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p type metal-oxide-semiconductor (MOS) capacitor

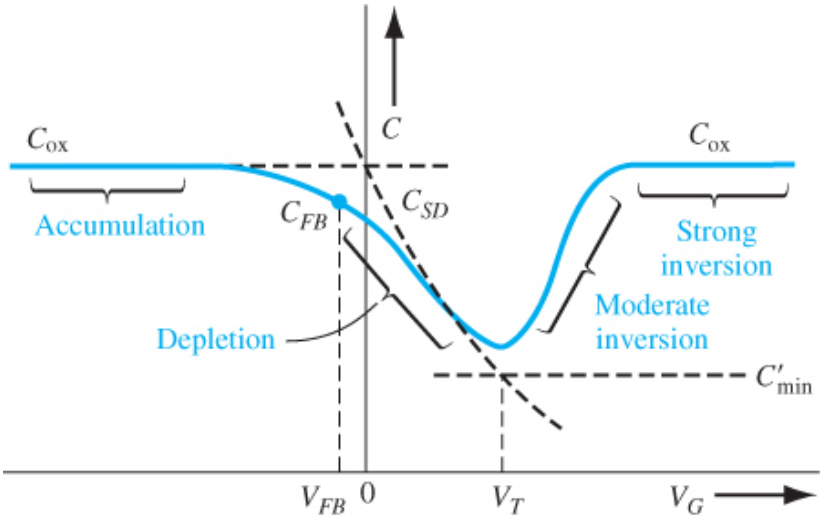

Figure 10.26 | Ideal low-frequency capacitance versus gate voltage of a MOS capacitor with a p-type substrate. Individual capacitance components are also shown.

- The capacitance goes through different modes, i.e., accumulation, depletion, moderate inversion, & strong inversion, as the gate voltage V_G **increases**.

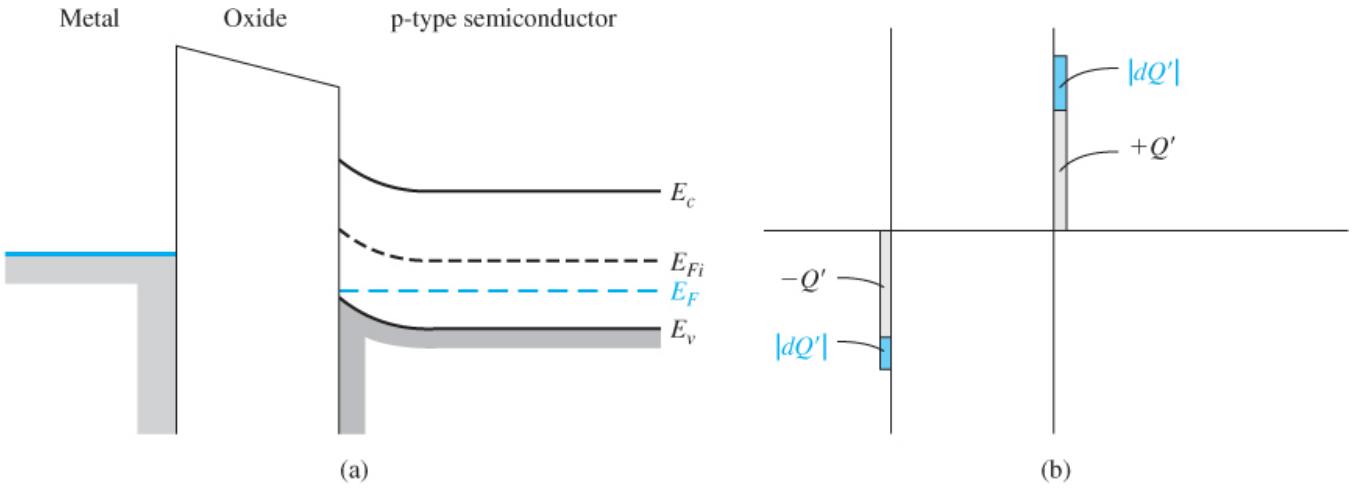

Figure 10.23 | (a) Energy-band diagram through a MOS capacitor for the accumulation mode. (b) Differential charge distribution at accumulation for a differential change in gate voltage.

