

# **A SEMICONDUCTOR DIODE**

## **“ *P-N* Junction “**

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# **A Semiconductor Devices**

**A Semiconductor devices can be defined as a unit which consists, partly, or wholly, of semiconducting materials and which can perform useful function in electronic apparatus and solid state research.**

**Examples of semiconductor devices are semiconductor diodes (P-N junction), transistors, integrated circuit (IC) etc.**

# ***P-N* Junction**

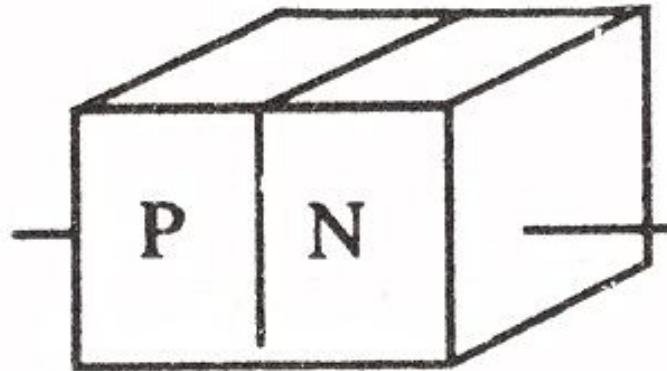
**When a *P*-type semiconductor is brought into contact with *N*-type semiconductor as the process of crystallisation is taking place, the resulting combination is called a *P-N* junction.**

**Most semiconductor devices contain one or more *P-N* junction.**

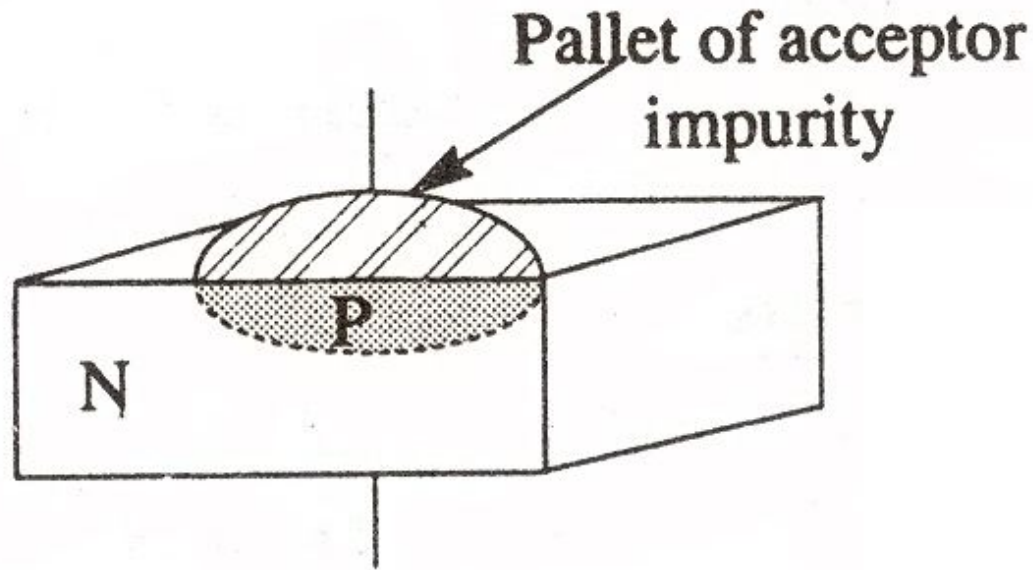
**The most important characteristic of a *P-N* junction is its ability to conduct current in one direction only.**

