CHAPTER 9: MOS Diode Model

9.1 MOS Diode DC Current Model

9.1.1 Model Equations

9.1.1.1 Source/bulk Diode

If the saturation current Isbs is larger than zero, the following equations is used to calculate the source/bulk diode current:

Vbs<0.5V

(9.1.1)

$$I_{bs} = I_{sbs}[\exp(\frac{V_{bs}}{Nv_{tm}}) - 1] + G_{\min} V_{bs}$$

V_{bs}>0.5V

(9.1.2)

$$I_{bs} = I_{sbs}[\exp(\frac{0.5}{Nv_{tm}}) - 1] + \frac{I_{sbs}}{Nv_{tm}}\exp(\frac{0.5}{Nv_{tm}})(V_{bs} - 0.5) + G_{\min} V_{bs}$$

Where *Nvtm=njKT/q*, nj is the emission coefficient of the source junction, and Isbs is calculated by

(9.1.3)

$$I_{sbs} = A_s J_s + P_s J_{ssw}$$

where Js is the saturation current density of the source/bulk diode, A_S is the area of the source junction. Jssw is the sidewall saturation current density of the source/bulk diode, Ps is the perimeter of the source junction. Js and Jssw are functions of temperature and can be described by:

(9.1.4a)

$$J_s = J_{s0}\exp[\frac{\frac{E_{g0}}{V_{tm0}} - \frac{E_g}{V_{tm}} + XTI\ln(\frac{T}{T_{nom}})}{N_j}]$$

(9.1.4b)

$$J_{ssw} = J_{s0sw}\,exp[\frac{\frac{E_{g0}}{V_{tm0}} - \frac{E_g}{V_{tm}} + XTI\,ln(\frac{T}{T_{nom}})}{N_j}]$$

(9.1.5)

$$E_g = 1.16 - \frac{7.02e^{-4}T^2}{T + 1108.0}$$

where Js0 is the saturation current density at Tnom. If Js0 is not given in the simulation, Js0=1.e-4A/m^2. Js0sw is the sidewall saturation current density at Tnom. The default value of Js0sw is 0.

If Isbs is less than zero, the source/bulk diode current is calculated by

(9.1.6)

$$I_{bs} = G_{\min} V_{bs}$$

9.1.1.2 Drain/bulk Diode

If the saturation current Isbd is larger than zero, the following equations is used to calculate the drain/bulk diode current:

Vbd<0.5V

(9.1.7)

$$I_{bd} = I_{sbd}[\exp(\frac{V_{bd}}{Nv_{tm}}) - 1] + G_{\min} V_{bd}$$

V_{bd}>0.5V

(9.1.8)

$$I_{bd} = I_{sbd}[\exp(\frac{0.5}{Nv_{tm}}) - 1] + \frac{I_{sbd}}{Nv_{tm}} \exp(\frac{0.5}{Nv_{tm}})(V_{bd} - 0.5) + G_{\min} V_{bd}$$

Where *Nvtm=njKT/q*, nj is the emission coefficient of the drain junction, and Isbd is calculated by

(9.1.9)

$$I_{sbd} = J_s A_D + J_{ssw} P_D$$

where Js is the saturation current density of the drain/bulk diode, A_D is the area of the drain junction. Jssw is the sidewall saturation current density of the drain/bulk diode, P_D is the perimeter of the drain junction. Js and Jssw are functions of temperature and given by (9.1.4a), (9.1.4b) and (9.1.5).

If Isbd is less than zero, the drain/bulk diode current is calculated by

(9.1.10)

$$I_{sbd} = G_{\min} V_{bd}$$

9.1.2 Parameters

The parameters for the DC model of the source/drain diode are listed in Table 9-1.

Symbols used in equation	Symbols used in SPICE	Description	Default	Unit
Js0	js	Saturation current density	1.e-4	A/m^2
Js0sw	jssw	Side wall saturation current density	0	A/m
nj	nj	Emission coefficient	1	none
XTI	xti	Junction current temperature exponent coefficient	3.0	none

Table 9-1. MOS Diode Model Parameters.

9.2 MOS Diode Capacitance Model

9.2.1 Model Equations

Source and drain junction capacitance can be divided into two components: the junction bottom area capacitance Cjb and the junction periphery capacitance Cjp. The formula for both the capacitances is similar, but with different model parameters. The equation of Cjb includes the parameters such as Cj, Mj, and Pb. The equation of Cjp includes the parameters such as Cjsw, Mjsw, Pbsw, Cjswg, Mjswg, Pbswg.

