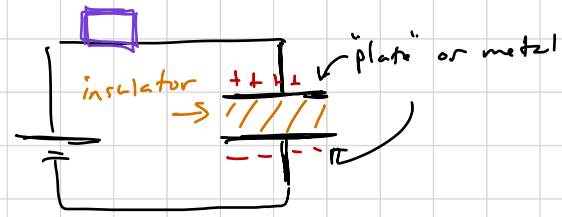
Lecture #13 — MOS Capacitor Characteristics

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

$$C = \frac{dQ}{dV}$$
dQ ~ change in charge
dV ~ change in voltage

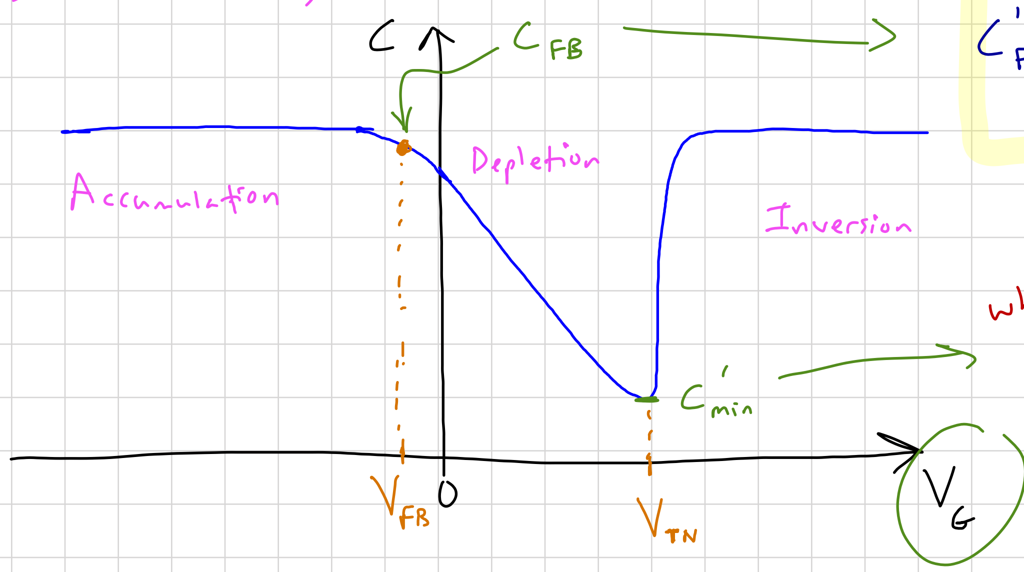


Ideal C-V

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

→ Low-frequency AC signal

(example using p-type MOS-C)



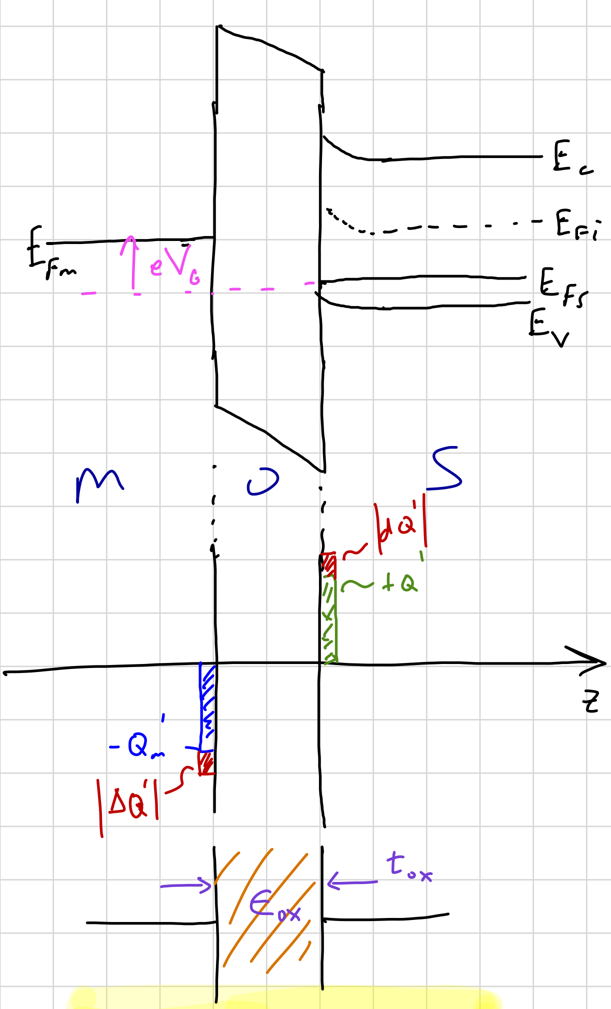
Flat Band Capacitance:

$$C'_{FB} = \frac{\epsilon_{ox}\epsilon_0}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)\sqrt{V_t\left(\frac{\epsilon_s \epsilon_0}{e N_a}\right)}}$$

