Q4

Depletion Layer Width (W_{dep})

$$W_{dep} = x_p + x_N \quad \text{—(iii)}$$

[x_n and x_p are width of depletion layer on two sides of junction]

we know,

$$N_a x_p = N_d x_N$$

$$\Rightarrow x_p = (N_d / N_a) x_N \quad \text{— (i)}$$

or $$x_N = (N_a / N_d) x_p$$

Built in potential, $\phi_{bi} = \frac{K_B T}{q} \left[\ln \frac{N_d N_a}{n_i^2} \right]$

Or $$\phi_{bi} = \frac{q}{2\epsilon_s} (N_a x_p^2 + N_d x_n^2) \quad \text{— (ii)}$$

So, using equation (i) and (ii)

$$x_p = \left[\frac{2\epsilon_s \phi_{bi}}{q} \left(\frac{N_d}{N_a} \right) \left(\frac{1}{N_a + N_d} \right) \right]^{1/2} \quad \text{— (iv)}$$

$$x_N = \left[\frac{2\epsilon_s \phi_{bi}}{q} \left(\frac{N_a}{N_d} \right) \left(\frac{1}{N_a + N_d} \right) \right]^{1/2} \quad \text{— (v)}$$

Using eq (iii), (iv) and (v)

$$W_{dep} = \left[\frac{2\epsilon_s \phi_{bi}}{q} \left(\frac{N_a + N_d}{N_a N_d} \right) \right]^{1/2} = \left[\frac{2\epsilon_s \phi_{bi}}{q} \left(\frac{1}{N_a} + \frac{1}{N_d} \right) \right]^{1/2}$$

if $N_a \gg N_d$, as in p^+N Junction

$$W_{dep} = \left[\frac{2\epsilon_s \phi_{bi}}{q} \left(\frac{1}{N_a} + \frac{1}{N_d} \right) \right]^{1/2} \simeq \left[\frac{2\epsilon_s \phi_{bi}}{q N_d} \right]^{1/2}$$

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and

$$x_N = \left[\frac{2 \epsilon_s \phi_{bi}}{q} \left(\frac{N_a}{N_d} \right) \left(\frac{1}{N_a + N_d} \right) \right]^{1/2}$$

$$\simeq \left[\frac{2 \epsilon_s \phi_{bi}}{q} \left(\frac{N_a}{N_d} \right) \left(\frac{1}{N_a} \right) \right]^{1/2}$$

$$\Rightarrow W_{dep} \simeq x_N$$

So, $x_p = x_N \dfrac{N_d}{N_a} \approx 0$

$\therefore$ for P^+N junction where $N_a >> N_d$,

$W_{dep} \simeq x_N$

and $x_p \simeq 0$

Illy for an N^+P junction where $N_d >> N_a$,

$W_{dep} \simeq x_p$ and $x_N \simeq 0$

So, depletion layer width is determined by higher doping concentration.

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