# Formation of a *P-N* Junction

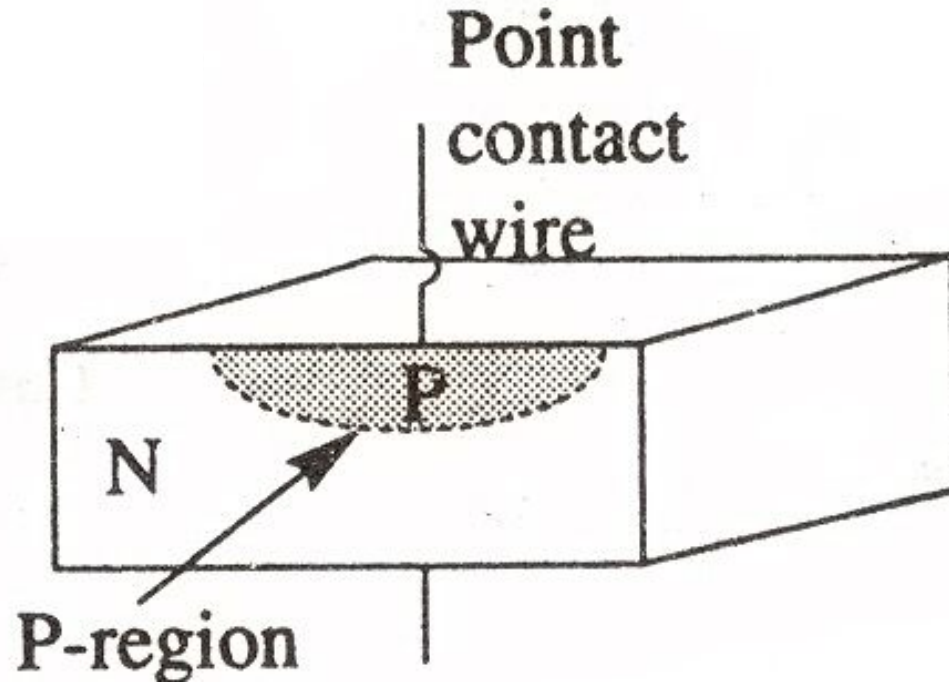
*P-N* junction may be of the grown, alloyed, or diffused type.



P and N regions have been grown into the germanium block by mixing acceptor and donor impurities, respectively into the single crystal during its formation.



**The diffused junction is made by placing a pellet of acceptor impurity, such as indium, on one face of a wafer of N-type germanium and then heating the combination to melt the impurity.**



**A pointed wire makes pressure contact with the face of an *N*-type germanium wafer.**

**The indium is absorbed into the germanium to produce a P region and hence a PN junction.**

**Silicon *P-N* junction is produced in similar manner.**

**The silicon has been processed in such a way as to make it *P*-type.**

**To create the junction, an *n*-type material is either inserted at the proper point in the crystal process**

**Or**

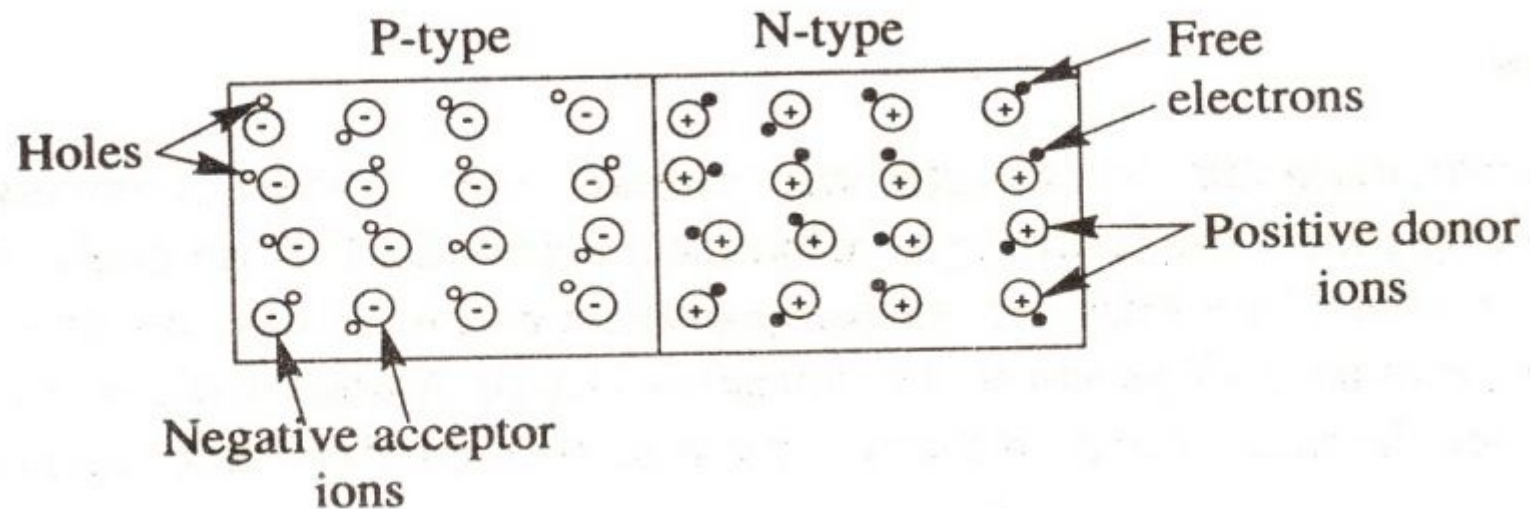
**An *n*-type material is later inserted into the body of *P*-type wafer.**

**Like germanium diodes, silicon diodes also are produced both in junction and point contact type.**

# The Process of P-N Junction

(i) At the junction, holes from the *P*-region diffuse into the *N*-region and free electrons from the *N*-region diffuse into the *P*-region. It is called as a diffusion.

