# New model equations in BSIMSOIv3.0

If SoiMod=0 (default), the model equation is identical to BSIMPD equation.
If SoiMod=1, the following equations (FD module) are added on top of BSIMPD.

$$V_{bs0} = \frac{C_{Si}}{C_{Si}+C_{BOX}} \cdot \left( phi - \frac{qN_{ch}}{2\varepsilon_{Si}} \cdot T_{Si}^{2} + V_{nonideal} + \Delta V_{DIBL} \right) + \eta_e \frac{C_{BOX}}{C_{Si}+C_{BOX}} \cdot \left( V_{es} - V_{FBb} \right)$$

$$\text{where } C_{Si} = \frac{\varepsilon_{Si}}{T_{Si}}, C_{BOX} = \frac{\varepsilon_{OX}}{T_{BOX}}, C_{OX} = \frac{\varepsilon_{OX}}{T_{OX}}$$

$$\Delta V_{DIBL} = D_{vbd0} \left( exp\left( -D_{vbd1} \frac{L_{eff}}{2\lambda} \right) + 2\,exp\left( -D_{vbd1} \frac{L_{eff}}{\lambda} \right) \right) \cdot \left( V_{bi} - 2\Phi_B \right)$$

$$\eta_e = K_{1b} - K_{2b} \cdot \left( exp\left( -D_{k2b} \frac{L_{eff}}{2\lambda} \right) + 2\,exp\left( -D_{k2b} \frac{L_{eff}}{\lambda} \right) \right)$$

$$phi = phi_{ON} - \frac{C_{OX}}{C_{OX} + \left( C_{Si}^{-1} + C_{BOX}^{-1} \right)^{-1}} \cdot N_{OFF,FD} V_t \cdot ln\left( 1 + exp\left( \frac{V_{th,FD} - V_{gs\_eff} - V_{OFF,FD}}{N_{OFF,FD} V_t} \right) \right)$$

$$phi_{ON} = 2\Phi_B + V_t\, ln\left( 1 + \frac{V_{gsteff,FD}\left( V_{gsteff,FD} + 2K1\sqrt{2\Phi_B} \right)}{MoinFD \cdot K1 \cdot V_t^{2}} \right),$$

$$V_{gsteff,FD} = N_{OFF,FD} V_t \cdot ln\left( 1 + exp\left( \frac{V_{gs\_eff} - V_{th,FD} - V_{OFF,FD}}{N_{OFF,FD} V_t} \right) \right)$$

Here Nch is the channel doping concentration. $V_{FBb}$ is the backgate flatband voltage. $V_{th,FD}$ is the threshold voltage at $V_{bs}$=$V_{bs0}$(phi=$2\Phi_B$). $V_t$ is thermal voltage. K1 is the body effect coefficient.

The lower bound of $V_{bs}$ (SPICE solution) is set to $V_{bs0}$. $V_{bsmos}$ is calculated by

$$V_{bsmos} = V_{bs} - \frac{C_{Si}}{2qN_{ch}T_{Si}} \left( V_{bs0}\left( T_{OX} \to \infty \right) - V_{bs} \right)^2 \quad \text{if } V_{bs} \le V_{bs0}\left( T_{OX} \to \infty \right)$$

$$= V_{bs} \quad \text{else}$$

The subsequent clamping of $V_{bsmos}$ will use the same equation that utilized in BSIMPD. Please download the BSIMPD manual at (www-device.eecs.Berkeley.edu/~bsimsoi).

# Gate-to-channel current (Igc) and gate-to-S/D current (Igs and Igd)*

Igc – determined by ECB for NMOS and HVB for PMOS (Hole tunneling from Valence Band), respectively.

$$Igc = W_{eff} L_{eff} \cdot A \cdot T_{oxRatio} \cdot V_{gs\_eff} \cdot V_{aux} \cdot \exp\left[-B \cdot T_{oxqm}\left(aigc - bigc \cdot V_{oxdepinv}\right) \cdot \left(1 + cigc \cdot V_{oxdepinv}\right)\right]$$

where $A = 4.97232e-7$ A/V$^2$ for NMOS and 3.42537e-7 A/V$^2$ fro PMOS, $B = 7.45669e11$ (g/F-s$^2$)$^{0.5}$ for NMOS and 1.16645e12 (g/F-s$^2$)$^{0.5}$ for PMOS, and

$$V_{aux} = nigc \cdot V_m \cdot \log\left(1 + \exp\left(\frac{V_{gs\_eff} - V_{th0}}{nigc \cdot V_{tm}}\right)\right), \qquad T_{oxRatio} = \left(\frac{T_{oxref}}{T_{oxqm}}\right)^{ntox} \cdot \frac{1}{T_{oxqm}^2}$$

Igs and Igd – Igs represents the gate tunneling current between the gate and the source diffusion region, while Igd represents the gate tunneling current between the gate and the drain diffusion region. Igs and Igd are determined by ECB fro NMOS and by HVB for PMOS, respectively.

