SLOT : E2 + TE 2

1) Given,

Junction area is $5 \times 10^{-4}\ cm^{-2}$

For Schottky, Reverse Saturation Current density is $3 \times 10^{-8}\ A/cm^2$

For P-N, Reverse Saturation Current density is $3 \times 10^{-12}\ A/cm^2$.

Temperature is 300K.

Current density for Schottky diode is

$$J = J_{AT}\left[\exp\left(\frac{e \times V_f}{KT}\right) - 1\right] \text{ and}$$

$$V_f = \left(\frac{KT}{e}\right) \ln\left(\frac{J}{J_{AT}}\right)$$

But $J = \dfrac{\text{Current}}{\text{Area}} = \dfrac{1 \times 10^{-3}}{5 \times 10^{-4}} = 2\ A/cm^2$.

At room temperature i.e, $T = 300K$, $\frac{KT}{e}$ is $0.0259\ V$.

So, $V_f = (0.0259) \cdot \ln\left(\dfrac{2}{3 \times 10^{-8}}\right) = 0.4667\ V$. for Schottky.

and $V_{f\ p\text{-}n\ diode} = (0.0259) \cdot \ln\left(\dfrac{2}{3 \times 10^{-12}}\right) = 0.7051\ V$.

2)

Given,

$e\phi_m = 4.92\ eV$

$e\chi_s = 3.51\ eV$

$N_c = N_v = 10^{19}\ m^{-3}$ and $N_D = 3\times10^{16}\ cm^{-3}$

and $E_g = 1eV$ $T = 300K$ (Room Temperature)

<u>Barrier Height</u> : $(e\phi_b)$

$e\phi_b = e\phi_m - e\chi_s \Rightarrow 4.92 - 3.51\ eV = 1.41\ eV$.

<u>Built in Potential</u> (V_{bi})

$E_F = E_c - k_B \cdot T \cdot \ln\left(\frac{N_c}{N_D}\right)$ $\left[\because E_c - E_F = e\phi_n\right]$

$\Rightarrow E_c - E_F = k_B T \ln\left(\frac{N_c}{N_D}\right) = e\phi_n$

So, $e\phi_n = 1.38\times10^{-23} \times 300 \times \ln\left(\frac{10^{19}}{3\times10^{16}}\right)$

$= 0.2096\ eV$.

$\therefore V_{bi} = \frac{e\phi_b - e\phi_n}{e} = \frac{1.41 - 0.2096}{e} \approx 1.2\ V$.

3) (a) Surface Potential : (ϕ_s)

Surface potential is the band bending in the Semi Conductor. It is the measure of Surface departure from the state of electrical neutrality which reflected in the energy band bending at the Semi Conductor.

Since the bands bend up, the Surface potential is -ve.

and $\phi_s = -0.24$ eV.

(b) Gate Voltage (V_g)

The gate voltage is the difference btw the fermi level in the metal and fermi level in SemiConductor. Hence, the in metal the fermi level is higher than in Semi Conductor the gate voltage will be negative.

So, $V_G = -0.96$ eV.

(c) Voltage across oxide ($\Delta\phi_{ox}$)

Voltage add up according to kirchoff's law.

$V_G = \Delta\phi_{ox} + \phi_s \Rightarrow \Delta\phi_{ox} = V_G - \phi_s = -0.96 - (-0.24)$

$\Rightarrow \Delta\phi_{ox} = 0.72$ eV.

$\Delta\phi_{ox} = \phi_{ox}(x = x_0) - \phi_{ox}(x = 0)$

It's negative because the potential is more negative at the top of the oxide than at the oxide Si interface.

ⓓ <u>Doping density</u> : (N_D)

We determine the Carrier density in the bulk, which we assume is equal to doping density.

From,

$$n_0 = n_i e^{(E_F - E_i)/K_B T} = N_D.$$

$$= 10^{10} \times e^{0.437/0.026} = 1.99 \times 10^{17}\ cm^{-3}.$$

ⓔ Width of depletion region (w)

$$W = \left[\frac{2 k_s \varepsilon_0}{e N_D} (-\phi_s) \right]^{1/2}$$

We know the surface potential from the fig.

and we have just determined the doping density, so.

$$W = \sqrt{\left[\frac{2 \times 11.8 \times 8.854 \times 10^{-14}}{1.6 \times 10^{-19} \times 1.99 \times 10^{17}} \times 0.24 \right]} = 3.97 \times 10^{-6}\ cm$$

So, $w = 3.97 \times 10^{-6}$ cm.

4) Given,

$L = 0.8\ \mu m$, $t_{ox} = 15\ nm$, $V_T = 0.7V$, $\mu_n = 550\ cm^2/V\text{-}s$

a) $$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.45 \times 10^{-11}}{15 \times 10^{-9}} = 2.3 \times 10^{-3}\ F/m^2.$$

$$k_n' = \mu_n C_{ox} = 550 \times 2.3 \times 10^{8} \times 10^{-15} \ (F/V\text{-}s)$$

$$= 1265 \times 10^{-7} = 126.5\ \mu A/V^2$$

1)

$W = 16\ \mu m$, $I_d = 100\ \mu A$

To find V_{GS} & $V_{DS(sat)}$

$$I_d = \frac{W \mu_n C_{ox}}{2L} (V_{GS} - V_T)^2$$

But $(V_{GS} - V_T)^2 = 10/127$ $\left[\because \left(\frac{100 \times 2 \times 0.8}{16 \times 127} \right) \right]$

So $V_{GS} - V_T = \sqrt{10/127} \Rightarrow V_{GS} = 0.28 + V_T$

$= 0.2 + 0.7 = 0.98$

$V_{GS} - V_{DS(sat)} = V_T$

$\Rightarrow V_{DS(sat)} = V_{GS} - V_T = 0.98 - 0.7 = 0.28$