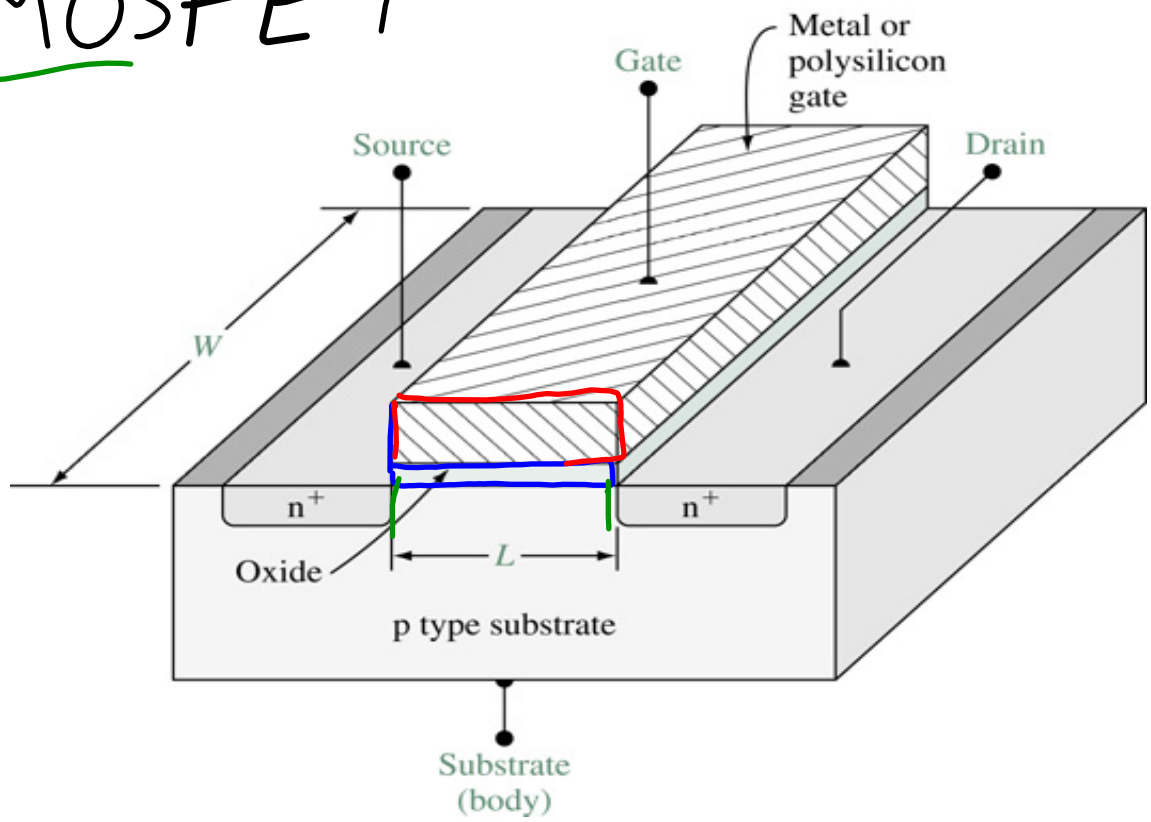
