# Chapter 5: Temperature Dependence and Self-Heating

Self-heating in SOI is more important than in bulk since the thermal conductivity of silicon dioxide is about two orders of magnitude lower than that of silicon [15]. It may degrade the carrier mobility, increase the junction leakage [20], enhance the impact ionization rate [24], and therefore affect the output characteristics [16] of floating-body SOI devices.

## 5.1. Temperature Dependence

The temperature dependence of threshold voltage, mobility, saturation velocity and series resistance in BSIMSOI is identical to BSIM3v3. However a different temperature dependence of diode characteristics is adopted in BSIMSOI4.0:

$$j_{sbjt} = i_{sbjt} \exp\left[ \frac{-E_g(300K)}{n_{diodes} V_t} X_{bjt} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{dbjt} = i_{dbjt} \exp\left[ \frac{-E_g(300K)}{n_{dioded} V_t} X_{bjt} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{sdif} = i_{sdif} \exp\left[ \frac{-E_g(300K)}{n_{diodes} V_t} X_{dif} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{ddif} = i_{ddif} \exp\left[ \frac{-E_g(300K)}{n_{dioded} V_t} X_{dif} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{srec} = i_{srec} \exp\left[ \frac{-E_g(300K)}{n_{recf0s} V_t} X_{rec} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{drec} = i_{drec} \exp\left[ \frac{-E_g(300K)}{n_{recf0d} V_t} X_{rec} \left( 1 - \frac{T}{T_{nom}} \right) \right]$$

$$j_{stun} = i_{stun} \exp\left[ X_{tun} \left( \frac{T}{T_{nom}} - 1 \right) \right]$$

$$j_{dtun} = i_{dtun} \exp\left[ X_{tun} \left( \frac{T}{T_{nom}} - 1 \right) \right] \tag{5.1}$$

$$n_{recrs} = n_{recr0s} \left[ 1 + nt_{recr} \left( \frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recrd} = n_{recr0d} \left[ 1 + nt_{recr} \left( \frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recfs} = n_{recf0s} \left[ 1 + nt_{recf} \left( \frac{T}{T_{nom}} - 1 \right) \right]$$

$$n_{recfd} = n_{recf0d} \left[ 1 + nt_{recf} \left( \frac{T}{T_{nom}} - 1 \right) \right]$$

The parameters $i_{sbjt}, i_{dbjt}, i_{sdif}, i_{ddif}, i_{srec}, i_{drec}, i_{stun}, i_{dtun}$ are diode saturation currents at the nominal temperature $T_{nom}$, and the parameters $X_{bjt}, X_{dif}, X_{rec}, X_{tun}$ are provided to model the temperature dependence. Notice that the non-ideality factors $n_{recfs}, n_{recfd}, n_{recrs}, n_{recrd}$ are also temperature dependent.

## 5.2. Self-Heating Implementation

BSIMPD/BSIMSOI models the self-heating by an auxiliary $R_{th}C_{th}$ circuit as shown in Fig. 5.1 [18]. The temperature node (T node) will be created in SPICE simulation if the self-heating selector *shMod* is ON and the thermal resistance is non-zero. The T node is treated as a voltage node and is connected to ground through a thermal resistance $R_{th}$ and a thermal capacitance $C_{th}$:

$$\boldsymbol{R_{th} = \frac{R_{th0}}{W'_{eff} + W_{th0}}, \; C_{th} = C_{th0}(W'_{eff} + W_{th0})} \tag{5.2}$$

where $R_{th0}$ and $C_{th0}$ are normalized thermal resistance and capacitance, respectively. $W_{th0}$ is the minimum width for thermal resistance calculation [19]. Notice that the current source is driving a current equal to the power dissipated in the device.

$$P = \left| I_{ds} \times V_{ds} \right| \tag{5.3}$$

To save computation time, the turn-on surface potential $\phi_s$ (Phi) is taken to be a constant within each timepoint because a lot of parameters (e.g. $X_{dep}$) are function of $\phi_s$. Each timepoint will use a $\phi_s$ calculated with the temperature iterated in the previous timepoint. However this approximation may induce error in DC, transient and AC simulation. Therefore, it is a tradeoff between accuracy and speed. The error in DC or transient is minimal if the sweeping step or time step is sufficiently small.

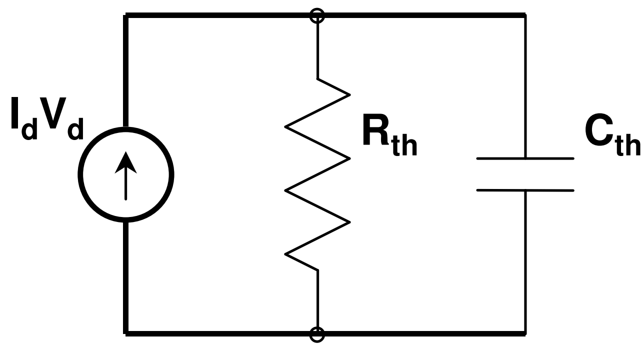


Fig. 5.1 Equivalent circuit for self-heating simulation.