Predictive Model for HCI (Beta Version)

Hot-carrier-Instability (HCI) manifests itself as an increase in the threshold voltage (V_{th}) and the degradation of the carrier mobility, especially for the NMOS transistor.

Threshold voltage degradation

The following analytical models describe the shift of V_{th} due to HCI.

$$\Delta V_{th} = \frac{q}{C_{ox}} K \sqrt{C_{ox}(V_{GS} - V_{th})} \exp\left(\frac{E_{ox}}{E_0}\right) \exp\left(-\frac{\varphi_{it}}{q\lambda E_m}\right) t^n$$

where, $E_m = \frac{V_{ds} - V_{dsat}}{l}$, $V_{dsat} = \frac{(V_{gs} - V_{th} + 2V_t) L_{eff} E_{sat}}{V_{gs} - V_{th} + 2V_t + A_{bulk} L_{eff} E_{sat}}$

$$E_{ox} = \frac{V_{gs} - V_{th}}{T_{ox}}, \; C_{ox} = \frac{\varepsilon_{ox}}{T_{ox}}, \; V_t = \frac{kT}{q}$$

Default values of model coefficients (technology independent):

K (nm/C$^{0.5}$)	**E_0 (V/nm)**	**A_{bulk}**	**φ_{it} (eV)**	**λ (nm)**	**n**	**L (nm)**	**E_{sat} (V/nm)**
1.7e8	**0.8**	**0.005**	**3.7**	**7.8**	**0.45**	**17**	**0.011**

Mobility degradation

$$\mu = \frac{1}{(1 + \alpha N_{it})^m} \mu_{eff}, \quad \text{where} \quad \alpha = 5, m = 1.6,$$

Nit: interface traps which can be extracted from the threshold voltage degradation model:

$$\Delta V_{th} = \frac{q}{C_{ox}} N_{it}$$

Technology extrapolations:

Technology Node (nm)	**250**	**180**	**130**	**90**	**65**	**45**	**32**
V_{DD} (V)	**1.8**	**1.5**	**1.3**	**1.2**	**1.1**	**1.0**	**0.9**
V_{th} (V)	**0.371**	**0.3**	**0.265**	**0.263**	**0.258**	**0.257**	**0.242**
EOT (nm)	**4**	**2.3**	**1.6**	**1.4**	**1.2**	**1.1**	**1**
μ_{eff} (cm^2/V/sec)	**591**	**402**	**295**	**247**	**197**	**166**	**138**