Junction Diode

Lecture - 6

(05/06/2021)

B.Sc (Electronics)
TDC PART - I
Paper – 1 (Group – B)
Unit – 5
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Barrier Width and Junction Capacitance of Contact Potential Across the P-N Junction (PART – 2)

(B) Barrier Width

⇨ The **Space Charge Region** has a **width** equal to,

$$X = X_1 + X_2 \quad \ldots\ldots \quad (19)$$

⇨ Now putting the value of X_1 **and** X_2 of **Equation (17)** and **Equation (18)** from **Lecture - 5** to the above **Equation (19),** then we get,

$$X = \left[\frac{2\,\epsilon\,V_B}{e\,N_a\left(1+\frac{N_a}{N_d}\right)}\right]^{\frac{1}{2}} + \left[\frac{2\,\epsilon\,V_B}{e\,N_d\left(1+\frac{N_d}{N_a}\right)}\right]^{\frac{1}{2}} \quad \ldots\ldots \quad (20)$$

$$X = \left(\frac{2\,\epsilon\,V_B}{e}\right)^{\frac{1}{2}} \left[\left\{\frac{N_d/N_a}{N_a + N_d}\right\}^{\frac{1}{2}} + \left\{\frac{N_a/N_d}{N_a + N_d}\right\}^{\frac{1}{2}}\right] \quad \text{..............................} \quad (21)$$

$$\therefore\; X = \left[\frac{2\,\epsilon\,V_B}{e\,(N_a + N_d)}\right]^{\frac{1}{2}} \left[\left(\frac{N_d}{N_a}\right)^{\frac{1}{2}} + \left(\frac{N_a}{N_d}\right)^{\frac{1}{2}}\right] \quad \text{..............................} \quad (22)$$

❖ **Example :-** **Consider a typical example with,**

- ✦ $N_d \approx N_a \approx 10^{21}$ **per** m^3
- ✦ $V_B = 0.5$ **volt**
- ✦ $\epsilon_0 = 8.85 \times 10^{-12}$ **farad / meter,**
- ✦ $\epsilon_r = 16$ **for Ge (Germanium)**

⇨ **So,** we know that, $\epsilon = \epsilon_0 \,.\, \epsilon_r$

- ✦ $\epsilon = 8.85 \times 10^{-12} \times 16$ **farad / meter (for Ge) and**
- ✦ $e = 1.6 \times 10^{-19}$ **coulomb**

⇨ Now putting the above values of **different parameters** in above **Equation (22),** then we find that the **Width (Thickness) of Junction Barrier** is,

$$X = \left[\frac{2\,\epsilon\,V_B}{e\,(N_a + N_d)}\right]^{\frac{1}{2}} \left[\left(\frac{N_d}{N_a}\right)^{\frac{1}{2}} + \left(\frac{N_a}{N_d}\right)^{\frac{1}{2}}\right] \quad \text{..............................} \quad (22)$$

$$X = \left[\frac{2 \times 1.6 \times 10^{-19} \times 0.5}{1.6 \times 10^{-19} \times (10^{21} + 10^{21})}\right]^{\frac{1}{2}} \left[\left(\frac{10^{21}}{10^{21}}\right)^{\frac{1}{2}} + \left(\frac{10^{21}}{10^{21}}\right)^{\frac{1}{2}}\right] \text{..............} \quad (23)$$

⇨ Then we find that **Width (Thickness) of Junction Barrier** is,

$$\therefore\; X = 10^{-6} \text{ meter} \quad \text{..} \quad (24)$$

⇨ Now, if $N_d \gg N_a$, then we can neglect N_a in the **Sum** $((N_a + N_d)$ and also the term $\frac{N_a}{N_d}$ can be **approximated to zero**. The **Equation (22)** gives,

$$X = \left(\frac{2\,\epsilon\,V_B}{e\,N_d}\right)^{\frac{1}{2}} \left(\frac{N_d}{N_a}\right)^{\frac{1}{2}} \quad \text{...} \quad (25)$$

$$X = \left(\frac{2\,\epsilon\,V_B}{e\,N_a}\right)^{\frac{1}{2}} \quad \text{...} \quad (26)$$

