SNS COLLEGE OF TECHNOLOGY
Coimbatore-35
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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

23ECB101 – CIRCUIT ANALYSIS AND DEVICES

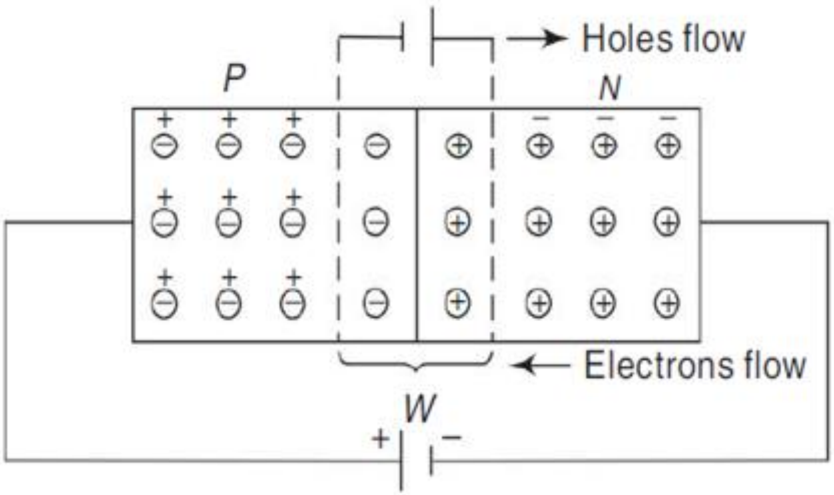
I YEAR/ II SEMESTER

UNIT 4 – SEMICONDUCTOR DIODES AND THEIR APPLICATIONS

TOPIC - Forward and Reverse biased P-N junction

Under forward-Bias Condition

- When the positive terminal of the battery is connected to the P-type and negative terminal to the N-type of the PN junction diode, the bias applied is known as **forward bias**.

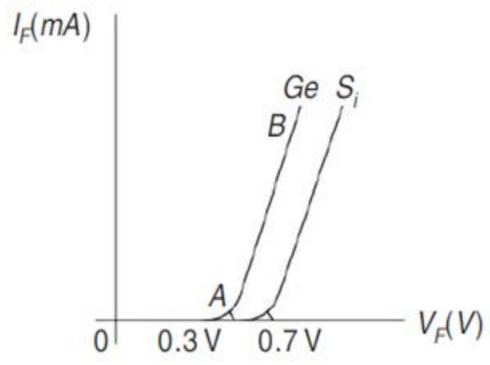


PN junction under forward bias

- As shown in Figure, the applied potential with external battery acts in opposition to the internal potential barrier and disturbs the equilibrium.
- As soon as equilibrium is disturbed by the application of an external voltage, the Fermi level is no longer continuous across the junction.
- Under the forward-bias condition, the applied positive potential *repels the holes* in the P-type region so that the holes move towards the junction.
- The applied negative potential repels the electrons in the N-type region and the *electrons move towards* the junction.
- Eventually, when the applied potential is *more than* the internal barrier potential, the depletion region and internal potential barrier disappear.

V–I Characteristics of a Diode under Forward Bias

- Under forward-bias condition, the V–I characteristics of a PN junction diode are shown in Figure.
- As the forward voltage (VF) is increased, for $V_F < V_O$, the forward current I_F is almost zero (region OA) because the potential barrier prevents the holes from P-region and electrons from N-region to flow across the depletion region in the opposite direction.

