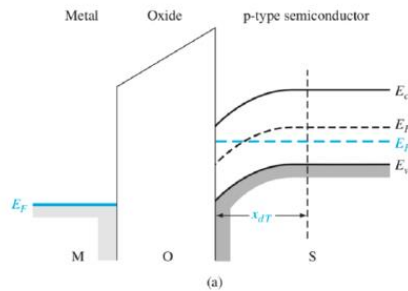


VE320 HW8 Solution

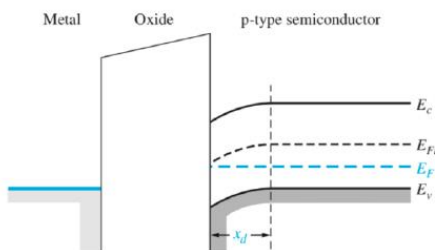
1.

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

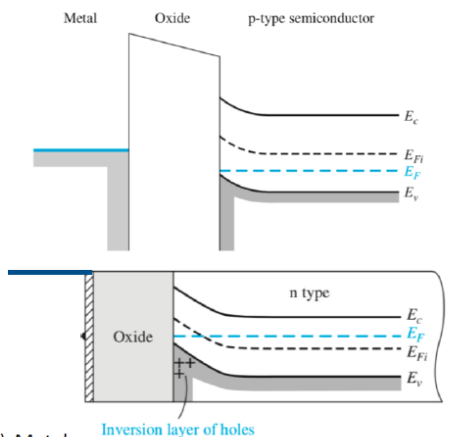
(a)



(b)



(c)



(d) Metal

2.

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

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

(b)

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

$$(i) \Delta V_{FB} = -\frac{Q'_{ss}}{C_{ox}} = -\frac{(4 \times 10^{10})(1.6 \times 10^{-19})}{1.726 \times 10^{-7}} = -0.0371 \text{ V}$$

$$(ii) \Delta V_{FB} = -\frac{(10^{11})(1.6 \times 10^{-19})}{1.726 \times 10^{-7}} = -0.0927 \text{ V}$$

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

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

$$(i) \Delta V_{FB} = -\frac{(4 \times 10^{10})(1.6 \times 10^{-19})}{2.876 \times 10^{-7}} = -0.0223 \text{ V}$$

$$(ii) \Delta V_{FB} = -\frac{(10^{11})(1.6 \times 10^{-19})}{2.876 \times 10^{-7}} = -0.0556 \text{ V}$$

3.

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{(3.9)(8.85 \times 10^{-14})}{220 \times 10^{-8}}$$

$$= 1.569 \times 10^{-7} \text{ F/cm}^2$$

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

$$= 6.4 \times 10^{-9} \text{ C/cm}^2$$

By trial and error, let $N_a = 4 \times 10^{16} \text{ cm}^{-3}$.

Now

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

$$= 0.3832 \text{ V}$$

$$x_{dT} = \left[\frac{4(11.7)(8.85 \times 10^{-14})(0.3832)}{(1.6 \times 10^{-19})(4 \times 10^{16})} \right]^{1/2}$$

$$= 1.575 \times 10^{-5} \text{ cm}$$

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

$$= (1.6 \times 10^{-19})(4 \times 10^{16})(1.575 \times 10^{-5})$$

$$= 1.008 \times 10^{-7} \text{ C/cm}^2$$

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

Then

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

$$= \frac{1.008 \times 10^{-7} - 6.4 \times 10^{-9}}{1.569 \times 10^{-7}}$$

$$= -0.94 + 2(0.3832)$$

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

4.

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

$$C_{ox} = \frac{(3.9)(8.85 \times 10^{-14})}{180 \times 10^{-8}}$$

$$= 1.9175 \times 10^{-7} \text{ F/cm}^2$$

Now

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

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

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

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

$$= 0.2877 \text{ V}$$

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

$$= 8.630 \times 10^{-5} \text{ cm}$$

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

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

$$= 1.381 \times 10^{-8} \text{ C/cm}^2$$

Now

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

$$= \frac{1.381 \times 10^{-8}}{1.9175 \times 10^{-7}} - 1.08 + 2(0.2877)$$

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

5.

(a) n-type

(b) We have

$$C_{ox} = \frac{200 \times 10^{-12}}{2 \times 10^{-3}} = 1 \times 10^{-7} \text{ F/cm}^2$$

Also

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} \Rightarrow t_{ox} = \frac{\epsilon_{ox}}{C_{ox}} = \frac{(3.9)(8.85 \times 10^{-14})}{1 \times 10^{-7}}$$

or

$$t_{ox} = 3.45 \times 10^{-6} \text{ cm} = 34.5 \text{ nm} = 345 \text{ \AA}$$

(c)

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

or

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

which yields

$$Q'_{ss} = 3 \times 10^{-8} \text{ C/cm}^2 = 1.875 \times 10^{11} \text{ cm}^{-2}$$

(d)

$$\begin{aligned} C'_{FB} &= \frac{\epsilon_{ox}}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s} \right) \sqrt{\left(\frac{kT}{e} \right) \left(\frac{\epsilon_s}{eN_d} \right)}} \\ &= \left[(3.9)(8.85 \times 10^{-14}) \right] + \left[3.45 \times 10^{-6} \right. \\ &\quad \left. + \left(\frac{3.9}{11.7} \right) \sqrt{\frac{(0.0259)(11.7)(8.85 \times 10^{-14})}{(1.6 \times 10^{-19})(2 \times 10^{16})}} \right] \end{aligned}$$

which yields

$$C'_{FB} = 7.82 \times 10^{-8} \text{ F/cm}^2$$

or

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