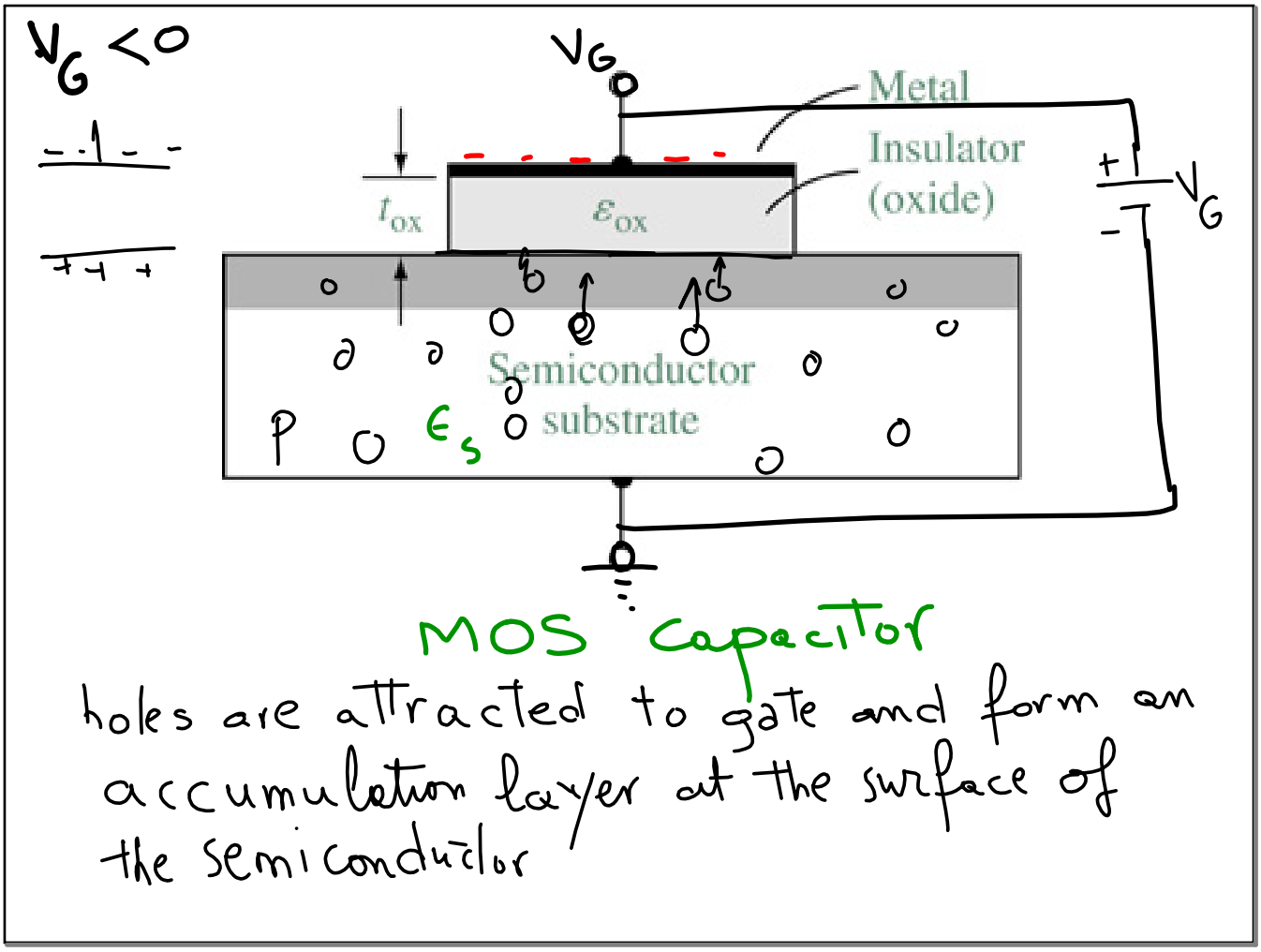
MOSFET

