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LEVEL 62 RPI Poli-Si TFT Model

Star-Hspice LEVEL 62 is an AIM-SPICE MOS16 poly-silicon (Poli-Si) thin-film transistor (TFT) model.

Model Features

The AIM-SPICE MOS16 Poli-Si TFT model features include:

- A design based on the crystalline MOSFET model
- Field effect mobility that becomes a function of gate bias
- Effective mobility that accounts for trap states:
  - For low V gs , it is power law
  - For high V gs , it is constant
- Reverse bias drain current function of electric field near drain and temperature
- A design independent of channel length
- A unified DC model that includes all four regimes for channel lengths down to 4 m:
  - Leakage (thermionic emission)
  - Subthreshold (diffusion-like model)
  - Above threshold (c-Si-like, with mFet)
  - Kink (impact ionization with feedback)
- An AC model that accurately reproduces C gc frequency dispersion
- An automatic scaling of model parameters that accurately model a wide range of device geometries

Using LEVEL 62 with Star-Hspice

When using the AIM-SPICE MOS16 Poli-Si TFT model:

1. Set LEVEL=62 to identify the model as the AIM-SPICE MOS16 Poli-Si TFT model.

2. The default value for L is 100m, and the default value for W is 100m.

3. The LEVEL 62 model is a 3-terminal model. No bulk node exists; therefore no parasitic drain-bulk or source-bulk diodes are appended to the model. A fourth node can be specified, but does not affect simulation results.

4. The default room temperature is 25oC in Star-Hspice, but is 27oC in some other simulators. The user may choose whether or not to set the nominal simulation temperature to 27oC by adding .OPTION TNOM=27 to the netlist.

Example

This is an example of a Star-Hspice model and element statement modified for use with LEVEL 62:

```
mckt drain gate source nch L=10e-6 W=10e-6
```

```
.MODEL nch nmos LEVEL=62

+ asat = 1 at = 3e-8 blk = 0.001 bt = 0.0 cgdo = 0.0

+ cgso = 0.0 dasat = 0.0 dd = 1.4e-7 delta = 4.0

+ dg = 2.0e-7 dmu1 = 0.0 dvt = 0.0 dvto = 0.0 eb = 0.68


+ eta = 7 etac0 = 7 etac00 = 0 i0 = 6.0 i00 = 150


+ lasat = 0lkink = 19e-6 mc = 3.0 mk = 1.3 mmu = 3.0

+ mu0 = 100 mu1 = 0.0022 mus = 1.0 rd = 0.0 rdx = 0.0

+ rs = 0.0 rsx = 0.0 tnom = 27 tox = 1.0e=7 vfb = -0.1

+ vkink = 9.1 von = 0.0 vto = 0.0
```

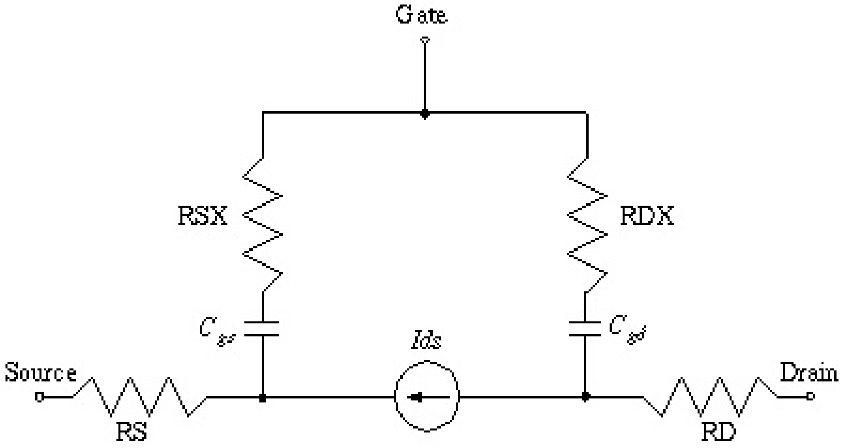
LEVEL 62 Model Parameters

Name	Unit	Default	Description
ASAT	-	1	Proportionality constant of Vsat
AT	m/V	3E-8	DIBL parameter 1
BLK	-	0.001	Leakage barrier lowering constant
BT	m.V	1.9E-6	DIBL parameter 2
CGDO	F/m	0	Gate-drain overlap capacitance per meter channel width
CGSO	F/m	0	Gate-source overlap capacitance per meter channel width
DASAT	1/°C	0	Temperature coefficient of ASAT