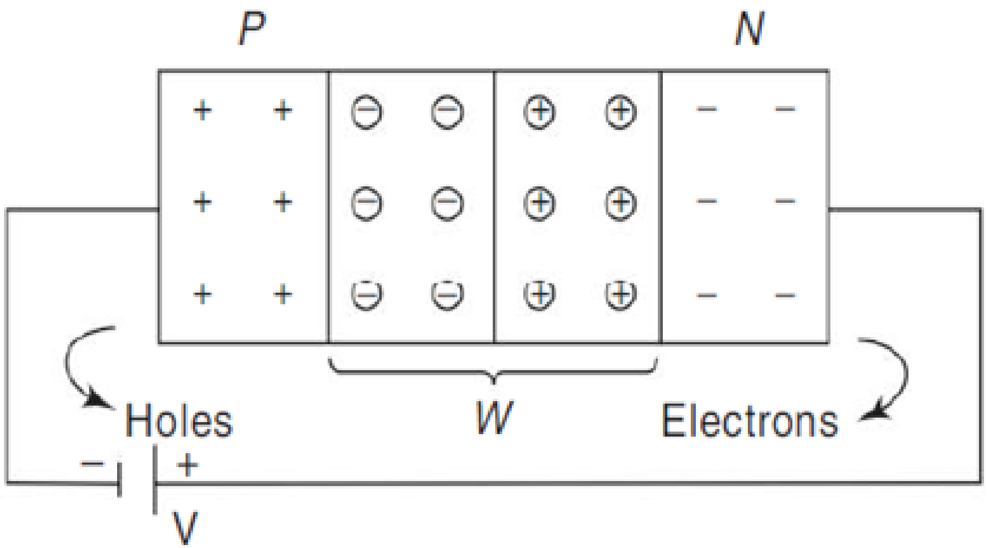


V–I characteristics of a diode under forward-bias condition

- For VF > VO, the potential barrier at the junction completely disappears and, hence, the holes cross the junction from P-type to N-type.
- The electrons cross the junction in the opposite direction, resulting in relatively large current flow in the external circuit.
- A feature worth to be noted in the forward characteristics shown in Figure is the cut in or threshold voltage (Vr) below which the current is very small.
- It is *<u>0.3V and 0.7V for germanium and silicon</u>*, respectively.
- At the cut-in voltage, the potential barrier is overcome and the current through the junction starts to increase rapidly.

Under Reverse-Bias Condition

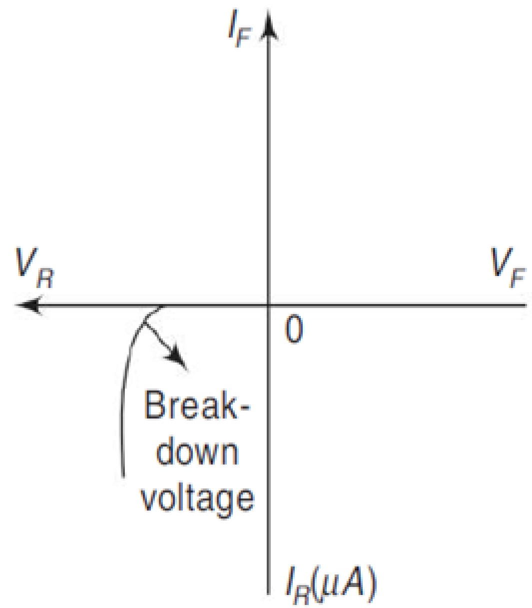
- When the negative terminal of the battery is connected to the P-type and positive terminal of the battery is connected to the N-type of the PN junction, the bias applied is known as **reverse bias**.



PN junction under reverse bias

- Under applied reverse bias as shown in Figure, holes which form the majority carriers of the P-side *move towards the negative terminal* of the battery and electrons which form the majority carrier of the N-side are *attracted towards the positive terminal* of the battery.
- Hence, the width of the depletion region which is depleted of mobile charge carriers increases.
- Thus, the electric field produced by applied reverse bias, is in the *same direction* as the electric field of the potential barrier.
- Hence, the resultant potential barrier is increased which prevents the flow of majority carriers in both directions.
- The depletion width, W, is proportional to $(Vo)^{1/2}$ under reverse bias.
- Therefore, theoretically, no current should flow in the external circuit.

- But in practice, a very small current of the order of a few microampere flows under reverse bias as shown in Figure.
- Electrons forming covalent bonds of the semiconductor atoms in the P- and N-type regions may absorb sufficient energy from heat and light to cause breaking of some covalent bonds.



V–I characteristics under reverse bias

- Hence, electron-hole pairs are continually produced in both the regions.
- Under the reverse-bias condition, the thermally generated holes in the P-region are attracted towards the negative terminal of the battery and the electrons in the N-region are attracted towards the positive terminal of the battery.
- Consequently, the minority carriers, electrons in the P-region and holes in the N-region, wander over to the junction and flow towards their majority carrier side giving rise to a small reverse current.
- This current is known as **reverse saturation current**, Io.
- The magnitude of the reverse saturation current mainly depends upon junction temperature because the major source of minority carriers is thermally broken covalent bonds.

- For large applied reverse bias, the free electrons from the N-type moving towards the positive terminal of the battery acquire sufficient energy to move with high velocity to dislodge valence electrons from semiconductor atoms in the crystal.
- These newly liberated electrons, in turn, acquire sufficient energy to dislodge other parent electrons.
- Thus, a large number of free electrons are formed which is commonly called an **avalanche of free electrons**.
- This leads to the breakdown of the junction leading to very large reverse current.
- The reverse voltage at which the junction breakdown occurs is known as **breakdown voltage, VBD**.

Assessment Questions

1. If the positive terminal of the battery is connected to the anode of the diode, then it is known as
a) Forward biased
b) Reverse biased
c) Equilibrium
d) Schottky barrier

2. During reverse bias, a small current develops known as
a) Forward current
b) Reverse current
c) Reverse saturation current
d) Active current

3. If the voltage of the potential barrier is V_0. A voltage V is applied to the input, at what moment will the barrier disappear?
a) $V < V_0$
b) $V = V_0$
c) $V > V_0$
d) $V << V_0$


THANK YOU