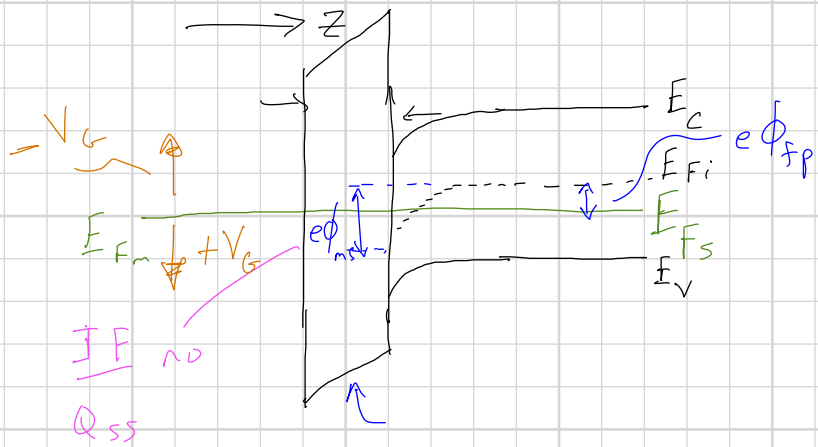
Lecture # 13

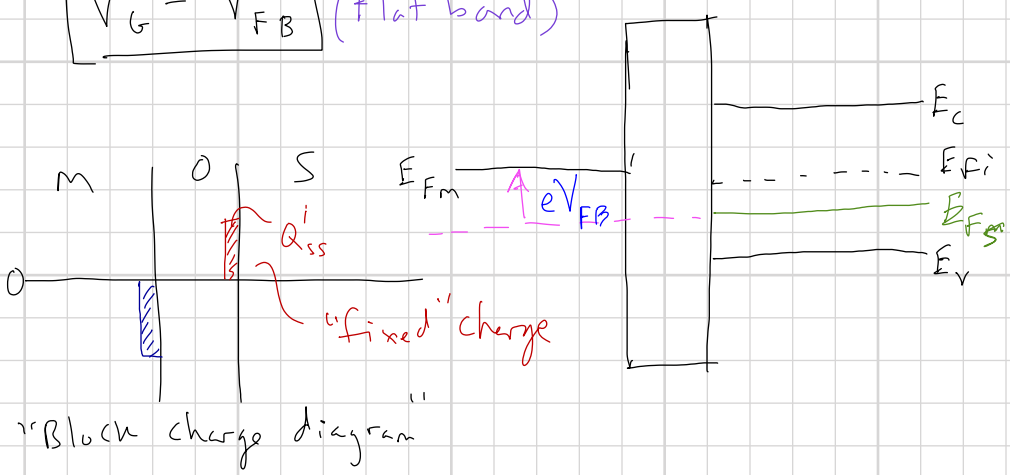
MOS Capacitor : C-V

Function of MOS-C (p-type)