- Accumulation mode ($V_G < 0$)
- Acts like parallel-plate capacitor, capacitance is constant $C_{ox} = \varepsilon_{ox} / t_{ox}$ (F/m^2 or F/cm^2)

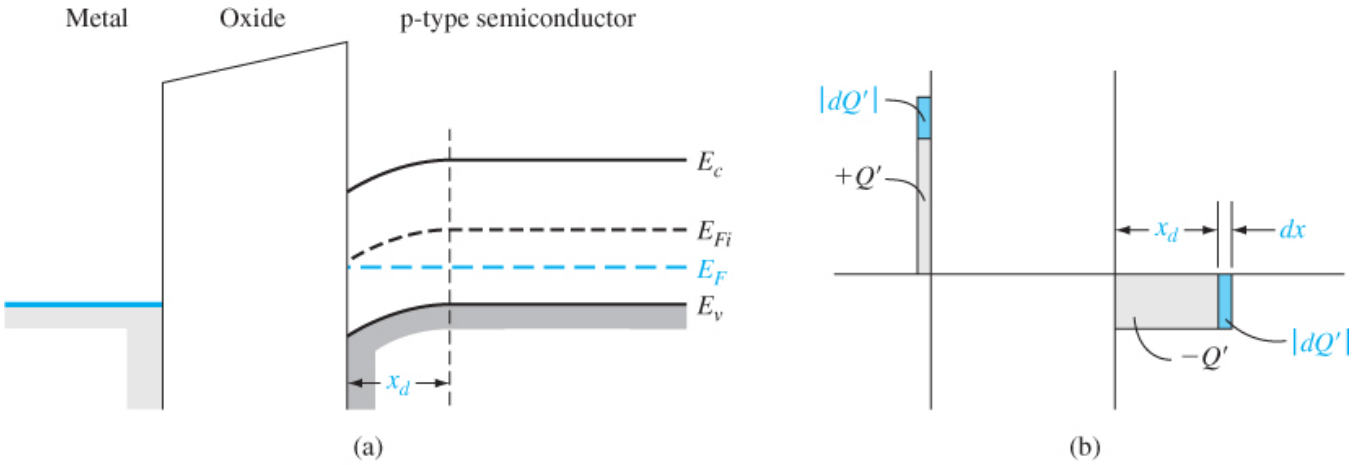

Figure 10.24 | (a) Energy-band diagram through a MOS capacitor for the depletion mode. (b) Differential charge distribution at depletion for a differential change in gate voltage.

- Depletion mode (V_G transitions from negative to positive, and depletion layer depth/thickness x_d climbs toward x_{dT})
- Capacitance is a combination of that from oxide and that from depletion layer charges $\dfrac{1}{C'(\text{depl})} = \dfrac{1}{C_{ox}} + \dfrac{1}{C_{SD}'}$ or $C'(\text{depl}) = \dfrac{\varepsilon_{ox}}{t_{ox} + \left(\dfrac{\varepsilon_{ox}}{\varepsilon_s}\right) x_d}$.
- At flat band, when $V_G = V_{FB}$, $C'_{FB} = \dfrac{\varepsilon_{ox}}{t_{ox} + \left(\dfrac{\varepsilon_{ox}}{\varepsilon_s}\right)\sqrt{\dfrac{k_B T}{e}\left(\dfrac{\varepsilon_s}{eN_a}\right)}}$.
- Minimum at threshold, when $V_G = V_{TG} = V_T$, $C'_{\min} = \dfrac{\varepsilon_{ox}}{t_{ox} + \left(\dfrac{\varepsilon_{ox}}{\varepsilon_s}\right) x_{dT}}$.