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

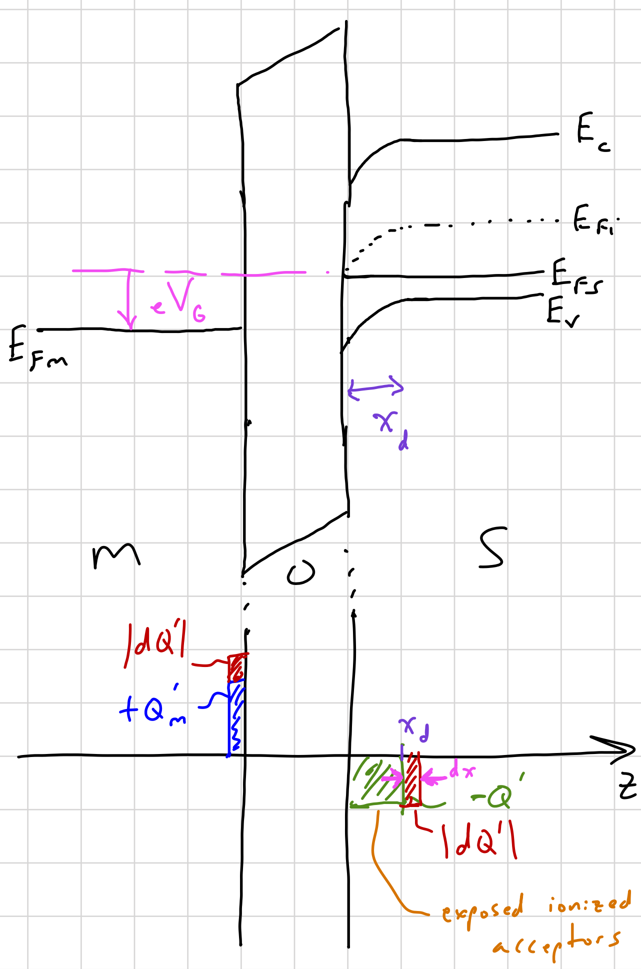
$$C'_{min} = \frac{\epsilon_{ox}\epsilon_0}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)x_{dT}}$$

Accumulation



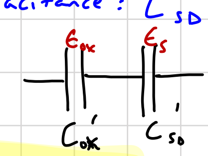
$$C'(acc) = C_{ox} = \frac{\epsilon_{ox}\epsilon_0}{t_{ox}}$$

Depletion



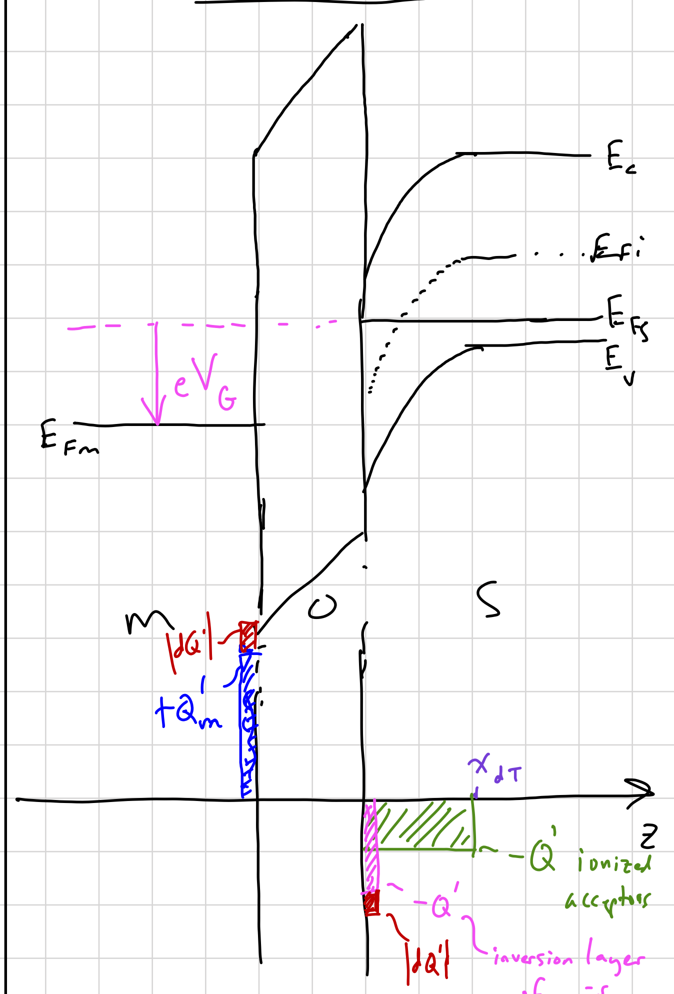
→ Because x_d will vary with dV_G, there is an additional capacitance: C_{SD}

$$\Rightarrow C'_{SD} = \frac{\epsilon_s \epsilon_0}{x_d}$$



$$C'(depl) = \frac{C'_{SD}C'_{ox}}{C'_{ox}+C'_{SD}} = \frac{\epsilon_{ox}\epsilon_0}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)x_d}$$