$V_G = 0$ V

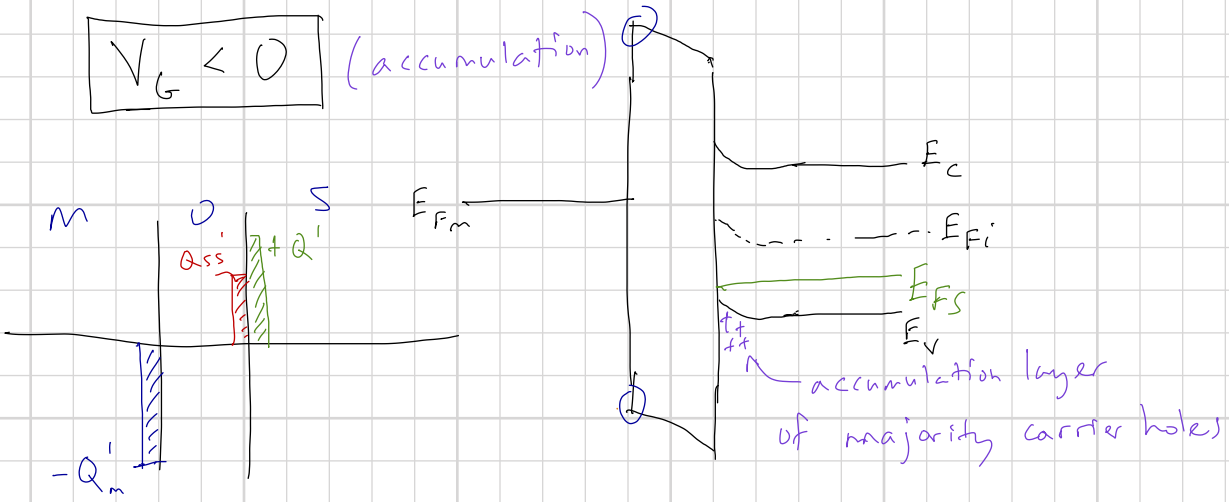


$V_G = V_{FB}$ (flat band)

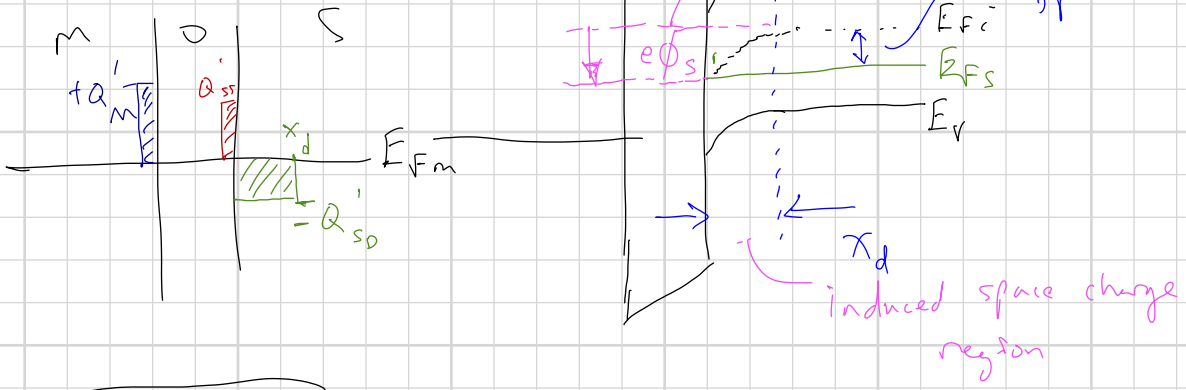


"Block charge diagram"

$V_G < 0$ (accumulation)



$V_G > 0$ (depletion)



$V_G = V_T$ (threshold inversion)

