APPENDIX A

List of Selected Formulae

P-n junction

$V_{bi} = \frac{kT}{q}\ln\frac{N_A N_D}{n_i^2}$; $N_A x_p = N_D x_n$; $W = x_p + x_n$; $C_j = \frac{\varepsilon_s}{W}$;

$W = \sqrt{\frac{2\varepsilon_s}{q}[\frac{1}{N_A}+\frac{1}{N_D}](V_{bi}-V)}$; $L_p = \sqrt{D_p\tau_p}$.

Bipolar junction transistors

$\gamma \equiv \frac{I_{Ep}}{I_E} = \frac{I_{Ep}}{I_{Ep}+I_{En}}$; $\alpha_T \equiv \frac{I_{Cp}}{I_{Ep}}$; $\alpha_0 = \gamma\alpha_T$; $\beta_0 = \frac{\alpha_0}{1-\alpha_0}$; $I_C = \alpha_0 I_E + I_{CBO}$;

$I_{CEO} = (1+\beta_0)I_{CBO}$; $p_n(x) = p_{no}e^{qV_{EB}/kT}(1-\frac{x}{W})$; $\gamma = \frac{1}{1+\frac{D_E}{D_p}\cdot\frac{N_B}{N_E}\cdot\frac{W}{L_E}}$;

$I_{Ep} = qA\frac{D_p p_{n0}}{W}e^{(qV_{EB}/kT)}$; $I_{En} = qA\frac{D_E n_{E0}}{L_E}(e^{qV_{EB}/kT}-1)$; $I_{Cn} = qA\frac{D_C n_{C0}}{L_C}$;

$p_{n0}\cdot N_B = n_{E0}\cdot N_E = n_{C0}\cdot N_C = n_i^2$; $\tau_B = \frac{W^2}{2D_p}$; $f_T = \frac{1}{2\pi\tau_B}$.

MOS devices

$\psi_s = 2\psi_B = \frac{2kT}{q}\ln(\frac{N_A}{n_i})$; $W_m^2 = \frac{2\varepsilon_s(2\psi_B)}{qN_A} = \frac{4\varepsilon_s kT}{q^2 N_A}\ln(\frac{N_A}{n_i})$; $V_T = \frac{qN_A W_m}{C_o} + 2\psi_B$;

$\frac{C}{C_0} = \frac{1}{\sqrt{1+\frac{2\varepsilon_{ox}^2 V}{qN_A\varepsilon_s d^2}}}$; $\frac{1}{C_{\min}} = \frac{d}{\varepsilon_{ox}} + \frac{W_m}{\varepsilon_s}$; $V_{FB} = \phi_{ms} - \frac{(Q_f+Q_m+Q_{ot})}{C_0}$.

$I_D = K_n[(V_{GS}-V_T)V_{DS} - \frac{V_{DS}^2}{2}]$ for $V_{DS} < V_{GS} - V_T$; $V_T = \frac{qN_A W_m}{C_0} + 2\psi_B$ when $V_{FB} = 0$;

$I_D = \frac{K_n}{2}(V_{GS}-V_T)^2$ for $V_{DS} \geq V_{GS} - V_T$; $K_n = \mu_n C_{ox}\frac{W}{L}$.

Thermal oxidation

$t_{ox}^2 + At_{ox} = B(t+\tau)$; $\tau = \frac{t_{oxi}^2}{B} + \frac{t_{oxi}}{B/A}$. $t_{ox} = \frac{-A+\sqrt{A^2+4B(t+\tau)}}{2}$

$D = D_o\exp(-\frac{E_a}{kT})$

APPENDIX A (continued)

List of Selected Formulae (continued)

Thermal diffusion

Constant source diffusion:

$$N(z,t) = N_s erfc(\frac{z}{2\sqrt{Dt}})$$

Limited source diffusion:

$$N(z,t) = \frac{Q}{\sqrt{\pi Dt}} \exp[-\frac{z^2}{4Dt}], \quad Q = \frac{2}{\sqrt{\pi}} N_s \sqrt{Dt}\ .$$

Ion implantation

Before Annealing

$$N(x) = \frac{Q}{\sqrt{2\pi}\Delta R_p} \exp[-\frac{(x-R_p)^2}{2\Delta R_p^2}]$$

After annealing

$$N(x) = \frac{Q}{\sqrt{2\pi}(\Delta R_p^2 + 2Dt)^{1/2}} \exp[-\frac{(x-R_p)^2}{2(\Delta R_p^2 + 2Dt)}]$$

$$Q = \int_0^\infty N(x)\,dx = \sqrt{2\pi} N_p \Delta R_p$$

APPENDIX B

Table of Physical Constants

Physical Constant	Symbol	Value	Units
Electronic charge	q	1.6×10^{-19}	C
Boltzmann's constant	k	8.62×10^{-5} 1.38066×10^{-23}	eV/K J/K
Planck's constant	h	6.626×10^{-34}	J·s
Permittivity of free space	ε_0	8.85×10^{-14}	F/cm
Dielectric constant of Si	ε_{Si}	11.7	-
Dielectric constant of SiO_2	ε_{ox}	3.9	-
Electron Mass	m	9.11×10^{-31}	kg
Speed of Light	c	3×10^{8}	m/s
Bandgap of Si at 300 K	E_g	1.12	eV
Intrinsic carrier concentration in Si at 300 K	n_i	9.65×10^{9}	cm^{-3}

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