Holes combine with the free electrons in the *N*-region whereas electrons combine with the holes in the *P*-region.





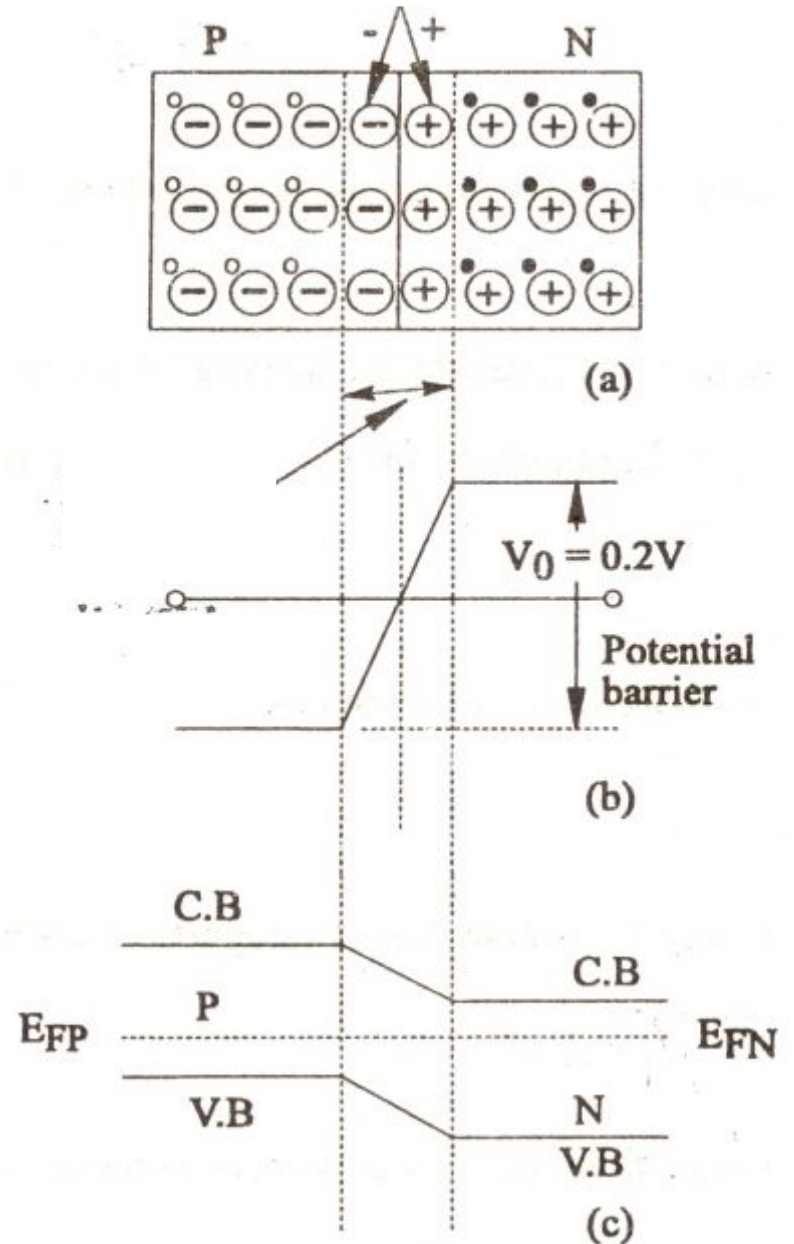
(ii) The diffusion of holes from *P*-region to *N* region and electrons *N* region to *P* region across the junction takes place because they move haphazardly due to thermal energy

and also because there is a difference in their concentrations (the *P* region has more holes whereas the *N* region has free electrons) in the two region.

(iii) As the free electrons move across the junction from *N* type to *P* type, positive donor ions are uncovered.

Hence a positive charge is built on the *N*-side of the junction.

At the same time, the free electrons cross the junction and uncover the the negative acceptor ions by filling in the holes. Therefore, a net negative charge is established on *P*-side of the junction.