9.2.1.1 Source/bulk Junction Capacitance

The source/bulk junction capacitance can be calculated by:

If Ps >Weff

(9.2.1a)

$$Capbs = A_S C_{jbs} + (P_S - W_{eff}) C_{jbssw} + W_{eff} C_{jbsswg}$$

Otherwise:

(9.2.1b)

$$Capbs = A_S C_{jbs} + P_S C_{jbsswg}$$

where Cjbs is the bottom area capacitance of the source/bulk junction, Cjbssw is the periphery capacitance of the source/bulk junction along the field oxide side, and Cjbsswg is the periphery capacitance of the source/bulk junction along the gate oxide side.

If Cj is larger than zero, Cjbs is calculated by:

if Vbs<0

(9.2.2)

$$C_{jbs} = C_j \left(1 - \frac{V_{bs}}{P_b}\right)^{-M_j}$$

if Vbs>0

(9.2.3)

$$C_{jbs} = C_j \left(1 + M_j \frac{V_{bs}}{P_b}\right)$$

If Cjsw is large than zero, Cjbssw is calculated by:

if Vbs<0

(9.2.4)

$$C_{jbssw} = C_{jsw}(1 - \frac{V_{bs}}{P_{bsw}})^{-Mswj}$$

if Vbs>0

(9.2.5)

$$C_{jbssw} = C_{jsw}(1 + M_{jsw}\frac{V_{bs}}{P_{bsw}})$$

If Cjswg is larger than zero, Cjbsswg is calculated by:

if Vbs<0

(9.2.6)

$$C_{jbsswg} = C_{jswg}(1 - \frac{V_{bs}}{P_{bswg}})^{-Mjswg}$$

if Vbs>0

(9.2.7)

$$C_{jbsswg} = C_{jswg}(1 + M_{jswg}\frac{V_{bs}}{P_{bswg}})$$

9.2.1.2 Drain/bulk Junction Capacitance

The drain/bulk junction capacitance can be calculated by:

If P_D > Weff:

(9.2.8a)

$$Capbd = A_D C_{jbd} + (P_D - W_{eff}) C_{jbdsw} + W_{eff} C_{jbdswg}$$

Otherwise:

(9.2.8b)

$$Capbd = A_D C_{jbd} + P_D C_{jbdswg}$$

where Cjbd is the bottom area capacitance of the drain/bulk junction, Cjbdsw is the periphery capacitance of the drain/bulk junction along the field oxide side, and Cjbdswg is the periphery capacitance of the drain/bulk junction along the gate oxide side.

If Cj is larger than zero, Cjbd is calculated by:

if Vbd<0

(9.2.9)

$$C_{jbd} = C_j \left(1 - \frac{V_{bd}}{P_b}\right)^{-M_j}$$

if Vbd>0

(9.2.10)

$$C_{jbd} = C_j \left(1 + M_j \frac{V_{bd}}{P_b}\right)$$

if Cjsw is larger than zero, Cjbdsw is calculated by:

if Vbd<0

(9.2.11)

$$C_{jbdsw} = C_{jsw}(1 - \frac{V_{bd}}{P_{bsw}})^{-Mswj}$$

if Vbd>0

(9.2.12)

$$C_{jbdsw} = C_{jsw}(1 + M_{jsw}\frac{V_{bd}}{P_{bsw}})$$

if Cjswg is larger than zero, Cjbdswg is calculated by:

if Vbd<0

(9.2.13)

$$C_{jbdswg} = C_{jswg}(1 - \frac{V_{bd}}{P_{bswg}})^{-Mjswg}$$

if Vbd>0

(9.2.14)

$$C_{jbdswg} = C_{jswg}(1 + M_{jswg}\frac{V_{bd}}{P_{bswg}})$$

9.2.2 Parameters

The parameters for the capacitance model of the source/drain diode are listed in Table 9-2.

Symbols used in equation	Symbols used in SPICE	Description	Default	Unit
Cj	cj	Bottom junction capacitance per unit area at zero bias	5e-4	F/m^2
Mj	mj	Bottom junction capacitance grading coefficient	0.5	none
Pb	pb	Bottom junction built-in potential	1.0	V
Cjsw	cjsw	Source/drain sidewall junction capacitance grading coefficient per unit length at zero bias	5e-10	F/m
Mjsw	mjsw	Source/drain sidewall junction capacitance grading coefficient	0.33	none
Pbsw	pbsw	Source/drain sidewall junction built-in potential	1.0	V
Cjswg	cjswg	Source/drain gate sidwall junction capacitance per unit length at zero bias	Cjsw	F/m
Mjswg	mjswg	Source/drain gate sidewall junction capacitance grading coefficient	Mjsw	none
Pbswg	pbswg	Source/drain gate sidewall junction built-in potential	Pbsw	V

Table 9-2. MOS Diode Capacitance Model Parameters.