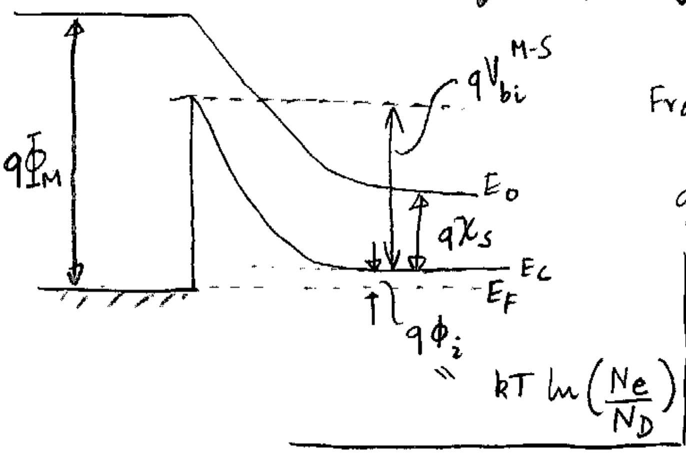
(a) Built-in voltage of the p-n junction: $\boxed{V_{bi}^{p\text{-}n} = \frac{kT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)}$



From band-diagram on left,

$$qV_{bi}^{M\cdot S} = q\Phi_M - q\chi_S - q\phi_i$$

$$= q\Phi_M - q\chi_S - kT \ln\left(\frac{N_C}{N_D}\right)$$

$$= qV_{bi}^{p\text{-}n} \quad \text{(Required)}.$$

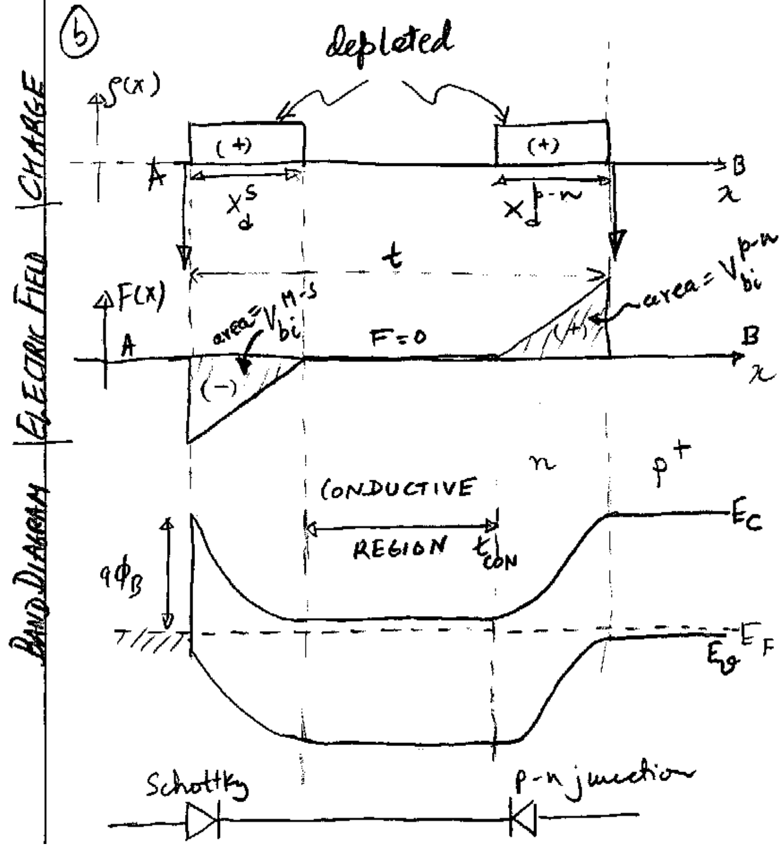
$\therefore$ The necessary work function is

$$q\Phi_M = qV_{bi}^{p\text{-}n} + kT \ln\left(\frac{N_C}{N_D}\right) + q\chi_S$$

$$= kT \ln\left(\frac{N_A N_D}{n_i^2}\right) + kT \ln\left(\frac{N_C}{N_D}\right) + q\chi_S$$

$$\boxed{q\Phi_M = q\chi_S + kT \ln\left(\frac{N_A N_C}{n_i^2}\right)}$$

(b)



From the figure on left, the depletion widths of the M-S & p-n junctions are the SAME, since the voltage drops across them are the same!

$\therefore$ $x_d^S = x_d^{p\text{-}n}$, where

$$V_{bi} = \frac{qN_D x_d^2}{2\epsilon_s} \quad @ \; V_g = 0.$$

$$\therefore \; x_d^S = x_d^{p\text{-}n} = \sqrt{\frac{2\epsilon_s V_{bi}}{qN_D}}$$

& The conductive region thickness is

$$\boxed{t_{CON} = t - 2x_d^S = t - 2\sqrt{\frac{2\epsilon_s V_{bi}}{qN_D}}}$$

Obviously, $\boxed{t^2 \geq \frac{8\epsilon_s V_{bi}}{qN_D}}$

Contd...

(c) Since the Schottky contact to n-layer & the ohmic contact to the p-layer are at the same potential,

$\boxed{+\text{ve } V_g}$ ⇒ Depletion Layer thicknesses x_d^S & $x_d^{p\text{-}n}$ shrink, n-layer <u>more conductive</u>.

$\boxed{-\text{ve } V_g}$ ⇒ Depletion layer thicknesses x_d^S & $x_d^{p\text{-}n}$ stretch, n-layer <u>less conductive</u>.

It is clear that a −ve V_g is needed to deplete the n-layer

When a bias is applied,

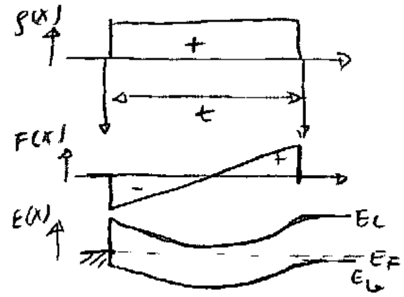
$$x_d^S = \sqrt{\frac{2\epsilon_s (V_{bi} + |V_g|)}{qN_D}} \qquad x_d^{p\text{-}n} \approx \sqrt{\frac{2\epsilon_s (V_{bi} + |V_g|)}{qN_D}}$$

$$\therefore \quad t_{CON} = t - \left\{ \sqrt{\frac{2\epsilon_s (V_{bi} + |V_g|)}{qN_D}} + \sqrt{\frac{2\epsilon_s (V_{bi} + |V_g|)}{qN_D}} \right\}$$

$\left(\frac{1}{N_A} + \frac{1}{N_D}\right) \approx \frac{1}{N_D}$ since $N_A \gg N_D$

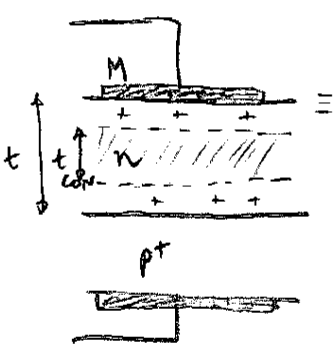
@ pinch-off, $\boxed{t_{CON} = 0}$ ⇒

$$t = 2\sqrt{\frac{2\epsilon_s (V_{bi} + |V_g|)}{qN_D}}$$



$$\Rightarrow \quad \boxed{V_g(\text{pinch-off}) = \frac{qN_D}{8\epsilon_s} t^2 - V_{bi}}$$

(d)



≡ MES FET — METAL-SEMICONDUCTOR

J FET — JUNCTION

MESJFET

FET — FIELD-EFFECT TRANSISTOR