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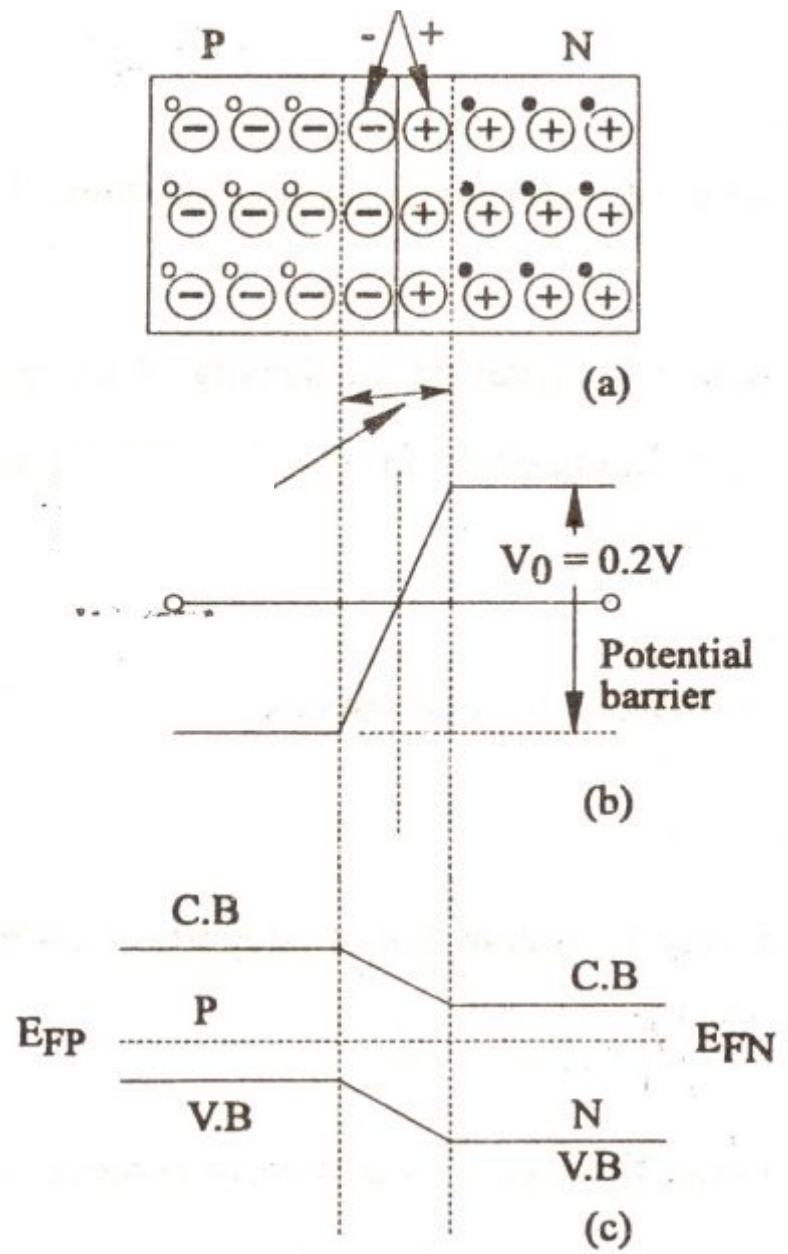
When a sufficient number of donor and acceptor ions is uncovered, further diffusion is stopped. Then, a barrier is set up against further movement of charger carriers.

This is called potential barrier or junction barrier. It is the order of 0.1 to 0.3 volt.

(iv) The region across the P-N junction in which the potential changes from positive to negative is called the depletion region.

The width of this region is of the order of  $6 \times 10^{-8}$  m.

(v) The potential barrier for a silicon P-N junction is about 0.7 volt, whereas for a germanium P-N junction it is approximately 0.3 volt.



# Biased Junction

## a. Forward Biasing

We have seen that the natural tendency of the majority carriers was to combine at the junction. This is how the depletion region and potential barrier were formed.

Actually, the combination of electrons and hole at the junction allows electrons to move in the same direction in both the P and N section.

In the N section, free electrons move toward the junction, and in the P section, for the holes move toward the junction, valence move away from the junction.

