Junction Diode

Lecture - 3

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B.Sc (Electronics)
TDC PART - I
Paper – 1 (Group – B)
Unit – 5
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➢ Basic Structure of P-N Junction

⇨ Most semiconductor devices employ one or more P-N junction. The P-N junction is the control element for the performance of all semiconductor devices such as rectifiers, amplifiers, switching devices, linear and digital integrated circuits.

⇨ The P-N junction is produced by placing a layer of P-type semiconductor next to the layer of N-type semiconductor. The interface separating the N and P regions is referred to as the metallurgical junctions.

⇨ **Figure (1) shown in below,** represents two blocks of semiconductor material, one P-type, and the other N-type. The P-type semiconductor block has mobile holes (shown by small white circles) and the same number of fixed **negative acceptor ions** (shown by encircled minus sign). Similarly the N-type semiconductor block has mobile or free electrons (shown by Black dots) and the same number of fixed donor positive ions.

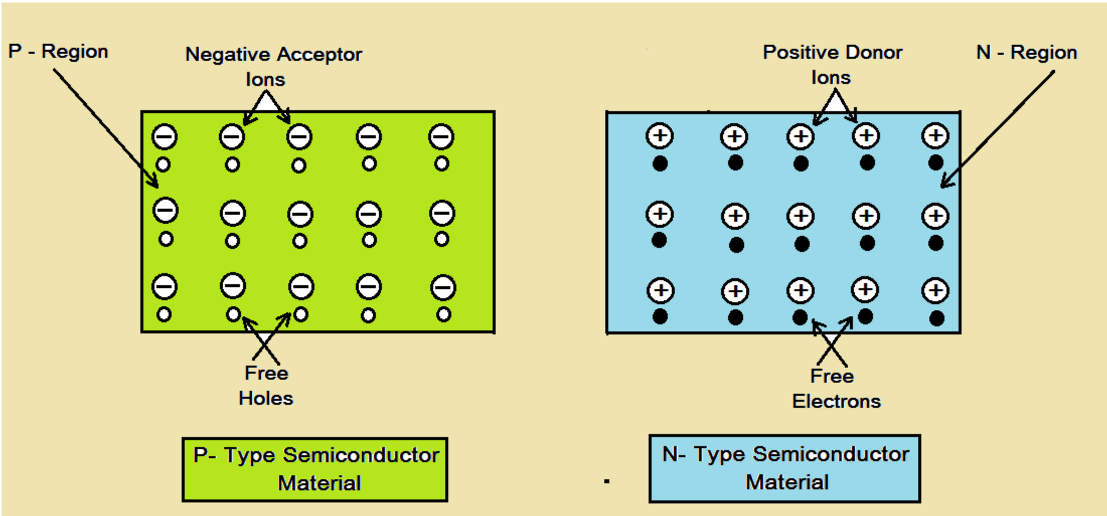
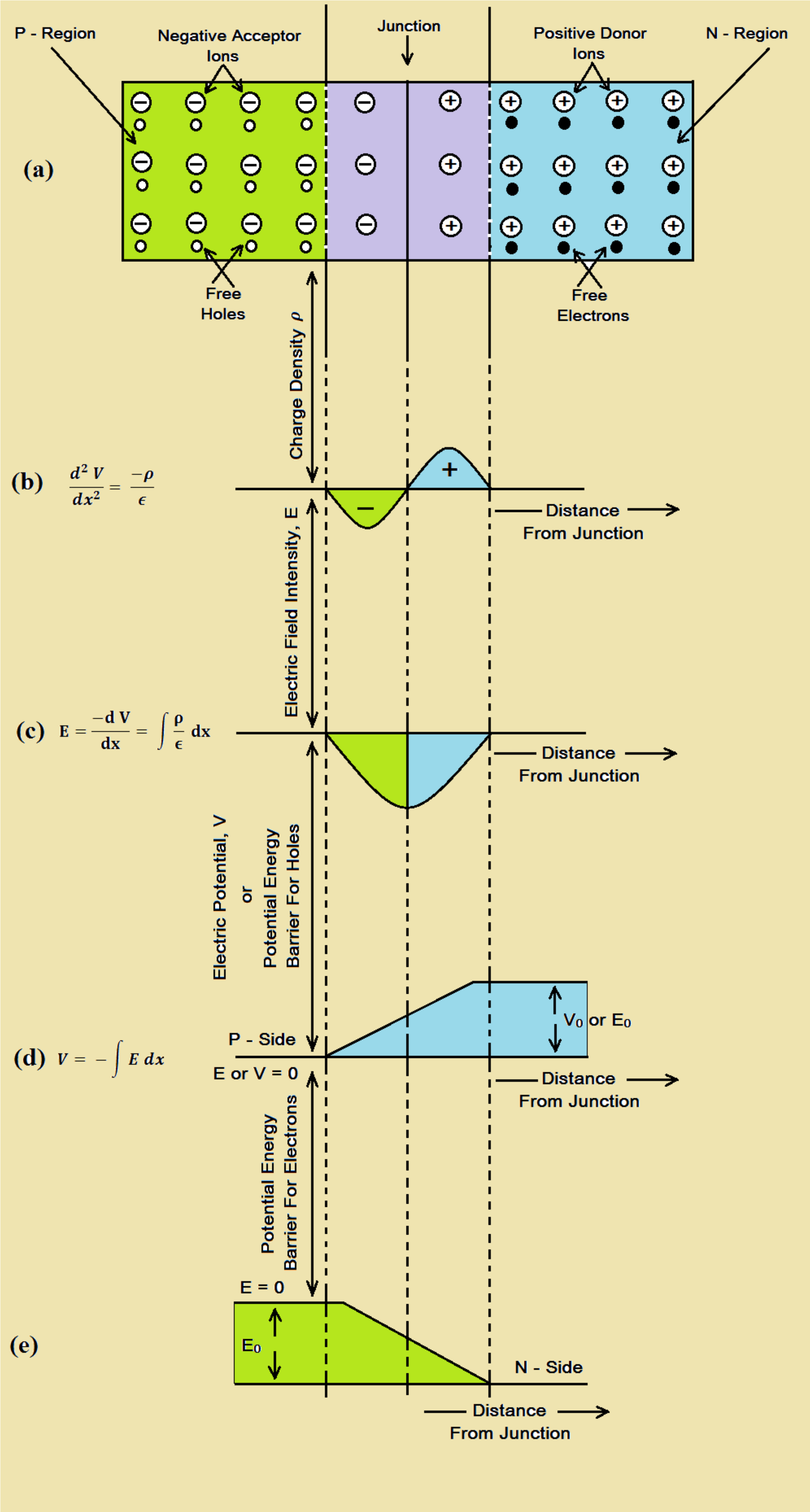


