Junction Diode

Lecture - 8

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B.Sc (Electronics)
TDC PART - I
Paper – 1 (Group – B)
Unit – 5
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➢ Charge Neutrality

⇨ The **semiconductor crystal is Electrical Neutral under Thermal Equilibrium conditions.** The **Electrons** are **distributed** among the **different Energy States**, **producing** both **Negative and Positive charge** but the **net charge density is zero**. This **Charge Neutrality condition** is used for **determination of the thermal-equilibrium Electron and Hole concentrations as a function of impurity doping concentration.**

➢ Compensated Semiconductors

⇨ **A** Semiconductor **containing both Donor and Acceptor impurity atoms in the same region** is **called a** Compensated Semiconductor**.**

⇨ It is **formed by diffusing** Donor Impurity **into a P – type material** $(N_A > N_D)$ or **by diffusing** Acceptor Impurity **into an N – type material** $(N_D > N_A)$. If $N_D = N_A$, **we have a completely compensated conductor**. **Compensated conductors** are **produced** quite **naturally** during **device fabrication.**

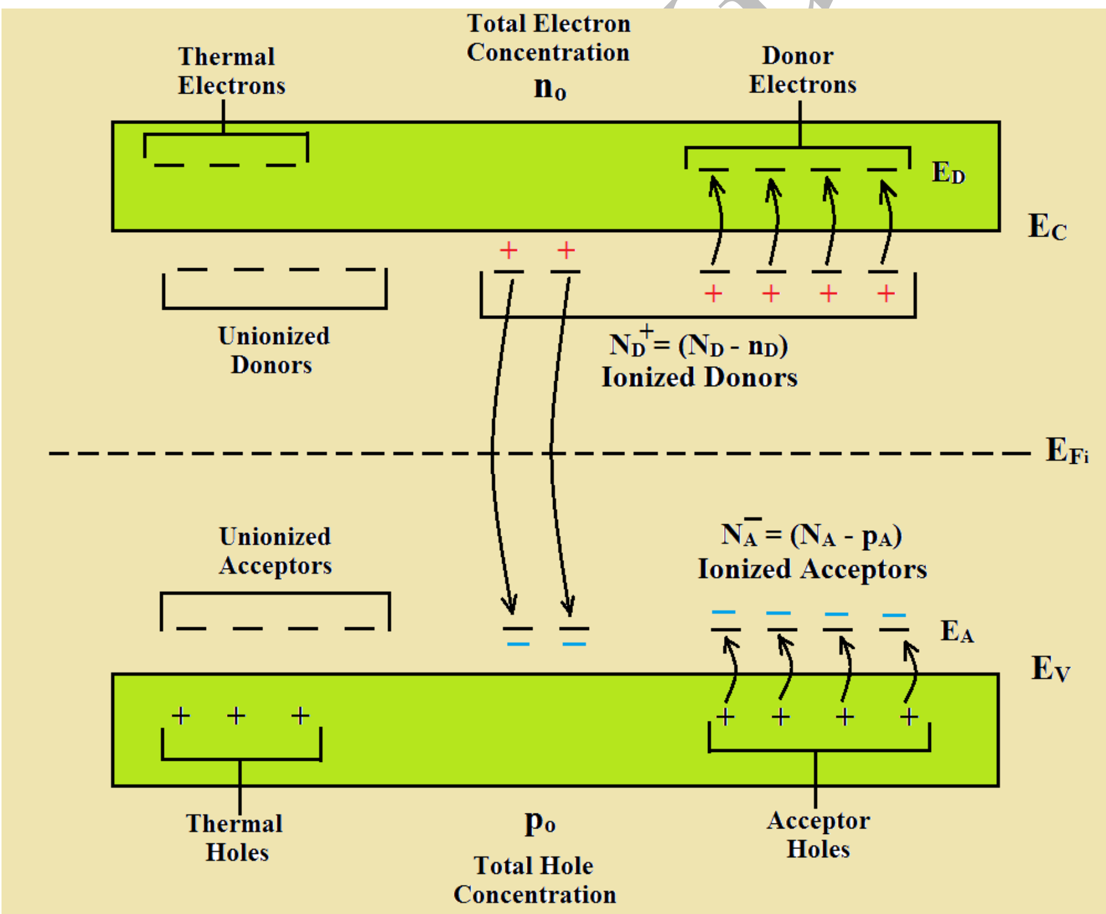

Fig. (1) Shown Energy Band Diagram of a Compensated Semiconductor showing Ionized and Unionized Donors and Acceptors.

- Energy band diagram of a compensated semiconductor is **shown above in Figure (1).** The above **Figure (1) depicts** how the **Electrons and Holes** can be **distributed among** the **various states**.

- The **charge density** of **Negative** and **Positive** charges can be **equated** for **Charge Neutrality** condition and thus we have,

$$n_o + N_A^- = p_o + N_D^+ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (56)$$

$$n_o + (N_A - p_A) = p_o + (N_D - n_D) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (57)$$

where p_o and n_o are the **Thermal Equilibrium Concentration of Holes and Electrons in the Valence and Conduction Bands respectively.**

- The parameter p_A **is the Concentration of Holes in the Acceptor Energy States**, so, $N_A^- = N_A - p_A$ **is the concentration of Negatively Charged Acceptor States**.

- Similarly, n_D **is the Concentration of Electrons in the Donor Energy States**, so, $N_D^+ = N_D - n_D$ **is the concentration of Positively Charged Donor States**.

- For **complete ionization** n_D and p_A **are both zero** so that above **Equation (57)** becomes,

$$p_o + N_D = n_o + N_A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (58)$$

⇨ If p_o is expressed as $\frac{n_i^2}{n_o}$, then,

$$\frac{n_i^2}{n_o} + N_D = n_o + N_A \quad \text{..} \quad (59)$$

$$n_o^2 - (N_D - N_A)n_o - n_i^2 = 0 \quad \text{...} \quad (60)$$

$$\therefore \; n_o = \frac{N_D - N_A}{2} + \sqrt{\frac{(N_D - N_A)^2}{4} + n_i^2} \quad \text{........................} \quad (61)$$

⇨ The **Positive sign** in the **quadratic equation** is required to be used, since, in the limit of an **Intrinsic Semiconductor** when $N_A = N_D = 0$, the **Electron Concentration** must be a **Positive quantity**, or $n_o = n_i$.

⇨ The above **Equation (61)** is used to determine the **Electron Concentration in an N – Type Semiconductor** or when $N_D > N_A$. This Equation is also valid for $N_A = 0$.

⇨ In the next **Lecture - 9,** we will discuss the detailed of the **Space Charge at a P-N Junction.**

to be continued ....

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