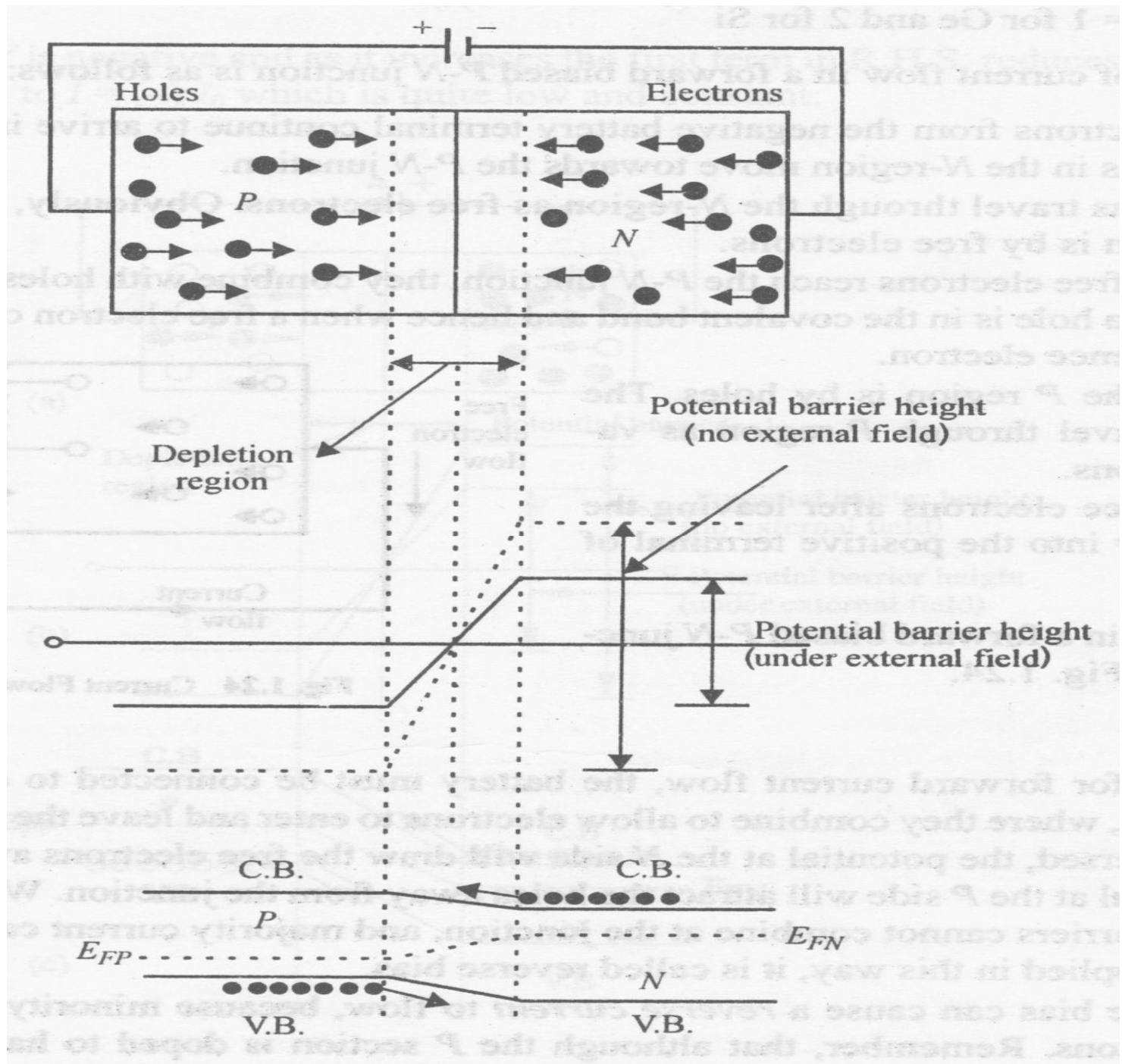
Therefore, electron flow in both the section is the same direction. This is of course, would be the basis of the current flow.