Fig. (1) Shown Two Blocks of Semiconductor Material, One P-type, and the Other N-type.

- **Normally the** holes, which are the majority charge carriers in P-type of material, are uniformly distributed through the volume of that material. Similarly the electrons, which are the majority charge carriers in N-type of material, are uniformly distributed through the volume of that material. Each region is electrically neutral because each of them carries equal positive and negative charges.

- **On the** formation of P-N junction some of the holes from P-type material tend to diffuse across the boundary into N-type material and some of the free electrons similarly diffuse into the P-type material, as illustrated in below **Figure (2).** This happen due to density gradient (as concentration of holes is higher on P-side than that on N-side and concentration of electrons is higher on N-side than that on P-side). **This process is known as Diffusion.**



P - Region
Negative Acceptor Ions
Junction
Positive Donor Ions
N - Region
(a)
Free Holes
Free Electrons
Charge Density ρ
(b) $\frac{d^2 V}{dx^2} = \frac{-\rho}{\epsilon}$
Distance From Junction
Electric Field Intensity, E
(c) $E = \frac{-dV}{dx} = \int \frac{\rho}{\epsilon} dx$
Distance From Junction
Electric Potential, V or Potential Energy Barrier For Holes
P - Side
V_0 or E_0
(d) $V = -\int E\, dx$
E or V = 0
Distance From Junction
Potential Energy Barrier For Electrons
E = 0
(e)
E_0
N - Side
Distance From Junction

Fig. (2) Shown a Schematic Diagram of a P-N Junction, Including the Charge Density, Electric Field Intensity, and Potential Energy Barriers at the Junction.

The doping profile of an ideal uniformly doped P-N junction is depicted in below **Figure (3).**