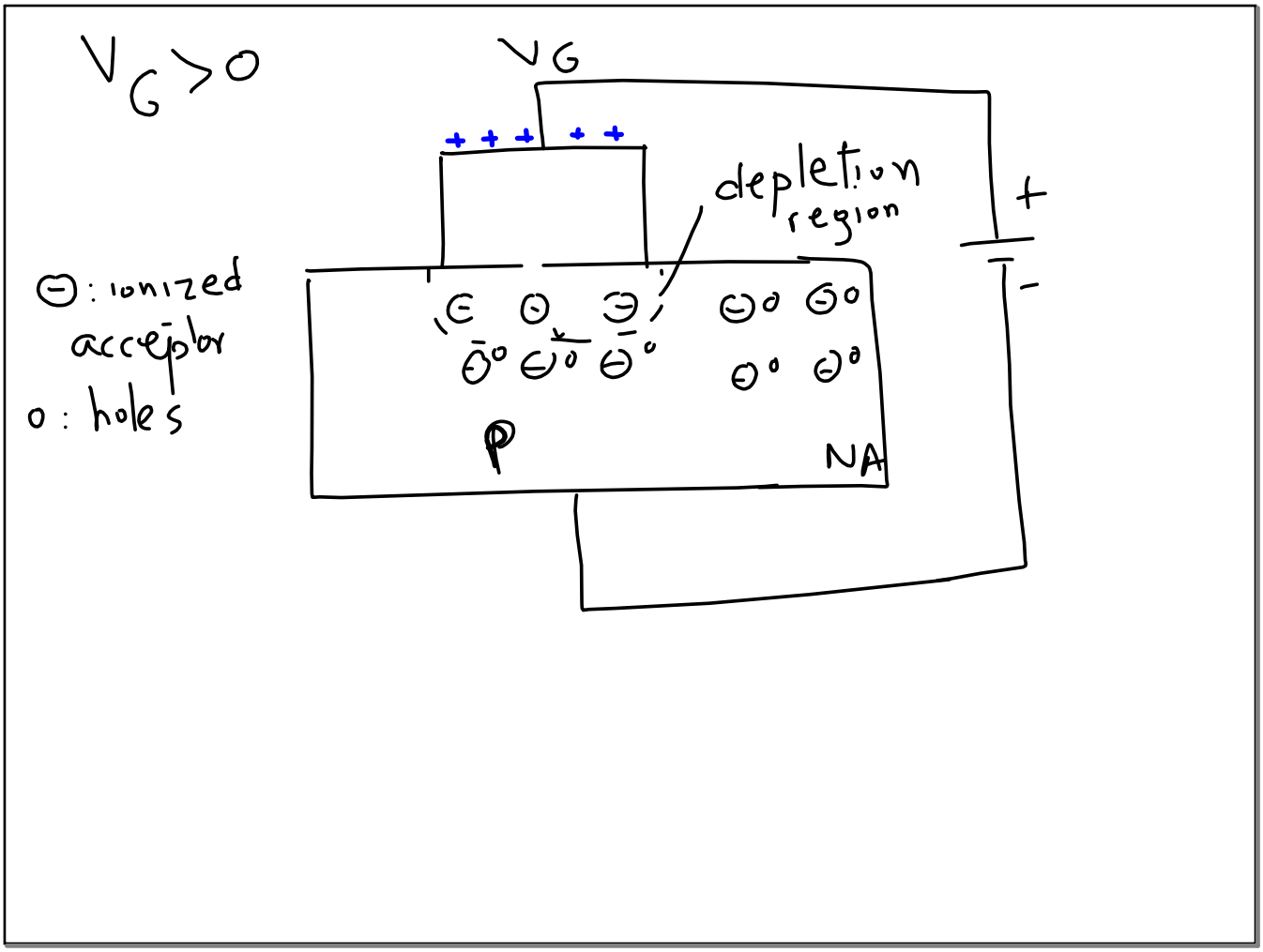


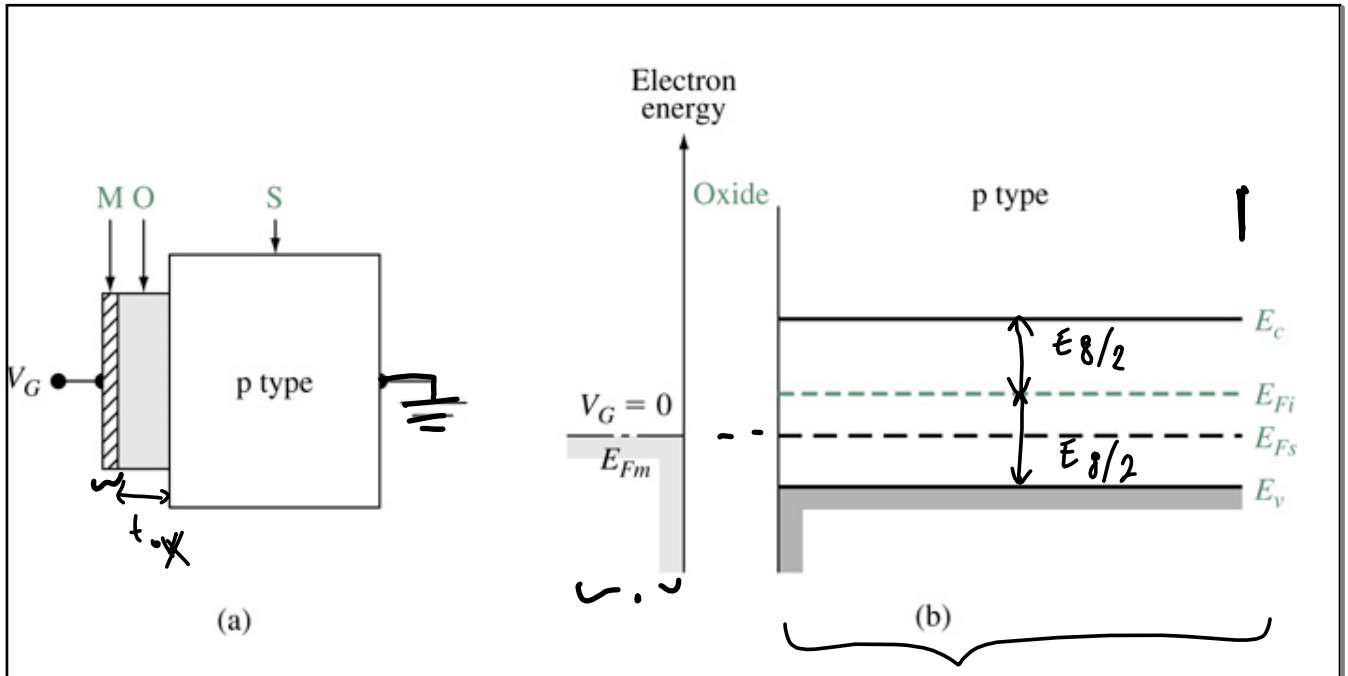
n-channel



MOS capacitor

holes are attracted to gate and form an accumulation layer at the surface of the semiconductor