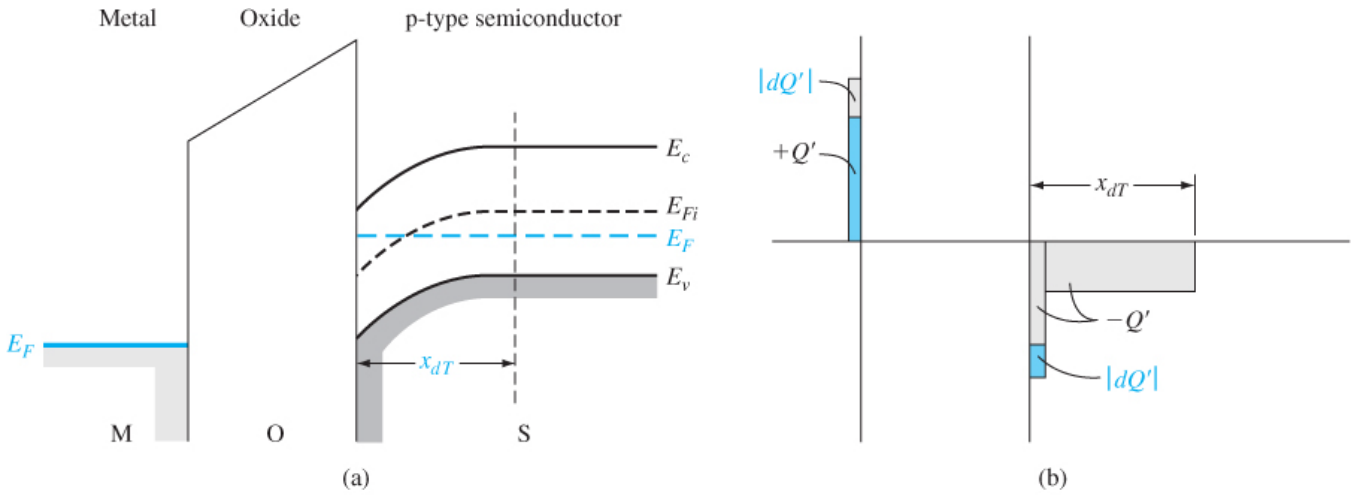

Figure 10.25 | (a) Energy-band diagram through a MOS capacitor for the inversion mode. (b) Differential charge distribution at inversion for a low-frequency differential change in gate voltage.

- Moderate and strong inversion modes ($V_G > V_T$ and inversion layer depth/thickness is x_{dT})
- For moderate inversion capacitance begins rising toward a constant value of $C'(\text{inv}) = C_{ox} = \varepsilon_{ox} / t_{ox}$ (F/m^2 or F/cm^2) where it begins acting like parallel-plate capacitor again.

n type metal-oxide-semiconductor (MOS) capacitor

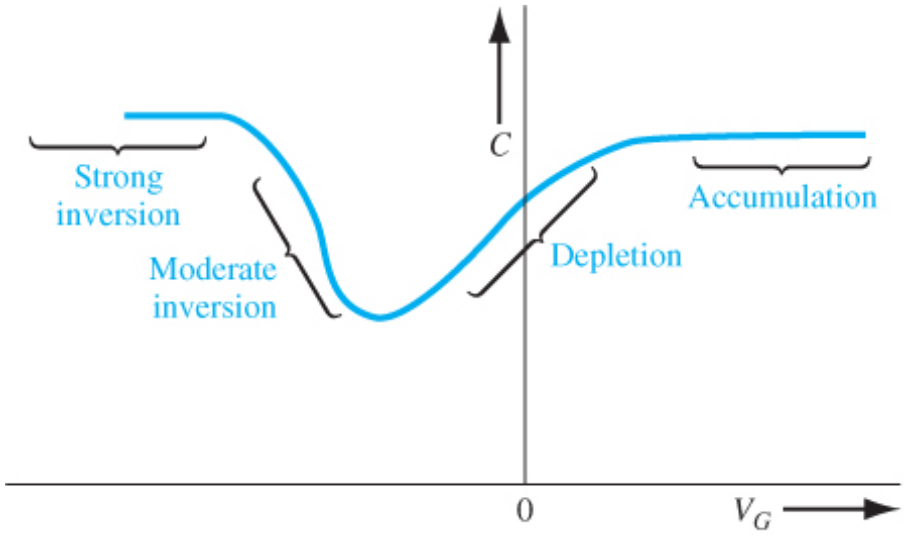

Figure 10.27 | Ideal low-frequency capacitance versus gate voltage of a MOS capacitor with an n-type substrate.

- The capacitance goes through different modes, i.e., accumulation, depletion, moderate inversion, & strong inversion, as the gate voltage **decreases**.