DD	m	1400 Å	Vds field constant
DELTA	-	4.0	Transition width parameter
DG	m	2000 Å	Vgs field constant
DMU1	cm2/Vs ° C	0	Temperature coefficient of MU1
DVT	V	0	The difference between VON and the threshold voltage
DVTO	V/°C	0	Temperature coefficient of VTO
EB	EV	0.68	Barrier height of diode
ETA	-	7	Subthreshold ideality factor
ETAC0	-	ETA	Capacitance subthreshold ideality factor at zero drain bias
ETAC00	1/V	0	Capacitance subthreshold coefficient of drain bias
I0	A/m	6.0	Leakage scaling constant
I00	A/m	150	Reverse diode saturation current
LASAT	M	0	Coefficient for length dependence of ASAT
LKINK	M	19E-6	Kink effect constant
MC	-	3.0	Capacitance knee shape parameter
MK	-	1.3	Kink effect exponent
MMU	-	3.0	Low field mobility exponent

MU0	cm2/Vs	100	High field mobility
MU1	cm2/Vs	0.0022	Low field mobility parameter
MUS	cm2/Vs	1.0	Subthreshold mobility
RD	µ	0	Drain resistance
RDX	Ω	0	Resistance in series with Cgd
RS	µ	0	Source resistance
RSX	Ω	0	Resistance in series with Cgs
TNOM	°C	25	Parameter measurement temperature
TOX	m	1e-7	Thin-oxide thickness
V0	V	0.12	Characteristic voltage for deep states
VFB	V	-0.1	Flat band voltage
VKINK	V	9.1	Kink effect voltage
VON	V	0	On-voltage
VTO	V	0	Zero-bias threshold voltage

Equivalent Circuit



Model Equations

Drain Current

The expression for the subthreshold current is given by:

$$I_{sub} = \mathrm{MUS} \cdot C_{ox} \frac{\mathrm{W}}{\mathrm{L}} V_{sth}^{2} \exp\left(\frac{V_{GT}}{V_{sth}}\right)\left[1 - \exp\left(-\frac{V_{DS}}{V_{sth}}\right)\right]$$

$$V_{sth} = ETA \cdot V_{th}, V_{th} = k_B \cdot TEMP/q$$

$$C_{ox} = \varepsilon_i \cdot \mathrm{L} \cdot \mathrm{W/TOX}$$

$$V_{GT} = V_{GS} - V_T$$

$$V_T = V_{TX} - \frac{\mathrm{AT} \cdot V_{DS}^{2} + \mathrm{BT}}{\mathrm{L}}$$

where ε_1 is the dielectric constant of the oxide and k B is the Boltzmanns constant.

Above threshold (*Vgt* > 0), the conduction current is given by:

$$I_{ds} = \begin{cases} \mu_{FET} C_{ox} \frac{W}{L} \left(V_{GT} V_{DS} - \frac{V_{DS}^2}{2\alpha_{sat}} \right) & \text{for} V_{DS} < \alpha_{sat} V_{GT} \\ \mu_{FET} C_{ox} \frac{W}{L} \frac{V_{GT}^2 \alpha_{sat}}{2} & \text{for} V_{DS} \geq \alpha_{sat} V_{GT} \end{cases}$$

$$\frac{1}{\mu_{FET}} = \frac{1}{\mathrm{MUO}} + \frac{1}{\mu_1 (2V_{GT} / V_{sth})^{\mathrm{MMU}}}$$

Subthreshold leakage current is the result of thermionic field emission of carriers through the grain boundary trap states and is described by:

$$I_{leak} = \mathrm{I0} \cdot \mathrm{W} \left[\exp\left(\frac{q \cdot \mathrm{BLK} \cdot V_{DS}}{kT} \right) - 1 \right] [X_{TFE} + X_{TE}] + I_{diode}$$