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p-type

$$\phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right)$$

n-type

$$\phi_{fn} = V_t \ln\left(\frac{N_d}{n_i}\right)$$

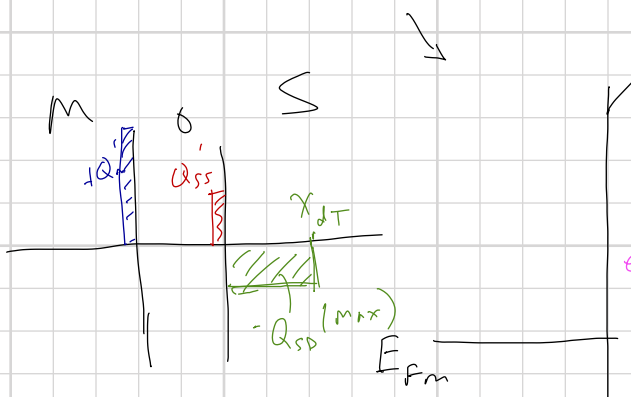
true for all bias conditions

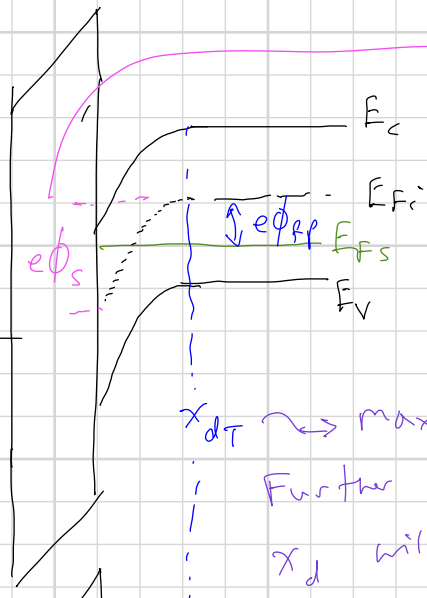
$$V_{FB} = \phi_{ms} - \frac{Q'_{ss}}{C_{ox}} \rightarrow \text{" "}$$

$$\hookrightarrow \phi_{ms} = \phi'_m - \left(\chi' + \frac{E_G}{2e} - \phi_f\right)$$

$$x_d = \left(\frac{2\epsilon_s \epsilon_0 \phi_s}{e N_a}\right)^{1/2} \qquad x_d = \left(\frac{2\epsilon_s \epsilon_0 \phi_s}{e N_d}\right)^{1/2}$$

$$e\phi_s = E_{Fi}\Big|_{bulk} - E_{Fi}\Big|_{surface}$$





@ V_T, $e\phi_s = 2e\phi_{fp}$

$$x_{dT} = \left(\frac{4\epsilon_s\epsilon_o\phi_{fp}}{eN_a}\right)^{1/2}$$

$$|Q'_{SD(max)}| = eN_a x_{dT}$$

$$x_{dT} = \left(\frac{4\epsilon_s\epsilon_o\phi_{fn}}{eN_d}\right)^{1/2}$$

$$|Q'_{SD(max)}| = eN_d x_{dT}$$

x_{dT} ↔ max. induced space charge region,

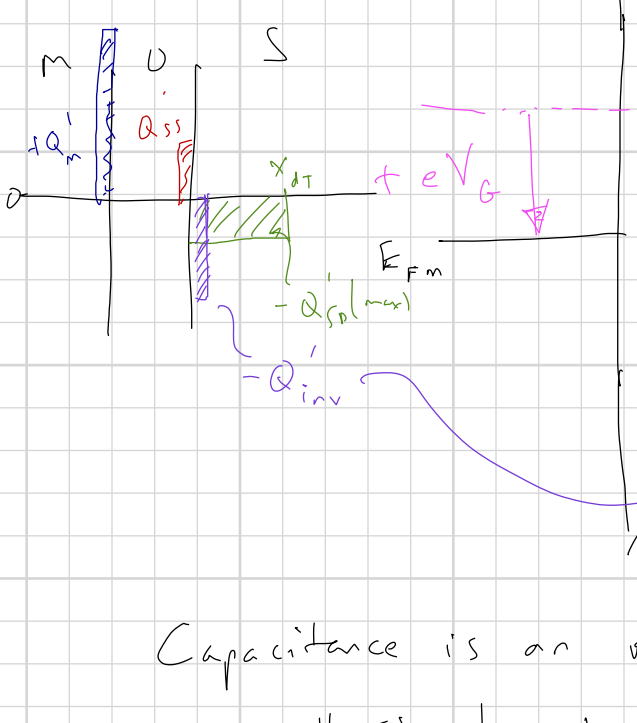
Further ↑ V_G will cause $e\phi_s$ ↑ but x_d will remain x_{dT}