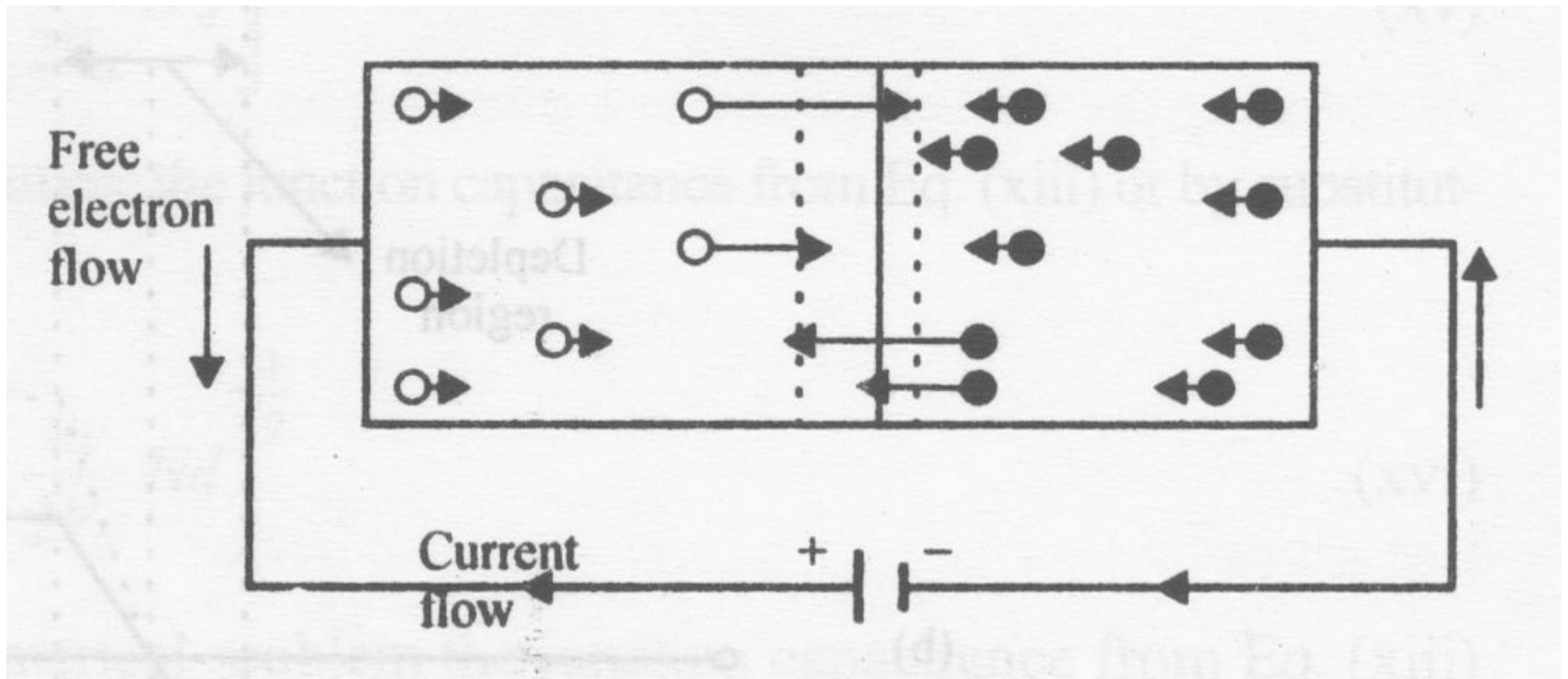
With the P-N junction alone, the action stops because there is no external circuit and because of the potential barrier that builds up.

So, for current to flow, a battery can be connected to the diode to overcome the potential barrier. And the polarity of the battery should be such that the majority carriers in both sections are driven toward the junction.

When the battery is connected in this way, it provides forward bias, causing forward or high current to flow, because it allows the majority carriers to provide the current flow.

To apply forward bias, positive terminal of the battery is connected to P type and negative terminal to N type.

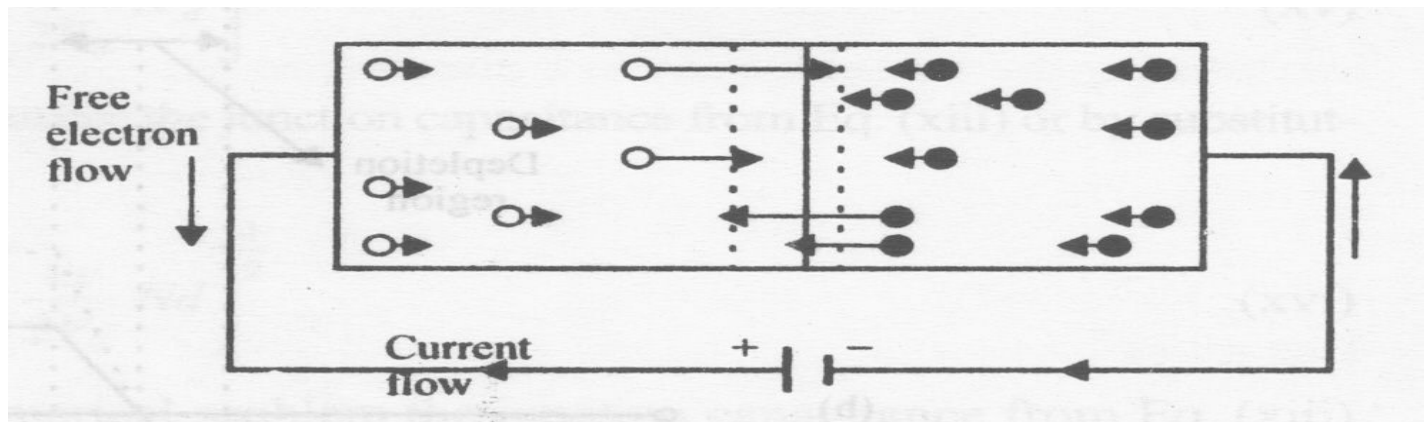




**The mechanism of current flow in a forward biased P-N junction is as follows:**

- (i) The free electrons from the negative battery terminal continue to arrive into the N region while the free electrons in the N region move towards the *P-N* junction.**

- (ii) The electrons travel through the N-region as free electrons. Obviously, current in N region of the P-N junction is by free electrons.
- (iii) When these free electrons reach the *P-N* junction, they combine with holes and become valence electrons. Since hole is in the covalent bond and hence when a free electron combines with a hole, it becomes a valence electron.
- (iv) Current in the P region is by holes. The electrons travel through P region as valence electrons.
- (v) These valence electrons after leaving the crystal, flow into the positive terminal of the battery.