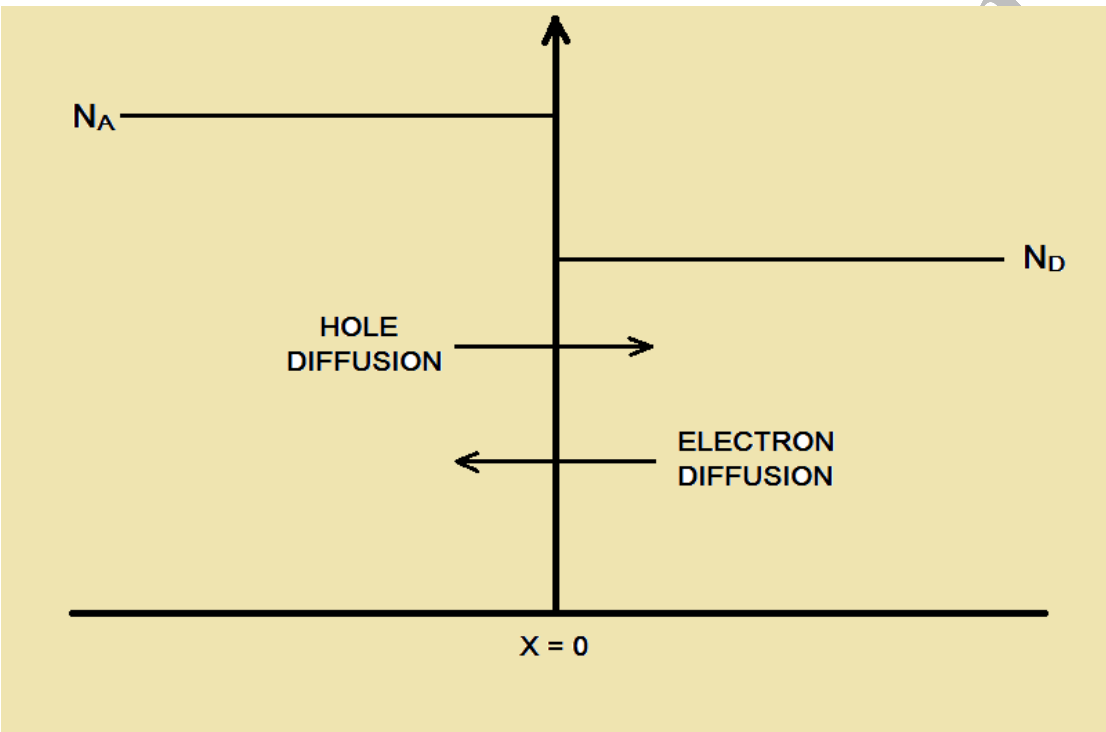


Fig. (3) Shown Doping Profile of an Ideal Uniformed Doped P-N junction.

- **As a result** of the displacement of the charges, an electric field appears at the junction. Equilibrium is established when the field becomes large enough to **restrain the process of diffusion.** The general shape of the charge distribution may be, as illustrated in **Figure (2) (b)**. The electric charges are confined to the neighbourhood of the junction and consist of immobile ions.

- **We see** that the free electrons crossing the junction create negative ions on the P-side by giving some atoms one more electron than their total number of protons. The electrons also leave positive ions (atoms with one fewer electron than the number of protons) behind them on the N-side. As negative ions are created on the P-side of the junction, the P-side acquires a negative potential, as illustrated in **Figure (2) (e).**

- **Similarly** the positive ions are created on the N-side and the N-side acquires a positive potential as illustrated in **Figure (2) (d).** The negative potential on the P-side prevents the migration of any more electrons from the N-type material to the P-type material.

- **Similarly** the Positive potential on the N-side prevents any further migration of holes across the boundary. Thus the initial diffusion of charge carriers creates a barrier potential at the junction.

- **The region** around the junction is completely ionised. As a result, there are no free electrons on the N-side, nor there holes on the P-side. Since the region around the junction is depleted of mobile charges **it is called the Depletion Region, the Space-charge Region, or the Transition Region.** The thickness of the depletion region (or layer) is of the order of **1 micron (10^{-6} m).**

- **The electric field** intensity in the neighbourhood of the junction is illustrated in **Figure (2) (c)**. The electric potential variation in the depletion region is shown in **Figure (2) (d)**, and the **negative integral** of the **function E** of **Figure (2) (c).** The variation constitutes a **potential-energy barrier** against the further diffusion of holes across the barrier.

- The form of **potential-energy barriers** against the flow of electrons from the N-side across the junction is shown in **Figure (2) (e)**. It is similar to that shown in **Figure (2) (d),** except that it is inverted, since the charge on electron is negative.

- The necessity for the existence of a potential barrier called the **Contact, or Diffusion Potential** is now considered further. Under open-circuited conditions **the net hole current must be zero**. If this statement were not true, the hole density at one end of the semiconductor would continue to **increase indefinitely** with time, a situation, which is obviously physically impossible. Since the **concentration of holes** in the P-side is much greater than that in the N-side, a **very large diffusion current** tends to flow across the junction from the P-type material to the N-type material.

- Hence an **electric field** must build up across the junction in such a direction that a drift current will tend to flow across the junction from the N-side to the P-side in order to counterbalance the diffusion current. This equilibrium condition of zero resultant hole current allows us to determine the height of the potential barrier in terms of the donor and acceptor concentrations. The magnitude of **Barrier Potential V_O** is of the order of few tenths of a volt **(0.3 V in case of Germanium (Ge) and 0.7 V for Silicon (Si)).**

- **Barrier Voltage** depends on doping density, electronic charge and temperature. For a given junction, the first two factors are fixed, thus making barrier potential dependent on temperature. Increase in temperature creates more minority charge carriers leading to their increased drift across the junction.

- ⇨ These extra minority charge carriers reduce the width of the depletion layer equivalent to reduction in potential barrier. It is found that for either, Silicon or Germanium diodes, the barrier potential decreases **2 mV** for each Celsius degree rise.

- ⇨ In the next **Lecture - 4,** we will discuss the detailed of the **Equilibrium Conditions**.

to be continued ....

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