$$Igs = W_{eff} Dlcig \cdot A \cdot T_{oxRatioEdg} \cdot V_{gs} \cdot V'_{gs} \cdot \exp\left[-B \cdot T_{oxqm} \cdot Poxedge \cdot \left(aigsd - bigsd \cdot V'_{gs}\right) \cdot \left(1 + cigsd \cdot V'_{gs}\right)\right]$$

and

$$Igd = W_{eff} Dlcig \cdot A \cdot T_{oxRatioEdg} \cdot V_{gd} \cdot V'_{gd} \cdot \exp\left[-B \cdot T_{oxqm} \cdot Poxedge \cdot \left(aigsd - bigsd \cdot V'_{gd}\right) \cdot \left(1 + cigsd \cdot V'_{gd}\right)\right]$$

where $A = 4.97232e-7$ A/V$^2$ for NMOS and 3.42537e-7 A/V$^2$ fro PMOS, $B = 7.45669e11$ (g/F-s$^2$)$^{0.5}$ for NMOS and 1.16645e12 (g/F-s$^2$)$^{0.5}$ for PMOS,

$$T_{oxRatioEdge} = \left(\frac{T_{oxref}}{T_{oxqm} \cdot Poxedge}\right)^{ntox} \cdot \frac{1}{\left(T_{oxqm} \cdot Poxedge\right)^2} ,$$

$$V'_{gs} = \sqrt{\left(V_{gs} - V_{fbsd}\right)^2 + 1.0e-4}$$ and

$$V'_{gd} = \sqrt{\left(V_{gd} - V_{fbsd}\right)^2 + 1.0e-4} .$$

Partition of Igc

To consider the drain bias effects, Igc is split into two components, Igcs and Igcd, that is Igc=Igcs+Igcd.

$$Igcs = Igc \cdot \frac{pi\,\mathrm{gcd} \cdot V_{ds} + \exp\left(-pi\,\mathrm{gcd} \cdot V_{ds}\right) - 1 + 1.0e-4}{pi\,\mathrm{gcd}^2 \cdot V_{ds}^2 + 2.0e-4}$$

and

$$I\,\mathrm{gcd} = Igc \cdot \frac{1 - \left(pi\,\mathrm{gcd} \cdot V_{ds} + 1\right) \cdot \exp\left(-pi\,\mathrm{gcd} \cdot V_{ds}\right) + 1.0e-4}{pi\,\mathrm{gcd}^2 \cdot V_{ds}^2 + 2.0e-4} .$$

* Also see BSIM4.2.0 Technical Notes

# New model parameters in BSIMSOIv3.0

| Symbol used in equation | Symbol used in SPICE | Description | Unit | Default |
|---|---|---|---|---|
| *SoiMod* | soiMod | SOI model selector. SoiMod=0: BSIMPD. SoiMod=1: FD module | - | 0 |
| $V_{nonideal}$ | vbsa | Offset voltage due to non-idealities | V | 0 |
| $N_{OFF,FD}$ | nofffd | Smoothing parameter in FD module | - | 1 |
| $V_{OFF,FD}$ | vofffd | Smoothing parameter in FD module | V | 0 |
| $K_{1b}$ | k1b | First backgate body effect parameter | - | 1 |
| $K_{2b}$ | k2b | Second backgate body effect parameter for short channel effect | - | 0 |
| $D_{k2b}$ | dk2b | Third backgate body effect parameter for short channel effect | - | 0 |
| $D_{vbd0}$ | dvbd0 | First short channel effect parameter in FD module | - | 0 |
| $D_{vbd1}$ | dvbd1 | Second short channel effect parameter in FD module | - | 0 |
| *MoinFD* | moinfd | Gate bias dependence coefficient of surface potential in FD module | - | 1e3 |
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# Parameter for the gate tunneling current model

| Parameter Name | Description | Default value with Unit | Binnable? | Note |
|---|---|---|---|---|
| igcmod | Global model selector for Igs, Igd, Igcs, Igcd current components | 0 | N/A | igcmod==1 turns on Igs, Igd, Igcs and Igcd. |
| igbmod | Global model selector for Igb current | 0 | N/A | Igbmod==1 turns on Igb. |
| aigc | Parameter for Igs, Igd, Igcs and Igcd | NMOS: 0.43<br>PMOS: 0.31<br>$(Fs^2/g)^{0.5}\ m^{-1}$ | Yes | - |
| bigc | Parameter fro Igcs and Igcd | NMOS: 0.054<br>PMOS: 0.024<br>$(Fs^2/g)^{0.5}\ (mV)^{-1}$ | Yes | - |
| cigc | Parameter for Igcs and Igcd | NMOS: 0.075 $V^{-1}$<br>PMOS: 0.03 $V^{-1}$ | Yes | - |
| aigsd | Parameter for Igs and Igd | NMOS: 0.43<br>PMOS: 0.31<br>$(Fs^2/g)^{0.5}\ m^{-1}$ | Yes | - |
| bigsd | Parameter fro Igs and Igd | NMOS: 0.054<br>PMOS: 0.024<br>$(Fs^2/g)^{0.5}\ (mV)^{-1}$ | Yes | - |
| cigsd | Parameter for Igs and Igd | NMOS: 0.075 $V^{-1}$<br>PMOS: 0.03 $V^{-1}$ | Yes | - |
| dlcig | S/D overlap length for Igs/Igd | Lint | No | - |
| nigc | Parameter for Igs, Igd, Igcs and Igcd | 1.0 | Yes | Note-1 |
| poxedge | Factor for the gate oxide thickness in the S/D overlap regions | 1.0 | Yes | Note-1 |
| pigcd | Vds dependence of Igcs and Igcd | 1.0 | Yes | Note-1 |
| ntox | Exponent for the tox ratio | 1.0 | No | - |
| toxref | Target oxide thickness in gate tunneling | 25.0A | No | Note-1 |
| toxqm | Equivalent oxide thickness in gate tunneling | $T_{ox}$ | No | Note-1 |

Note-1: if the value is less than or equal to zero, fatal errors are issued.