

MOS CAPACITANCE

ACCUMULATION:

$$C_{OX} = \frac{\epsilon_s \epsilon_0 x}{x_{ox}}$$

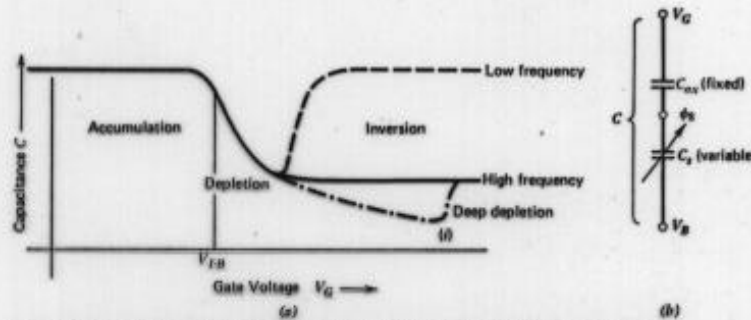
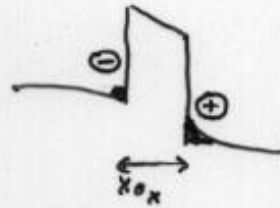
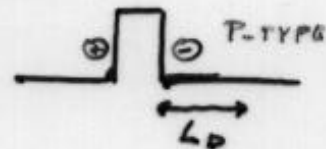
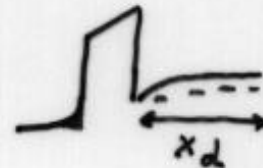


Figure 8.7 (a) Small-signal capacitance of an MOS system with p-type silicon. Low-frequency behavior: both the bias voltage and the ac measuring signal vary slowly (less than ~10 Hz). High-frequency behavior: bias voltage varies slowly, but the ac measuring signal varies rapidly (typical circuits use 1 MHz); deep-depletion behavior: both the gate bias voltage and the ac measuring signal vary rapidly. The behavior at point (f) is described in the text. (b) The equivalent circuit for the overall capacitance C is the series connection of C_{ox} (fixed) and C_s (variable) with voltages V_G , ϕ_s , and V_B at the gate, interface, and substrate, respectively.

FLAT BAND : $C_{FB} = \frac{1}{1/C_{OX} + L_D/\epsilon_s \epsilon_0}$



DEPLETION : $C_{DEPL} = \frac{1}{1/C_{OX} + x_d/\epsilon_s}$



INVERSION :

$$\begin{cases} C = \frac{1}{1/C_{OX} + x_d/\epsilon_s} & \text{HIGH FREQUENCY} \\ C = C_{OX} & \text{LOW FREQUENCY} \end{cases}$$

MOS ELECTRONICS

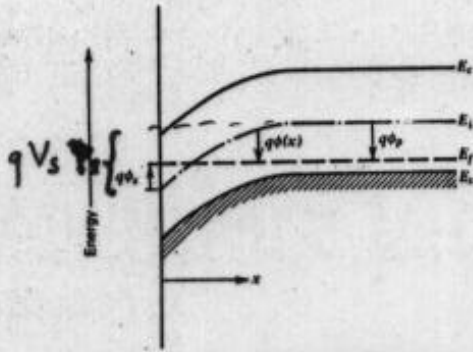


Figure 8.8 Energy-band diagram showing the potential as defined in Equation 8.3.1 in the vicinity of the silicon surface in an MOS system. The sketch corresponds to a positive value of surface potential (ϕ_s).

$$\begin{cases} \phi(x) = \frac{1}{q} [E_f - E_i(x)] \\ \phi(0) = \frac{1}{q} [E_f - E_i(0)] = \phi_s > 0 \end{cases}$$

$$\begin{cases} p = n_i \exp\left(-\frac{q\phi}{kT}\right) & (1.1.27) \\ n = n_i \exp\left(\frac{q\phi}{kT}\right) & (1.1.2c) \end{cases}$$

$$p_s = N_A = n_i \exp\left(-\frac{q\phi_p}{kT}\right)$$

$\phi_p < 0$

$$\begin{cases} p_s = N_A \exp\left[\frac{q(\phi_p - \phi_s)}{kT}\right] \\ n_s = \frac{n_i^2}{N_A} \exp\left[\frac{q(\phi_s - \phi_p)}{kT}\right] \end{cases}$$

ONSET OF STRONG INVERSION: $\phi_s = -\phi_p$ $n_s = N_A$

$$= \frac{q N_A x_{dmax}^2}{2\epsilon_s \epsilon_0} + \phi_p \Rightarrow x_{dmax} = \left[\frac{4\epsilon_s \epsilon_0 |\phi_p|}{q N_A} \right]^{1/2}$$

V_s

Table 8.1 MOS Surface-Charge Conditions for p-type Silicon

$(V_G - V_{FB})$	ϕ_s	Surface Charge Condition	Surface Carrier Density
Negative	Negative $ \phi_s > \phi_p $	Accumulation	$p_s > N_A$
0	Negative $\phi_s = \phi_p$	Neutral (Flat-band)	$p_s = N_A$
Positive (small)	Negative $ \phi_s < \phi_p $	Depletion	$n_s < p_s < N_A$
Positive (larger)	0	Intrinsic	$p_s = n_s = n_i$
Positive (larger)	Positive $ \phi_s < \phi_p $	Weak inversion	$n_s < p_s < N_A$
Positive (larger)	Positive $\phi_s = -\phi_p$	Onset of strong inversion	$n_s = N_A$
Positive (larger)	Positive $ \phi_s > \phi_p $	Strong inversion	$n_s > N_A$

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Positive (larger)	0	Intrinsic	$p_s = n_s = n_i$
Positive (larger)	Positive $ \phi_s < \phi_p $	Weak inversion	$n_i < n_s < N_a$
Positive (larger)	Positive $\phi_s = -\phi_p$	Onset of strong inversion	$n_s = N_a$
Positive (larger)	Positive $ \phi_s > \phi_p $	Strong inversion	$n_s > N_a$