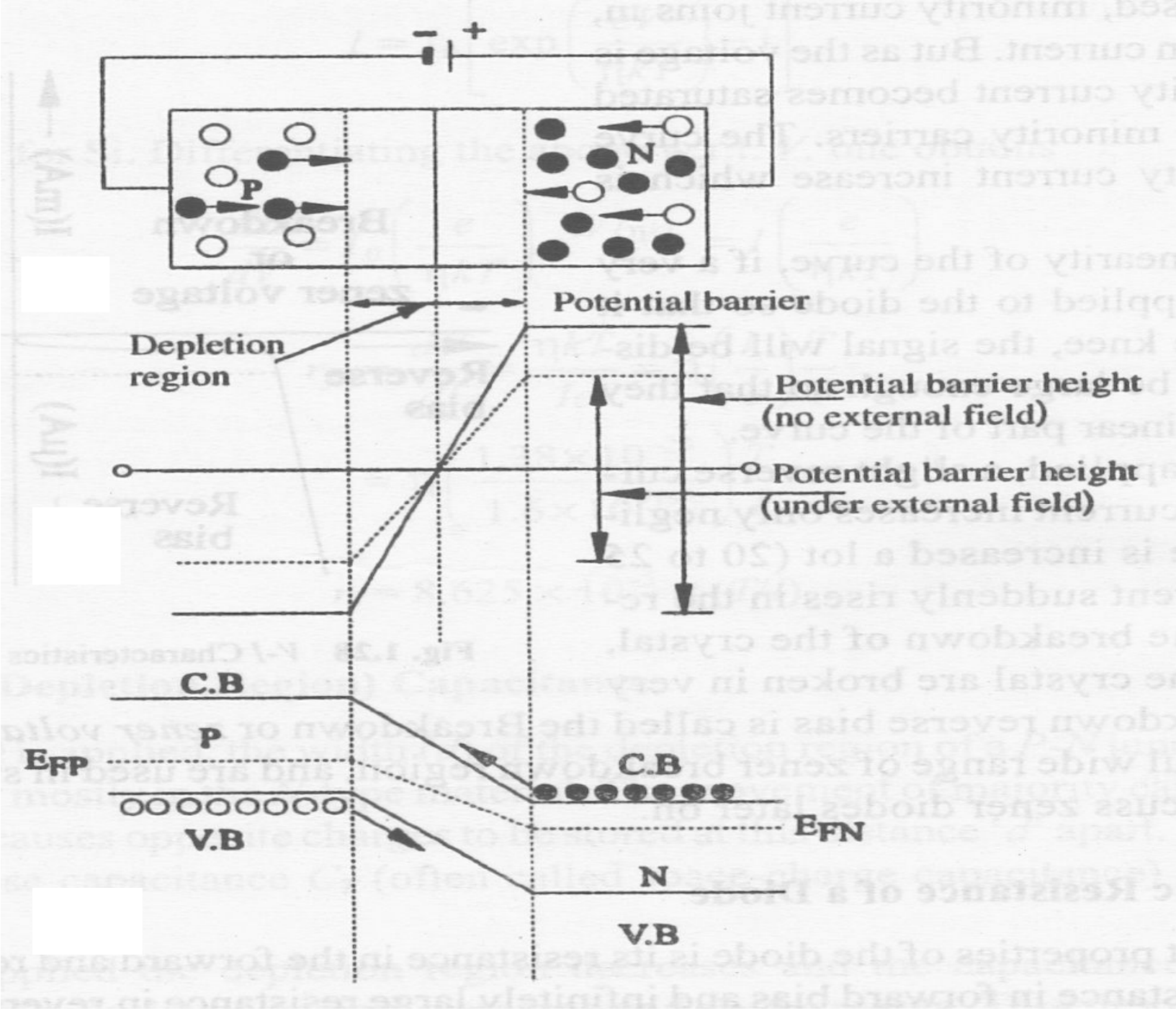
## b. Reverse Biasing

We have seen that for the forward current flow, the battery must be connected to drive majority carriers toward the junction, where they combine to allow electrons to enter and leave the P-N junction.

