff})\left[\frac{V_{gsteff} + C_0 \cdot (VTHO - VFB - \Phi_s)}{TOXE}\right]^{EU} + UD\left(\frac{V_{th} \cdot TOXE}{V_{gsteff} + 2V_{th}}\right)^2}$$

Where: $$f(L_{eff}) = 1 - UP \cdot e^{-L_{eff}/LP}$$

The model is backward compatible with UP=0.0, UD=0.0

Scalable Substrate Resistance Model

$$R_X = R_{X\_HORI} \parallel R_{X\_VERT} \quad \text{where} \quad R_{X\_H(V)} = R_0 L^{a} W^{ß} NF^{?}$$



5 Resistor Network

	HORIZONTAL CONTACT				VERTICAL CONTACT			
	R_0	a	b	g	R_0	a	b	g
R_1	1	2	3	4	NR	NR	NR	NR
R_2	1/5	2/6	3/7	4/8	NR	NR	NR	NR
R_3	5/9	6/10	7/11	8/12	9/13	10/14	11/15	12/16
R_4	13/17	14/18	15/19	16/20	17/21	18/22	19/23	20/24
R_5	13/25	14/18	15/19	16/20	17/26	18/22	19/23	20/24

- R1, R2 need not differentiate contact arrangements.
- R4 and R5 expected to have similar scaling laws.

Temperature Dependence for VOFF, VFBSDOFF

$$VOFF(T) = VOFF(TNOM) \cdot [1 + TVOFF \cdot (T - TNOM)]$$

$$\begin{aligned} VFBSDOFF(T) = {} & VFBSDOFF(TNOM) \\ & \cdot [1 + TVFBSDOFF \cdot (T - TNOM)] \end{aligned}$$

New Temperature Mode (TempMod = 2)

Share the same temperature equations as for TempMod=1
AND:

From:

$$\Delta V_{th}(DITS) = -nv_t \cdot ln\left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot \left(1 + e^{-DVTP1 \cdot V_{ds}}\right)}\right)$$

To:

$$\Delta V_{th}(DITS) = -nv_{tnom} \cdot ln\left(\frac{L_{eff}}{L_{eff} + DVTP0 \cdot \left(1 + e^{-DVTP1 \cdot V_{ds}}\right)}\right)$$

Vfbzb(T)

$$V_{fbzb}(T) = V_{fbzb}(TNOM) - KT1 \cdot \left(\frac{T}{TNOM} - 1\right)$$

Igate(T)

T is replaced by TNOM

DELVTO: an Instance Parameter

if vth0 is given:

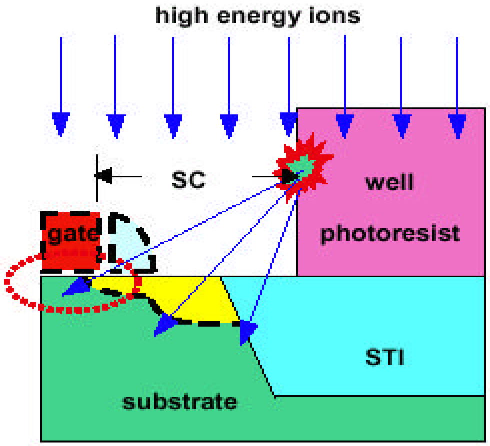
$$Vth0 = Vth0 + DELVTO;$$

if vth0 is not given,

$$Vfb = Vfb + DELVTO;$$

$$Vth0 = Vfb + phi + k1 * sqrt(k1)$$

Well-Proximity Effect Modeling



Instance parameters: SCA, SCB, SCC, SC

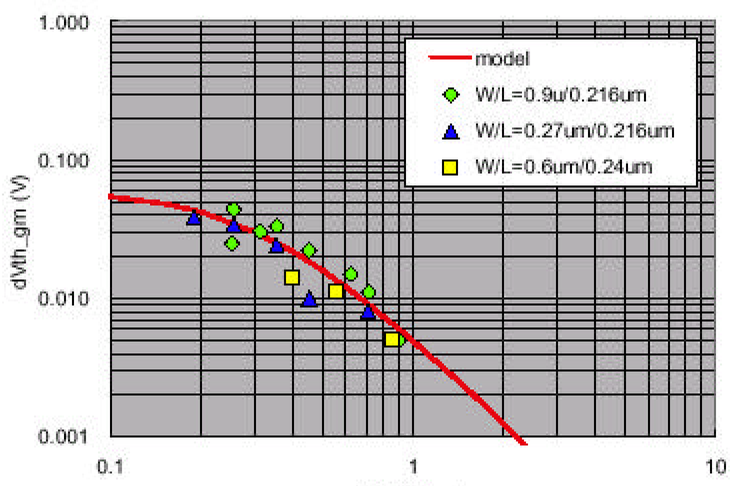
Model parameters: WEB, WEC, KVTH0WE, K2WE, KU0WE,SCREF,WPEMOD