❖ **V.V.I :-** Which shows that **Width of Space Charge Region Decreases** as the **Impurity Concentration Increases.**

⇨ Further, we find the ratio of **Potential Distribution in Space Charge Region on P – side** V_1 and **Potential Distribution in Space Charge Region on N – side** V_2,

$$\frac{V_1}{V_2} = \left(\frac{X_1}{X_2}\right)^2 \left(\frac{N_a}{N_d}\right) \quad \text{...} \quad (27)$$

⇨ And we find the ratio of **Width of Space Charge Region in the P – side** X_1 and **Width of Space Charge Region in the N – side** X_2,

$$\frac{X_1}{X_2} = \frac{N_d}{N_a} \quad \text{...} \quad (28)$$

⇨ Now from above two relations given in **Equation (27)** and **Equation (28),** we find that,

$$\frac{V_1}{V_2} = \frac{N_d}{N_a} \quad \text{...} \quad (29)$$

❖ **V.V.I :-** We note here from above **Equation (29)** that, when $N_d \gg N_a$, $V_1 \gg V_2$ which **implies** that the **Potential Charge** is **confined to the region** which has **impurity in small amounts** (light doped).

(C) Junction Capacitance

⇨ The **Total Positive Charge in the N – type region** is equal to

$= e\, N_d\, X_2$ **coulumb/meter²** and

⇨ The **Total Negative Charge in the P – type region** is equal to

$= -\, e\, N_a\, X_1$ **coulumb/meter²**

⇨ But from **Equation (15)** from **Lecture – 5,**

$$N_a\, X_1 \;=\; N_d\, X_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(15)} \text{ From Lecture - 5}$$

⇨ On putting for X_1, we find that $-\, e\, N_a\, X_1$ is equal to $+\, e\, N_d\, X_2$ which implies that **Positive and Negative charge per meter²** have equal magnitude. The **Capacitance C per meter²** of the **Barrier/Depletion layer** is then given by,

$$C \;=\; \frac{d}{d\,V_B}\left(+\, e\, N_d\, X_2\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(30)}$$

⇨ Now putting the value of X_2 of **Equation (18)** from **Lecture - 5** to the above **Equation (30),** then we get,

$$C \;=\; \frac{d}{d\,V_B}\left[e\, N_d \left\{\frac{2\,\epsilon\, V_B}{e\, N_d\left(1+\frac{N_d}{N_a}\right)}\right\}^{\frac{1}{2}}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(31)}$$

$$\therefore\ C = \epsilon \left[\frac{e\, N_a\, N_d}{2\, \epsilon\, V_B\, (N_a + N_d)}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

⇨ Now using **Equation (22),** then we get **Junction Capacitance** as,

$$X = \left[\frac{2\, \epsilon\, V_B}{e\, (N_a + N_d)}\right]^{\frac{1}{2}} \left[\left(\frac{N_d}{N_a}\right)^{\frac{1}{2}} + \left(\frac{N_a}{N_d}\right)^{\frac{1}{2}}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$\therefore\ C = \frac{\epsilon}{X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

❖ **Example :- Consider a typical example with,**

- $\epsilon = 8.85 \times 10^{-12} \times 16$ **farad / meter (for Ge)** and
- **Thickness of Junction Barrier** is, $X = 10^{-6}$ **meter**

$$\therefore\ C = \frac{\epsilon}{X} = \frac{8.85 \times 10^{-12} \times 16}{10^{-6}} = 144\ \mu F/meter^2$$

⇨ In the next **Lecture - 7,** we will discuss the detailed of the **Barrier Potential in Terms of the Intrinsic Density of either Carrier (PART – 3)**.

to be continued ....

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