$V_G > 0$
V_G
depletion region
+
-
⊖ : ionized acceptor
o : holes
P
NA

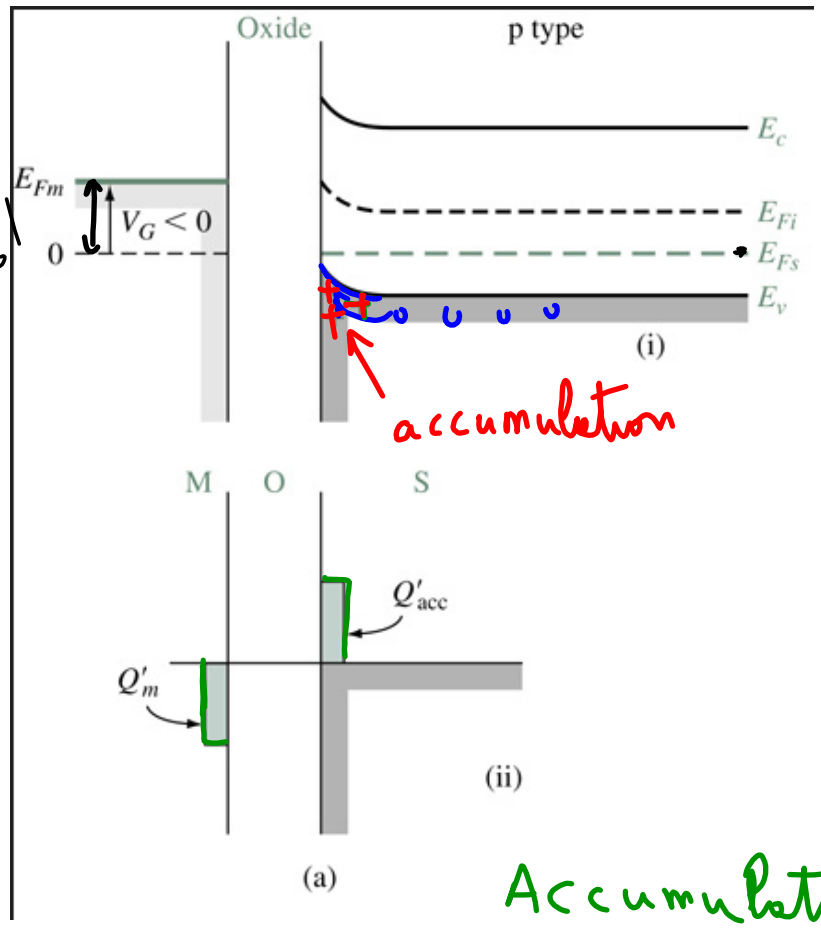


Assume Flat band condition

Equilibrium

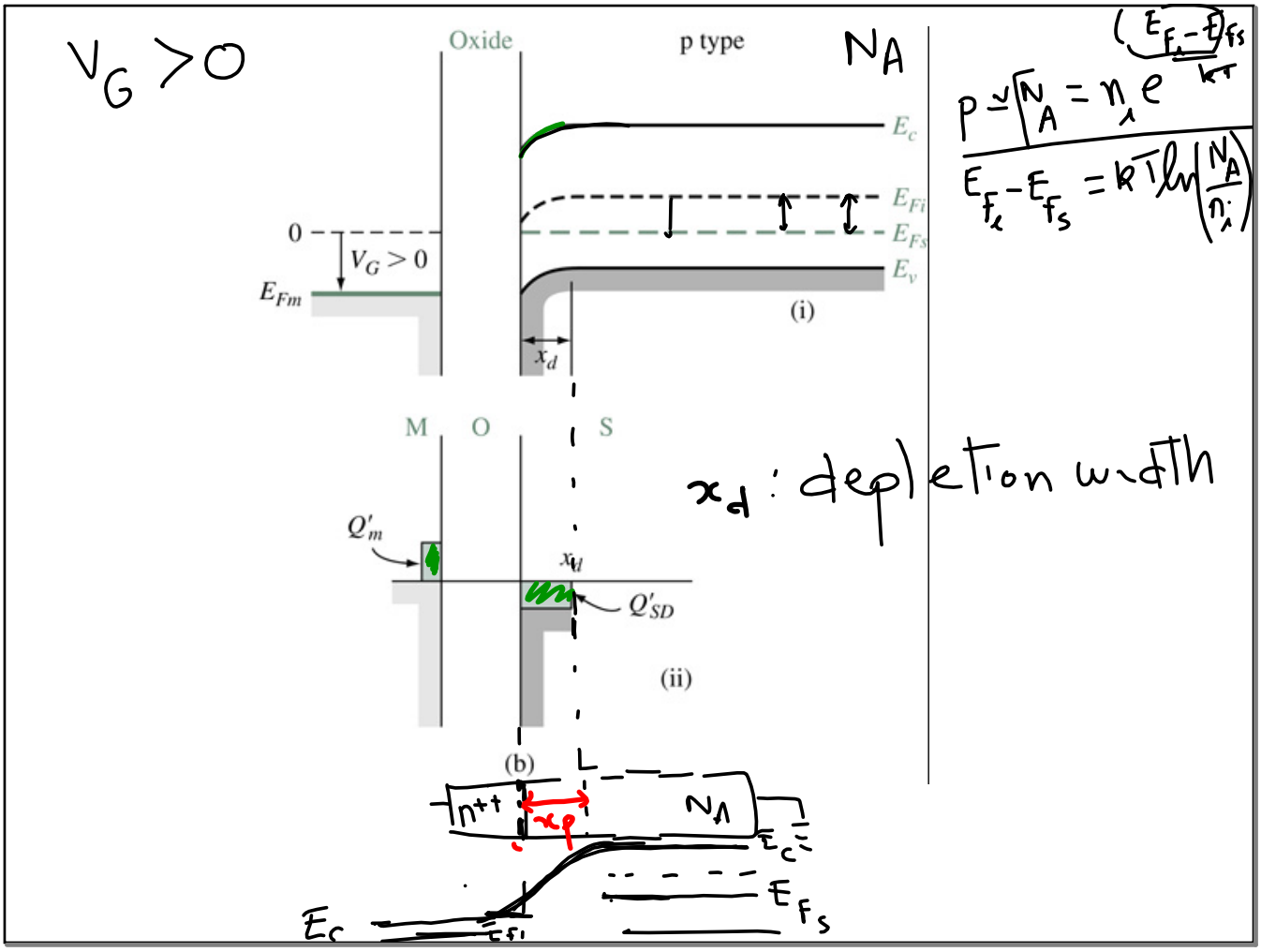
$V_G < 0$

$e|V_G|$

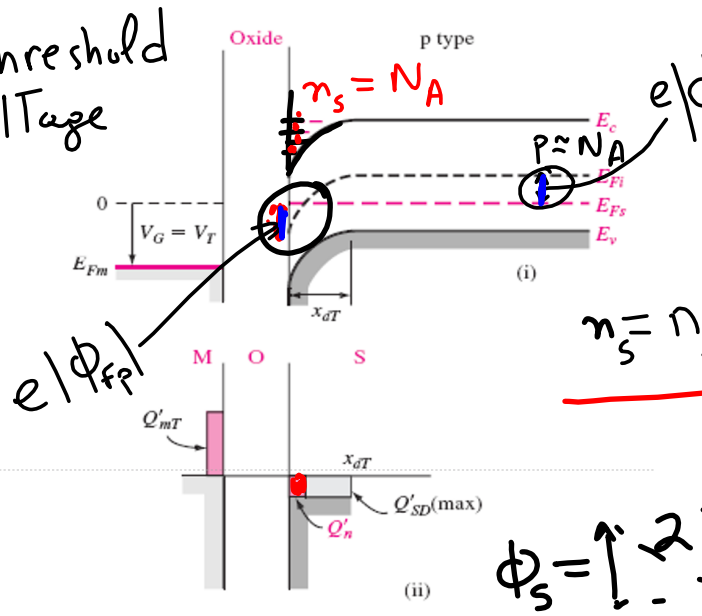


accumulation

Accumulation


$V_G > 0$
Oxide
p type
N_A
E_c
E_{Fi}
E_{Fs}
E_v
0
$V_G > 0$
E_{Fm}
(i)
x_d
M O S
Q'_m
x_d
Q'_{SD}
(ii)
(b)
L
n^+
N_A
x_p
E_c
E_{Fs}
E_c
E_{Fi}
$p \simeq N_A = n_i e^{\frac{(E_{Fi}-E_{Fs})}{kT}}$
$E_{Fi} - E_{Fs} = kT \ln\left(\frac{N_A}{n_i}\right)$
x_d : depletion width

$V_G = V_T$: threshold voltage



