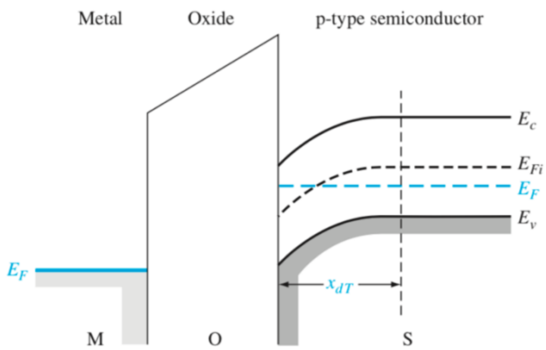
1.

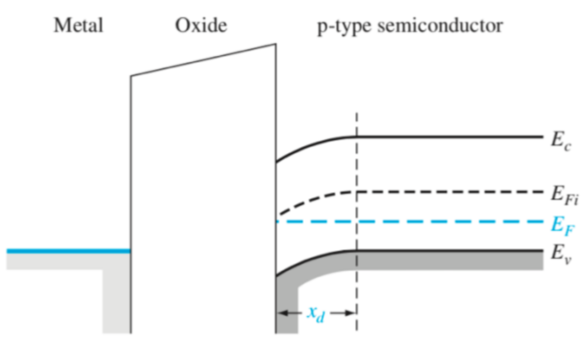
(a) p-type; inversion
(b) p-type; depletion
(c) p-type; accumulation
(d) n-type; inversion

(a)

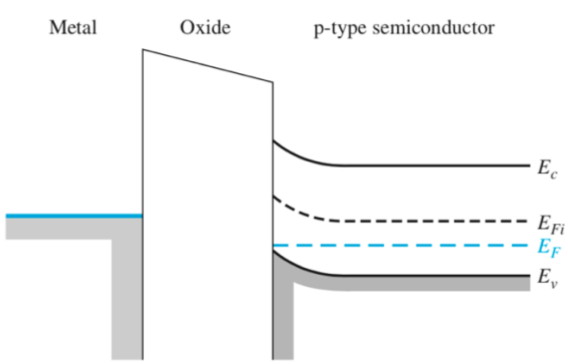


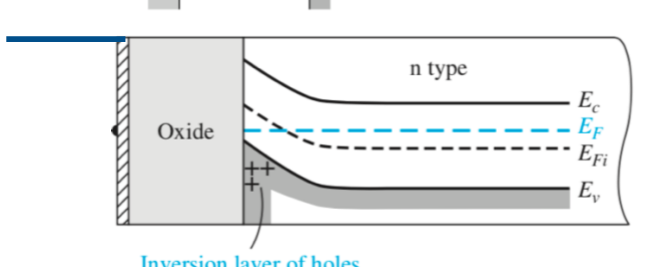
(a)

(b)



(c)





(d) Metal

2.

(a) $\phi_{ms} \cong -0.42\text{ V}$

$V_{FB} = \phi_{ms} = -0.42\text{ V}$

(b)

$$C_{ox} = \frac{(3.9)(8.85\times 10^{-14})}{200\times 10^{-8}} = 1.726\times 10^{-7}\text{ F/cm}^2$$

$$\text{(i) } \Delta V_{FB} = -\frac{Q'_{ss}}{C_{ox}} = -\frac{(4\times 10^{10})(1.6\times 10^{-19})}{1.726\times 10^{-7}}$$

$$= -0.0371\text{ V}$$

$$\text{(ii) } \Delta V_{FB} = -\frac{(10^{11})(1.6\times 10^{-19})}{1.726\times 10^{-7}}$$

$$= -0.0927\text{ V}$$

(c) $V_{FB} = \phi_{ms} = -0.42\text{ V}$

$$C_{ox} = \frac{(3.9)(8.85\times 10^{-14})}{120\times 10^{-8}} = 2.876\times 10^{-7}\text{ F/cm}^2$$

$$\text{(i) } \Delta V_{FB} = -\frac{(4\times 10^{10})(1.6\times 10^{-19})}{2.876\times 10^{-7}}$$

$$= -0.0223\text{ V}$$

$$\text{(ii) } \Delta V_{FB} = -\frac{(10^{11})(1.6\times 10^{-19})}{2.876\times 10^{-7}}$$

$$= -0.0556\text{ V}$$

3.

$$C_{ox} = \frac{\in_{ox}}{t_{ox}} = \frac{(3.9)(8.85\times10^{-14})}{220\times10^{-8}}$$

$$= 1.569\times10^{-7}\ \text{F/cm}^2$$

$$Q'_{ss} = (1.6\times10^{-19})(4\times10^{10})$$

$$= 6.4\times10^{-9}\ \text{C/cm}^2$$

By trial and error, let $N_a = 4\times10^{16}\ \text{cm}^{-3}$.

