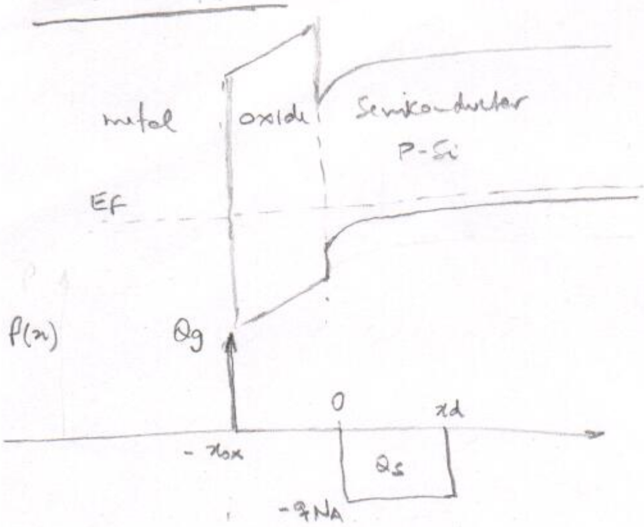
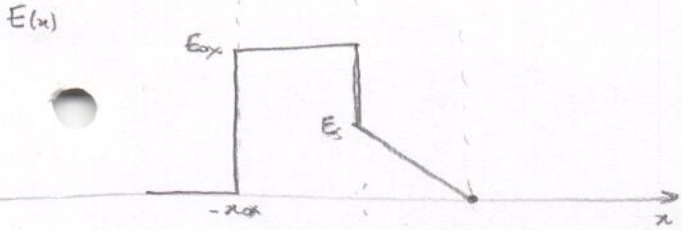
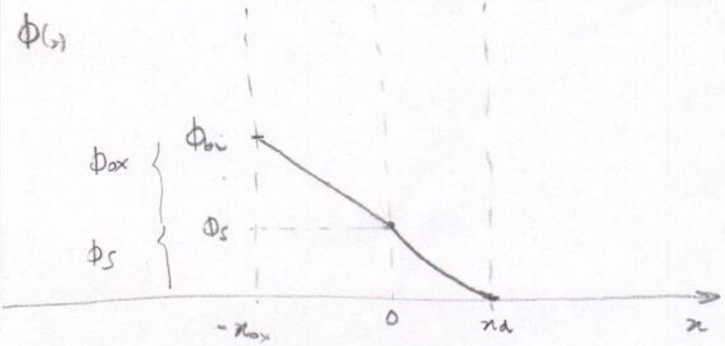
Course 20







$\cdot \; \dfrac{\partial \phi}{\partial x} = -E(x)$

$\Rightarrow$ in oxide : $\phi_{ox} = -E_{ox} \cdot x_{ox}$

$$\phi_{ox} = + \frac{q \cdot N_A \, x_d}{\varepsilon_{ox}} \cdot x_{ox} = + \frac{q N_A x_d}{C_{ox}}$$

$\Rightarrow$ in semiconductor :

$$\phi_s = \frac{q \cdot N_A}{\varepsilon_s} \left(\frac{x^2}{2} - x_d \, x \right) + a$$

at $x = x_d$, $\phi_s = 0$ (reference)

$$\phi_s(x_d) = \frac{q N_A}{\varepsilon_s} \left(\frac{x_d^2}{2} - x_d^2 \right) + a = 0$$

$$\boxed{a = \frac{q N_A}{2 \varepsilon_s} \cdot x_d^2} \Rightarrow \phi_s(x) = \frac{q N_A}{2 \varepsilon_s} \left(x^2 - 2 x_d x + x_d^2 \right)$$

at $x = 0$ $\Rightarrow \phi_s = + \dfrac{q N_A}{\varepsilon_s} \cdot \dfrac{x_d^2}{2}$

$$q \phi_{bi} = W_s - W_M$$

$$Q_g = -Q_s = + q N_A x_d \quad \left(\begin{array}{c} \text{sheet charge} \\ C/cm^2 \end{array} \right)$$

$\cdot \; \dfrac{\partial E(x)}{\partial x} = \dfrac{\rho(x)}{\varepsilon}$

$\cdot$ in oxide $\quad E(x) = $ cte

Q_g Q_s

$$\frac{Q}{cm^2} = V \cdot \frac{C}{m^2} \Rightarrow \frac{C}{cm^2} = \frac{Q/cm^2}{V}$$

$$\left(\text{capacitance per area} = \frac{\text{charge per area}}{\text{voltage}} \right)$$

thus

$\cdot \; \phi_{ox} = \dfrac{-Q_s}{C_{ox}}$

and

$$E_{ox} = \frac{\phi_{ox}}{x_{ox}} = \frac{-Q_s}{\varepsilon_{ox}/x_{ox} \cdot x_{ox}} = -\frac{Q_s}{\varepsilon_{ox}}$$

$\cdot$ in semiconductor $\quad \dfrac{\partial E(x)}{\partial x} = \dfrac{\rho(x)}{\varepsilon_s} \Rightarrow E(x) = -\dfrac{q N_A}{\varepsilon}(x - x_d)$

$\rho(x) \rightarrow [C/cm^3]$

(sheet charge)

$\cdot \; Q_s = -q N_A \cdot x_d$

$\cdot \; \varepsilon_s E_s = \varepsilon_{ox} \cdot E_{ox}$

$$\Rightarrow E_s = \frac{\varepsilon_{ox} E_{ox}}{\varepsilon_s} = \frac{-Q_s}{\varepsilon_s} = \frac{q N_A \cdot x_d}{\varepsilon_s}$$

and

$$\frac{\partial E(x)}{\partial x} = \frac{Q_s}{\varepsilon_s} \Rightarrow E(x) = -\frac{Q_s}{\varepsilon}(x - x_d)$$

Q_s (volume charge) $= qN_A$

$$E(x) = -\frac{q \cdot N_A}{\varepsilon_s}(x - x_d)$$

at $x = 0 \Rightarrow E(x) = \dfrac{q N_A x_d}{\varepsilon_s}$! same result

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thus

$$\phi_{bi} = \phi_s + \phi_{ox}$$

$$\phi_{bi} = \frac{q \cdot N_A \cdot x_d^2}{2 \varepsilon_s} + \frac{q \cdot N_A \cdot x_d}{C_{ox}}$$

and $q\phi_{bi} = (W_s - W_M) \Rightarrow$ we can calculate x_d !