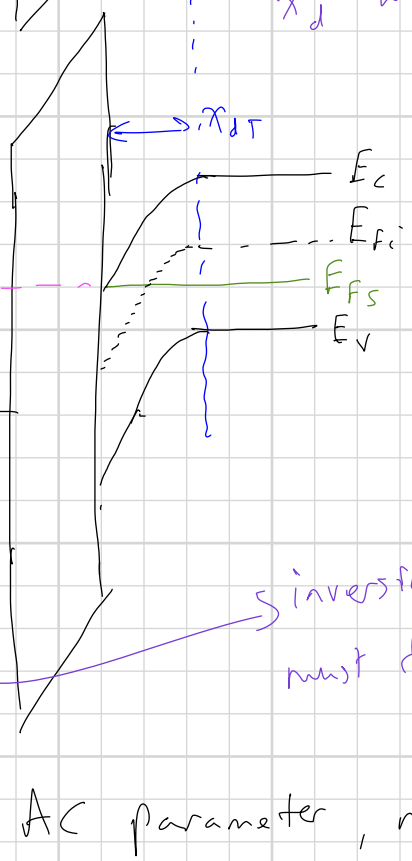
$$C_{ox} = \frac{\epsilon_{ox}\epsilon_o}{t_{ox}}$$

$$V_{TN} = \frac{|Q'_{SD(max)}|}{C_{ox}} - \frac{Q'_{ss}}{C_{ox}} + \phi_{ms} + 2\phi_{fp} + V_{FB}$$

$$V_{TP} = \left(-|Q'_{SD(max)}| - Q'_{ss}\right)\frac{t_{ox}}{\epsilon_{ox}\epsilon_o} + \phi_{ms} - 2\phi_{fn}$$

$V_G > V_T$ (inversion)





Inversion layer charge must form to balance overall charge!

Capacitance is an AC parameter, not DC, thus is measured by adding a small-signal onto an applied DC signal

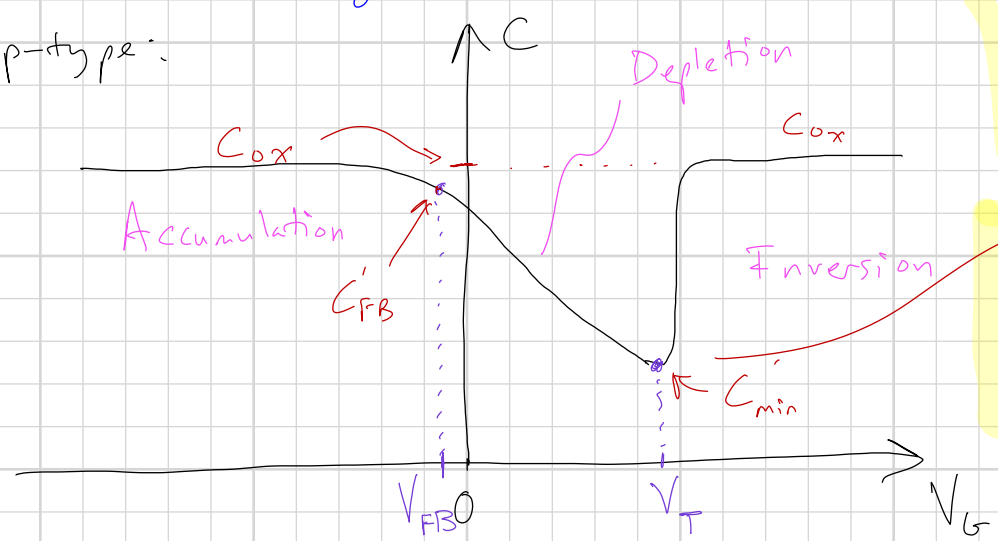
$$C = \frac{dQ}{dV}$$ — change in charge; " " voltage

Ideal C-V

→ No oxide trapped charges and no interface states (at oxide-S.C. interface)

→ low frequency AC signal

Ex: p-type:



Flat-Band Cap.

$$C'_{FB} = \frac{\epsilon_{ox}\epsilon_o}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)\sqrt{V_t\left(\frac{\epsilon_s\epsilon_o}{eN_a}\right)}}$$

when $x_d = x_{dT}$ ($V_G = V_T$)

$$C'_{min} = \frac{\epsilon_{ox}\epsilon_o}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)x_{dT}}$$