$E_{F_s} - E_{F_i}$ / kT

$n_s = n_i e = N_A$

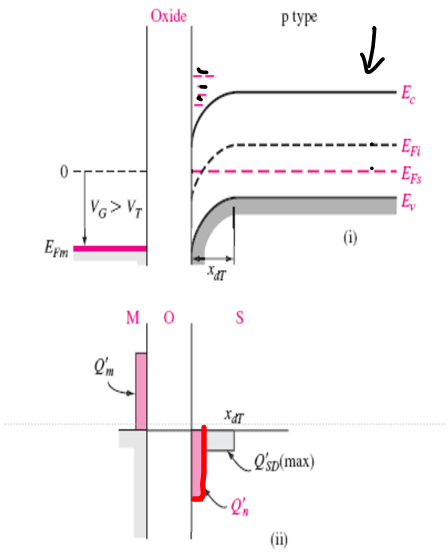
$e|\phi_{Fp}|$

$\phi_s = 2|\phi_{Fp}|$ ---o

$V_G = V_T$: Threshold voltage

At threshold voltage, the electron density at the surface is equal to the hole density in the bulk region.

$V_G > V_T$



$V_G > V_T$: inversion

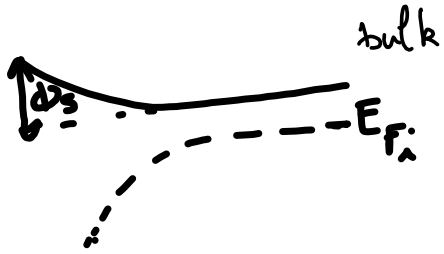
In inversion, the electron density at the surface becomes greater than the hole density in the bulk region.

Depletion Width x_d

From a pn junction $x_p = \left[\frac{2\epsilon_s (V_{bi} - V_a)}{e} \frac{N_D}{N_A} \frac{1}{(N_A + N_D)}\right]^{1/2}$