Now

$$\phi_{fp} = (0.0259)\ln\left(\frac{4\times10^{16}}{1.5\times10^{10}}\right)$$

$$= 0.3832\ \text{V}$$

$$x_{dT} = \left[\frac{4(11.7)(8.85\times10^{-14})(0.3832)}{(1.6\times10^{-19})(4\times10^{16})}\right]^{1/2}$$

$$= 1.575\times10^{-5}\ \text{cm}$$

$$|Q'_{SD}(\max)|$$

$$= (1.6\times10^{-19})(4\times10^{16})(1.575\times10^{-5})$$

$$= 1.008\times10^{-7}\ \text{C/cm}^2$$

$$\phi_{ms} \cong -0.94\ \text{V}$$

Then

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

$$= \frac{1.008\times10^{-7} - 6.4\times10^{-9}}{1.569\times10^{-7}} - 0.94 + 2(0.3832)$$

Then $V_{TN} = 0.428\ \text{V} \cong 0.45\ \text{V}$

4.

(a) $\phi_{ms} \cong -1.03\text{ V}$

$$C_{ox} = \frac{(3.9)(8.85\times10^{-14})}{180\times10^{-8}}$$

$$= 1.9175\times10^{-7}\text{ F/cm}^2$$

Now

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

$$= -1.03 - \frac{(1.6\times10^{-19})(6\times10^{10})}{1.9175\times10^{-7}}$$

$$V_{FB} = -1.08\text{ V}$$

(b) $\phi_{fp} = (0.0259)\ln\left(\dfrac{10^{15}}{1.5\times10^{10}}\right)$

$$= 0.2877\text{ V}$$

$$x_{dT} = \left[\frac{4(11.7)(8.85\times10^{-14})(0.2877)}{(1.6\times10^{-19})(10^{15})}\right]^{1/2}$$

$$= 8.630\times10^{-5}\text{ cm}$$

$|Q'_{SD}(\max)|$

$$= (1.6\times10^{-19})(10^{15})(8.630\times10^{-5})$$

$$= 1.381\times10^{-8}\text{ C/cm}^2$$

Now

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

$$= \frac{1.381\times10^{-8}}{1.9175\times10^{-7}} - 1.08 + 2(0.2877)$$

or $V_{TN} = -0.433\text{ V}$

5.

(a) n-type

(b) We have

$$C_{ox} = \frac{200\times10^{-12}}{2\times10^{-3}} = 1\times10^{-7}\ \text{F/cm}^2$$

Also

$$C_{ox} = \frac{\in_{ox}}{t_{ox}} \Rightarrow t_{ox} = \frac{\in_{ox}}{C_{ox}} = \frac{(3.9)(8.85\times10^{-14})}{1\times10^{-7}}$$

or

$$t_{ox} = 3.45\times10^{-6}\ \text{cm} = 34.5\ \text{nm} = 345\ \overset{o}{A}$$

(c)

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

or

$$-0.80 = -0.50 - \frac{Q'_{ss}}{10^{-7}}$$

which yields

$$Q'_{ss} = 3\times10^{-8}\ \ \text{C/cm}^2 = 1.875\times10^{11}\ \text{cm}^{-2}$$

(d)

$$C'_{FB} = \frac{\in_{ox}}{t_{ox} + \left(\frac{\in_{ox}}{\in_s}\right)\sqrt{\left(\frac{kT}{e}\right)\left(\frac{\in_s}{eN_d}\right)}}$$

$$= \left[(3.9)(8.85\times10^{-14})\right] \div \Bigg[3.45\times10^{-6} + \left(\frac{3.9}{11.7}\right)\sqrt{\frac{(0.0259)(11.7)(8.85\times10^{-14})}{(1.6\times10^{-19})(2\times10^{16})}}\Bigg]$$

which yields

$$C'_{FB} = 7.82\times10^{-8}\ \ \text{F/cm}^2$$

or

$$C_{FB} = 156\ \text{pF}$$