$$X_{TFE} = \frac{X_{TFE,lo} X_{TFE,hi}}{X_{TFE,lo} + X_{TFE,hi}}$$

$$X_{TE} = \exp(-W_C)$$

$$W_C = (E_c - E_t) / kT = 0.55\mathrm{eV} / kT$$

$$X_{TEF,lo} = \begin{cases} \frac{4\sqrt{\pi}}{3} f \exp\left(\frac{4}{27} f^2 - W_C \right) & \text{for } f \leq f_{lo} \\ X_{TFE,lo}(f_{lo}) \exp\left[\left(\frac{1}{f_{lo}} + \frac{8}{27} f_{lo} \right) (f - f_{lo}) \right] & \text{for } f > f_{lo} \end{cases}$$

$$f = F / F_0$$

$$F = \left[\frac{V_{DS}}{\mathrm{DD}} - \frac{V_{GS} - \mathrm{VFB}}{\mathrm{DG}}\right]$$

$$F_0 = (kT)^{3/2}\frac{4}{3}\frac{2\pi\sqrt{2m^*}}{qh}$$

$$m^* = 0.27m_0$$

$$f_{lo} = \frac{3}{2}(\sqrt{W_C + 1} - 1)$$

$$X_{TEF,ki} = \begin{cases} \frac{2W_C}{3}\exp\left(1 - \frac{2W_C}{3}\right) & \text{for } f < f_{ki} \\ \left(1 - \frac{3\sqrt{W_C}}{2f}\right)^{-1}\exp\left(\frac{-W_C^{3/2}}{f}\right) & \text{for } f \geq f_{ki} \end{cases}$$

$$f_{ki} = 3\left(\frac{W_C^{3/2}}{2W_C - 3}\right)$$

$$I_{diode} = 100 \cdot W\exp\left(-\frac{\mathrm{EB}}{k_BT}\right)\left[1 - \exp\left(-\frac{qV_{DS}}{k_BT}\right)\right]$$

Finally, for very large drain biases, the kink effect is observed. It is modeled as impact ionization in a narrow region near the drain. The expression can be written as:

$$I_{kink} = A_{kink}I_{ch}(V_{DS} - V_{DSAT})\exp\left(-\frac{\mathrm{VKINK}}{V_{DS} - V_{DSAT}}\right)$$

$$A_{kink} = \frac{1}{\mathrm{VKINK}}\left(\frac{\mathrm{LKINK}}{\mathrm{L}}\right)^{\mathrm{MK}}, V_{DSAT} = \alpha_{sat}V_{GT}$$

The impact ionization current, *Ikink* , is added to the drain current.

Threshold Voltage

If VTO is not specified:

$$V_T = \mathrm{VON} - \mathrm{DVT}$$

else:

$$V_T = \mathrm{VTO}$$

Temperature Dependence

$$V_{TX} = V_T - \mathrm{DVTO}(\mathrm{TEMP} - \mathrm{TNOM})$$

$$\mu_1 = \mathrm{MU1} + \mathrm{DMU1}(\mathrm{TEMP} - \mathrm{TNOM})$$

$$\alpha_{sat} = \mathrm{ASAT} - \frac{\mathrm{LASAT}}{\mathrm{L}} - \mathrm{DASAT}(\mathrm{TEMP} - \mathrm{TNOM})$$

Capacitance

$$C_{gs} = C_f + \frac{2}{3}C_{god}\left[1 - \left(\frac{V_{DSAT} - V_{DSE}}{2V_{DSAT} - V_{DSE}}\right)^2\right]$$

$$C_{gd} = C_f + \frac{2}{3}C_{gos}\left[1 - \left(\frac{V_{DSAT}}{2V_{DSAT} - V_{DSE}}\right)^2\right]$$

$$C_f = 0.5 \cdot \mathrm{EPS} \cdot \mathrm{W}$$

$$C_{gcd} = \frac{C_{ox}}{1 + \eta_{cd} \exp\left(-\frac{V_{GT}}{\eta_{cd} V_{th}}\right)}$$

$$C_{gcs} = \frac{C_{ox}}{1 + \mathrm{ETAC0} \cdot \exp\left(-\frac{V_{GT}}{\mathrm{ETAC0} \cdot V_{th}}\right)}$$

$$C_{ox} = \mathrm{W} \cdot \mathrm{L} \cdot \epsilon / \mathrm{TOX}, \eta_{cd} = \mathrm{ETAC0} + \mathrm{ETAC00} \cdot V_{DSE}$$

$$V_{DSE} = \frac{V_{DS}}{\left[1 + (V_{DS} / V_{DSAT})^{\mathrm{MC}}\right]^{1/\mathrm{MC}}}$$

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