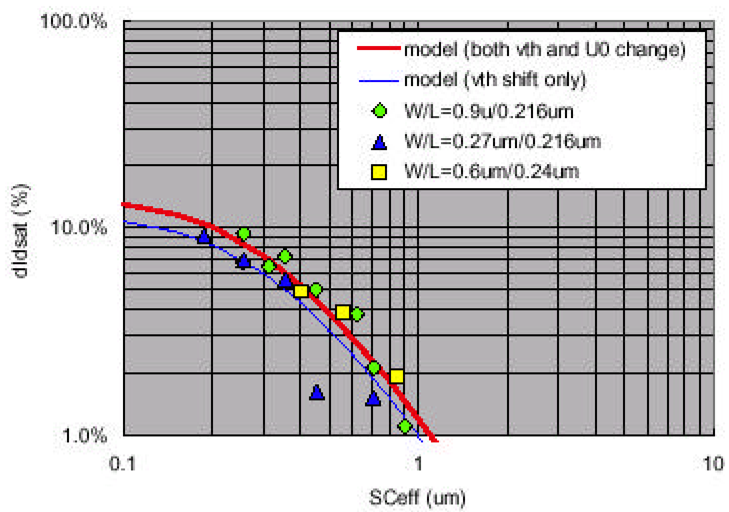
Model equations:

$$Vth0 = Vth0_{org} + \mathbf{KVTH0WE} \cdot (\mathbf{SCA} + \mathbf{WEB} \cdot \mathbf{SCB} + \mathbf{WEC} \cdot \mathbf{SCC})$$

$$K2 = K2_{org} + \mathbf{K2WE} \cdot (\mathbf{SCA} + \mathbf{WEB} \cdot \mathbf{SCB} + \mathbf{WEC} \cdot \mathbf{SCC})$$

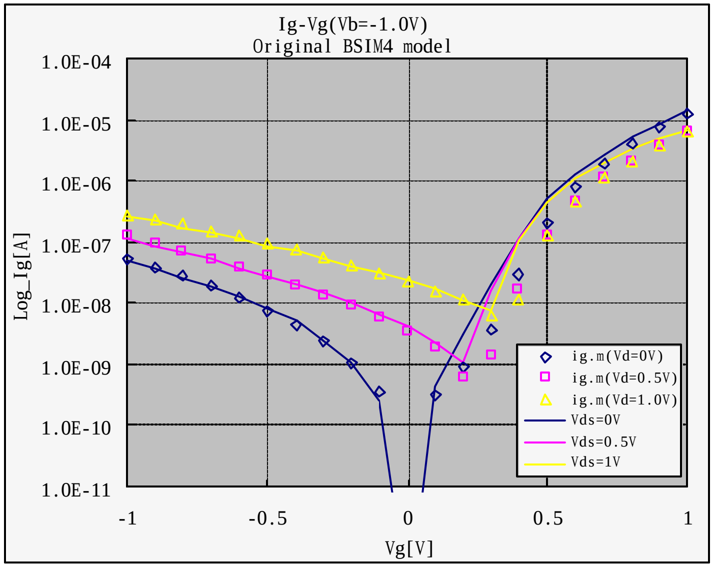
$$\mu_{eff} = \mu_{eff,org} \cdot (1 + \mathbf{KU0WE} \cdot (\mathbf{SCA} + \mathbf{WEB} \cdot \mathbf{SCB} + \mathbf{WEC} \cdot \mathbf{SCC}))$$



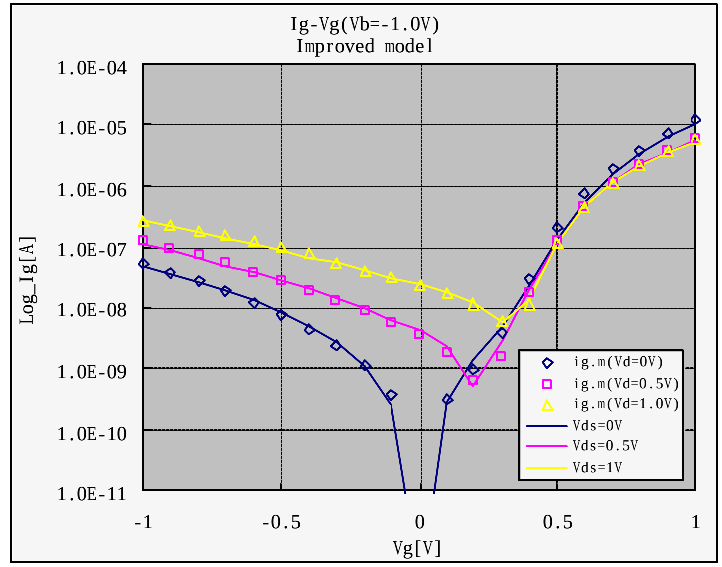


- Deep well doping alters Vth of devices near the mask edge: Vth(SC)
- CMC well-proximity effect model is able to capture the distance effect

Gate Current Vbs Dependence



Original Igc Model



Improved Igc model

$$Igc0 = W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gse} \cdot V_{aux} \cdot \exp\left[-B \cdot TOXE\left(AIGC - BIGC \cdot V_{oxdepinv}\right) \cdot \left(1 + CIGC \cdot V_{oxdepinv}\right)\right]$$

IGCMOD=1 $$V_{aux} = NIGC \cdot v_t \cdot \log\left(1 + \exp\left(\frac{V_{gse} - VTH0}{NIGC \cdot v_t}\right)\right)$$

IGCMOD=2 $$V_{aux} = NIGC \cdot v_t \cdot \log\left(1 + \exp\left(\frac{V_{gse} - VTH\_bsim4}{NIGC \cdot v_t}\right)\right)$$

Was physically derived !

- **Implementing full BSIM4 Vth model into Igc enables the accurate prediction of Igc Vbs dependence.**