n^{++} p $\Rightarrow N_D \gg N_A$

$$x_d = \left[\frac{2\epsilon_s \phi_s}{e} \frac{1}{N_A}\right]^{1/2}$$



$$\phi_s = \frac{E_{F_i}(\text{bulk}) - E_{F_i}(\text{surface})}{e}$$

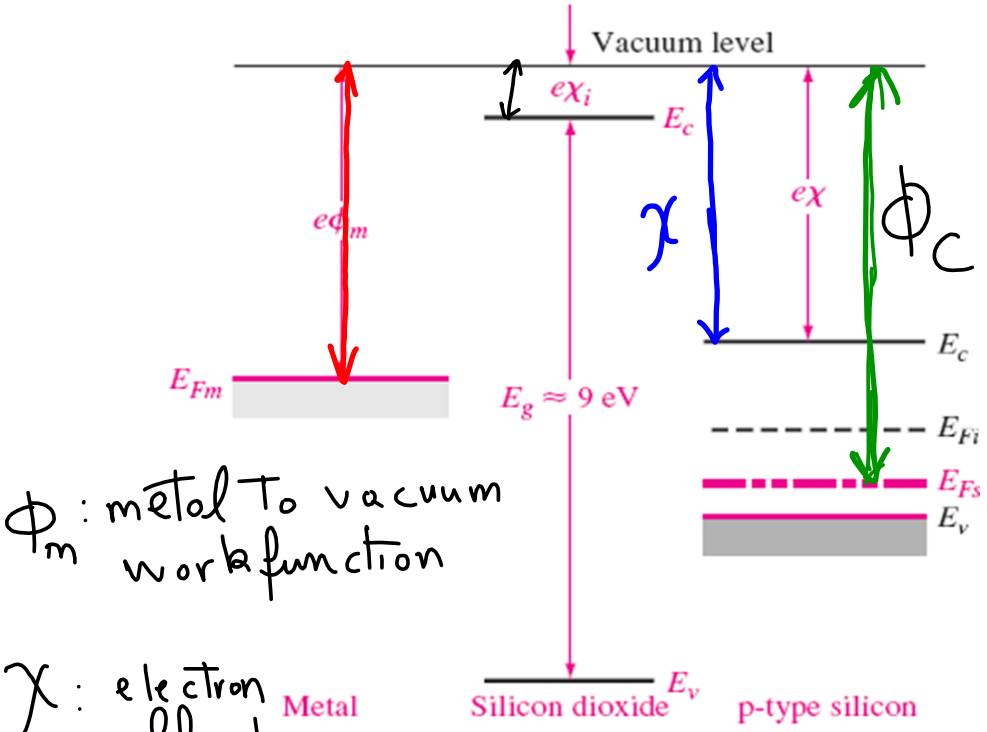
$$\phi_{F_p} \equiv \frac{E_{F_i} - E_{F_i}}{e} = -\frac{kT}{e} \ln\left(\frac{N_A}{n_i}\right)$$

At threshold, $n_s = N_A$; $\phi_s = 2|\phi_{Fp}|$

$x_d \equiv x_{dT}$

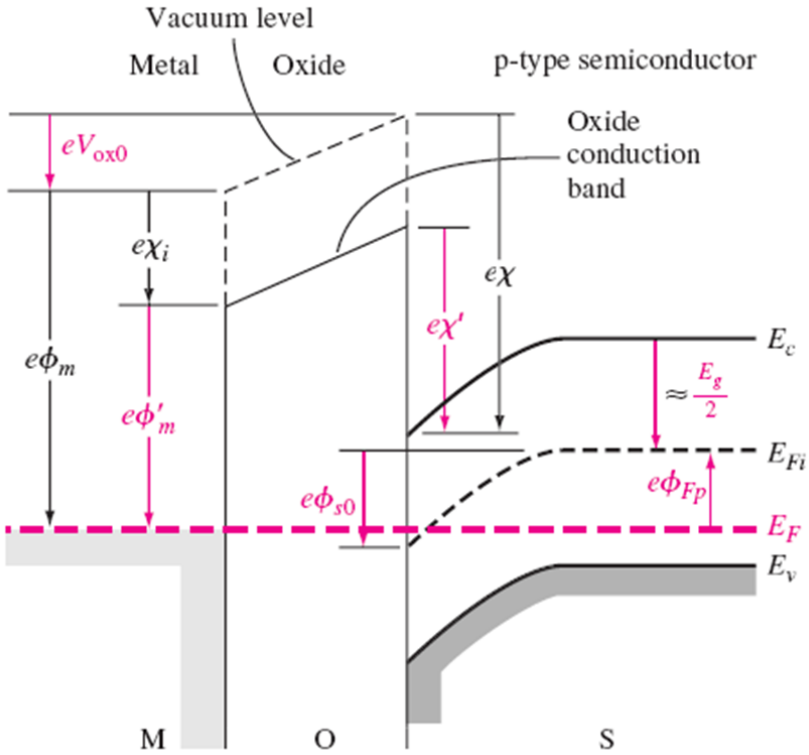
$$x_{dT} = \left[\frac{2\epsilon_s 2|\phi_{Fp}|}{e}\frac{1}{N_A}\right]^{1/2}$$

$$x_{dT} = \left[\frac{4\epsilon_s|\phi_{Fp}|}{e}\frac{1}{N_A}\right]^{1/2}$$



ϕ_m : metal To vacuum workfunction

χ : electron affinity


Vacuum level
Metal
Oxide
p-type semiconductor
Oxide
conduction
band
eV_{ox0}
$e\chi_i$
$e\chi$
$e\chi'$
$e\phi_m$
$e\phi'_m$
E_c
$\approx \frac{E_g}{2}$
E_{Fi}
$e\phi_{Fp}$
$e\phi_{s0}$
E_F
E_v
M
O
S