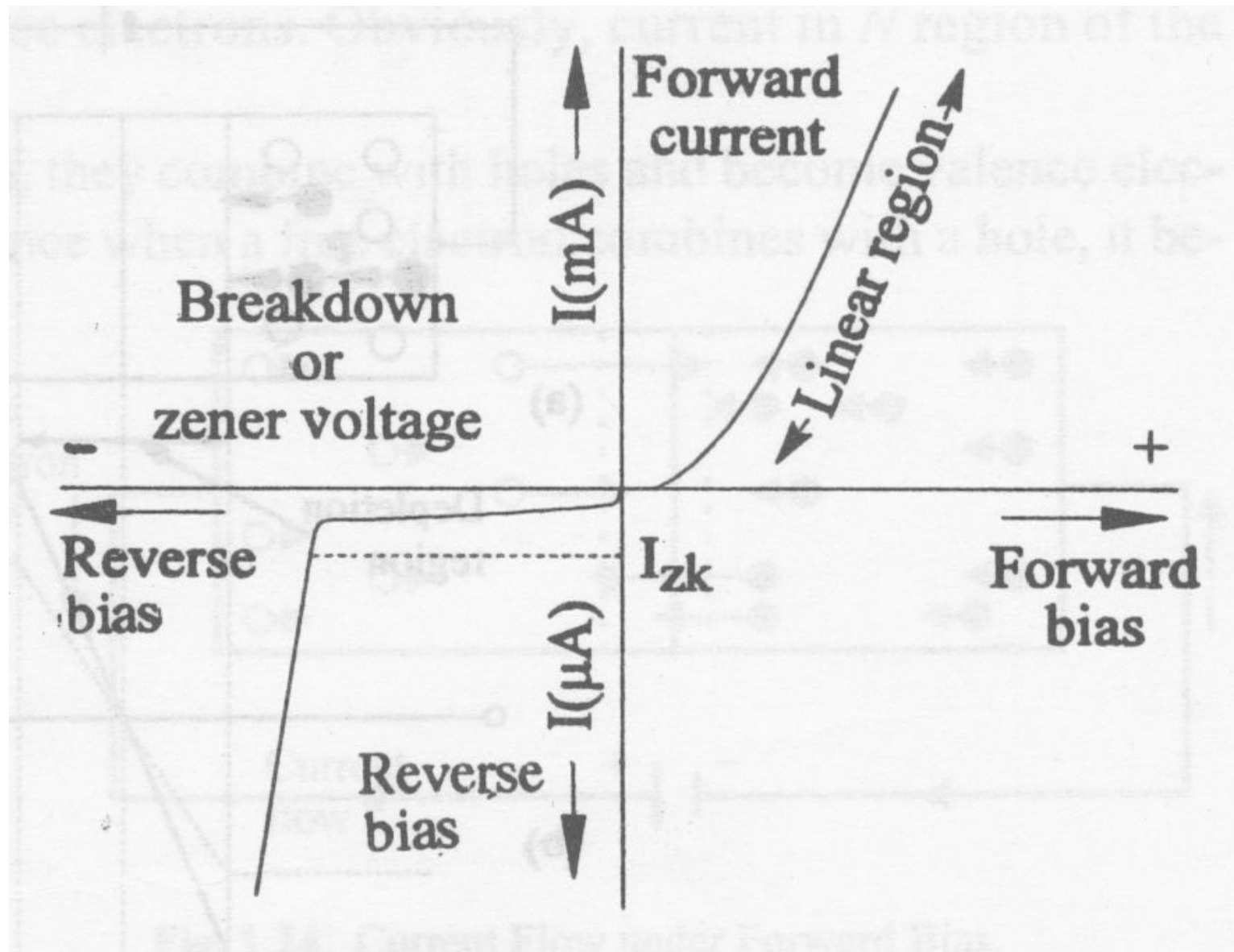
If the battery connections are reversed, the potential at the N side will draw the free electrons away from the junction, and the negative potential at the P side will attract the holes away from the junction.

With this battery connections, then, the majority carriers cannot combine at the junction, and majority current cannot flow. For this reason, when voltage is applied in this way, it is called **reverse bias**.





# Volt-Ampere Characteristics of *P-N* Junction



# Effect of Temperature on *P-N* Junction Diodes

From a consideration of the energies of the carriers crossing the depletion region in a P-N junction diode, an involved calculation yields the following relation between diode current, voltage and temperature:

$$I = I_o \left( e^{\frac{V}{\eta V_T}} - 1 \right)$$

Where,

$I$  = the diode current, forward if positive, reverse if negative, same unit as  $I_0$

$I_0$  = the diode reverse current, also called the reverse saturation current, at temperature  $T$

$V$  = the diode voltage, positive for forward bias, negative for reverse bias, in volts

$\eta$  = 1 for germanium, 2 for silicon

$V_T = \frac{T}{11600}$ , a quantity in volts, dependent upon temperature