Inversion

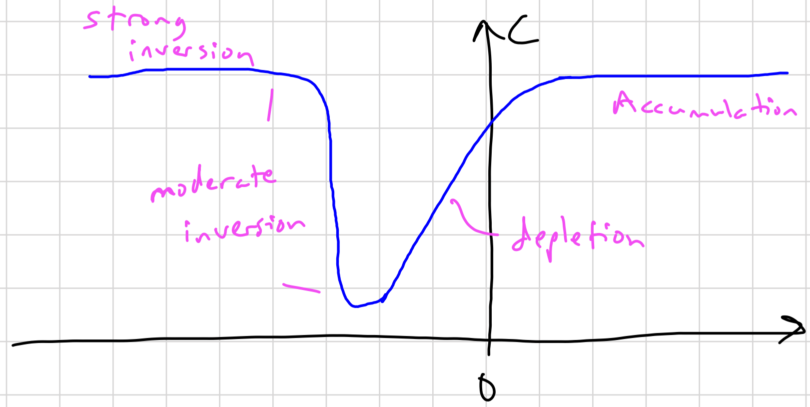


→ At low freq., the minority carriers are able to respond to dV_G by increase/decrease in inversion layer:

$$C'(inv) = C_{ox} = \frac{\epsilon_{ox}\epsilon_0}{t_{ox}}$$

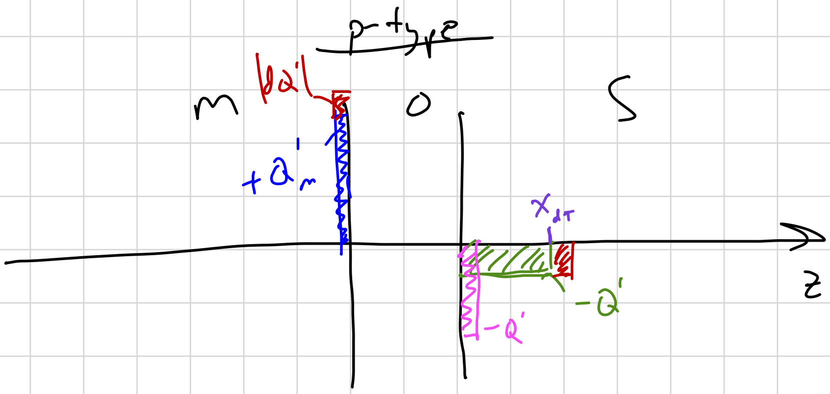
★ at low frequency (~5-100 Hz)

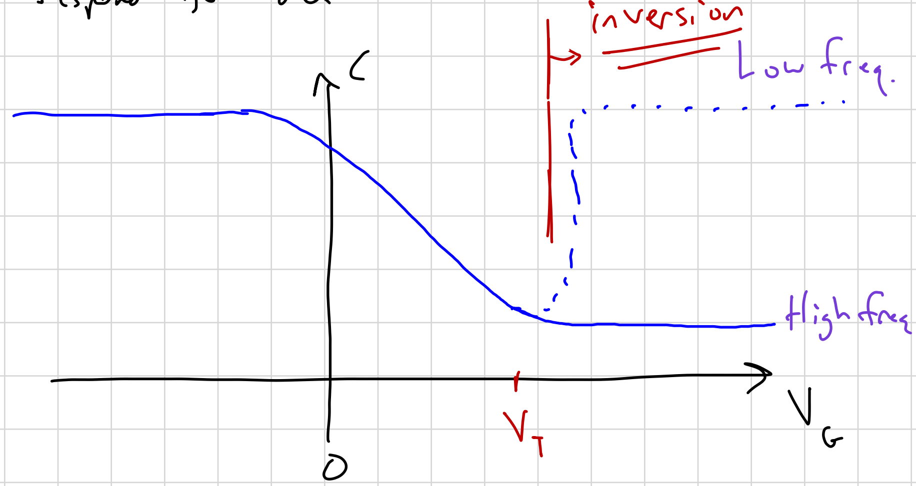
- What about n-type, ideal MOS?



- Frequency Effects

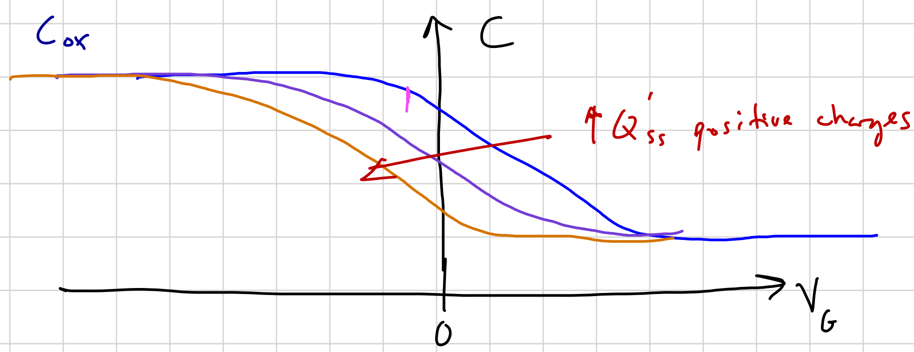
→ operation at high freq (> 1 MHz) does not allow sufficient time for minority carrier diffusion, hence x_d goes beyond x_{dT} to respond to dQ'





Fixed/Trapped oxide charges

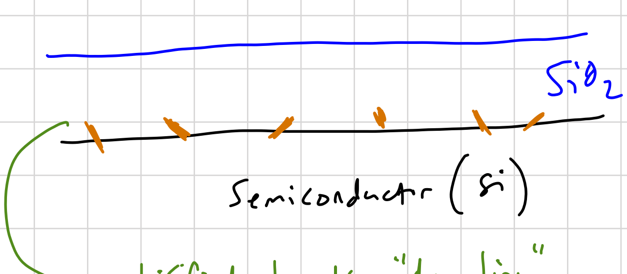
Consider: $V_{FB} = \phi_{ms} - \frac{Q'_{ss}}{C_{ox}}$ → V_{FB} will shift more negative with positive fixed charge and vice versa



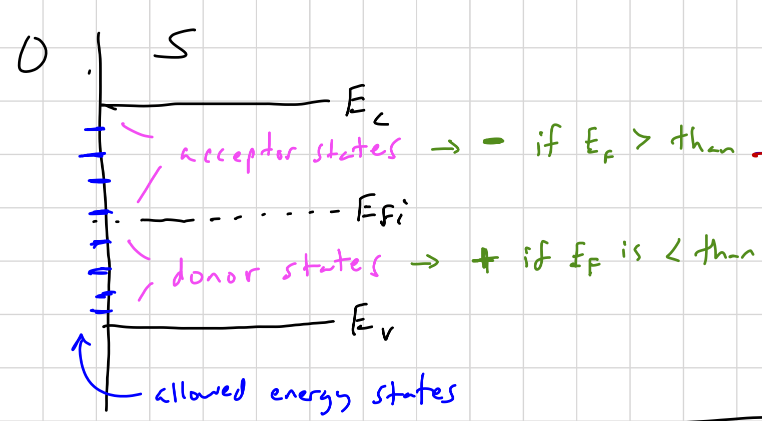
Interface traps/states at oxide-S.C.

→ much trickier than fixed charge because they will fill and empty of charge either + or − depending on bias conditions and even sweep direction:

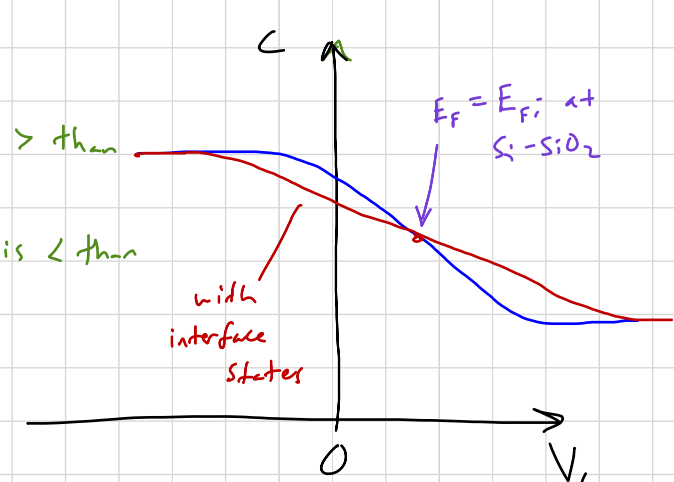
Physically:



Energy Space:



C-V:



⟹ "Smears" out the C-V