Semiconductor Diode

Overview

- Introduction
- What are P-type and N-type semiconductors??
- What are Diodes?
- Forward Bias & Reverse Bias
- Characteristics Of Ideal Diode
- Shockley Equation
- I – V Characteristics of Diodes

Introduction

Semiconductors are materials whose electrical properties lie between Conductors and Insulators.

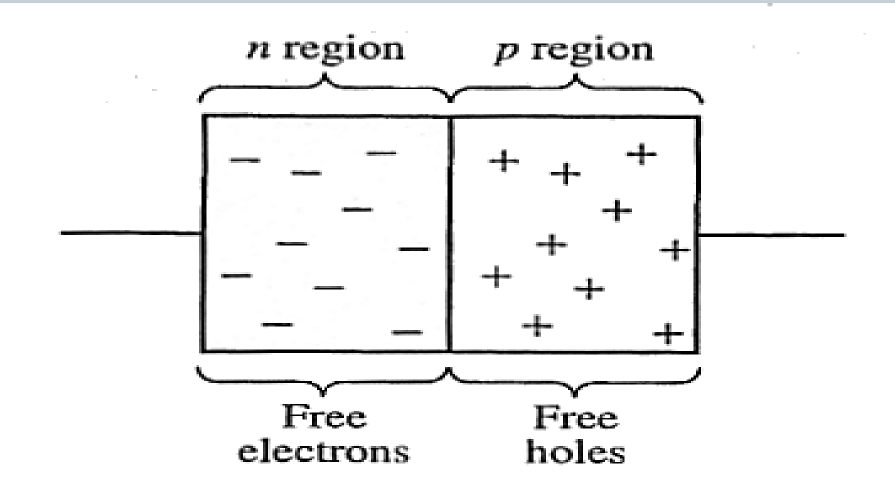
Ex : Silicon and Germanium

What are P-type and N-type ?

- Semiconductors are classified in to P-type and N-type semiconductor
- P-type: A P-type material is one in which holes are majority carriers i.e. they are positively charged materials (++++)
- N-type: A N-type material is one in which electrons are majority charge carriers i.e. they are negatively charged materials (-----)

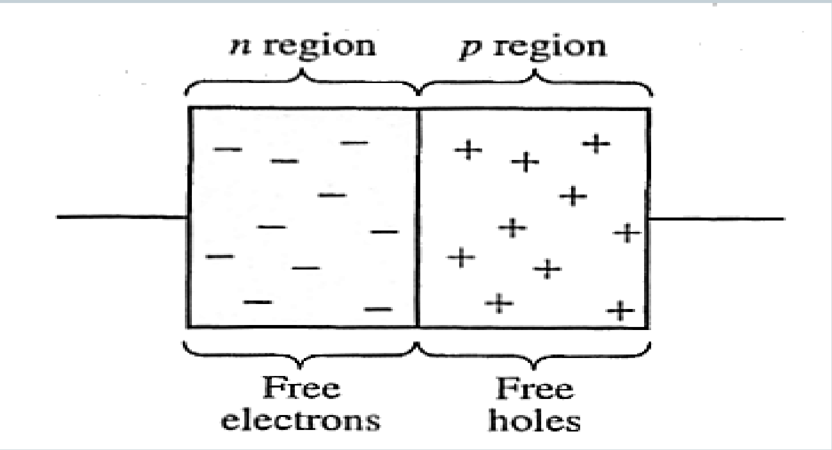
Diodes

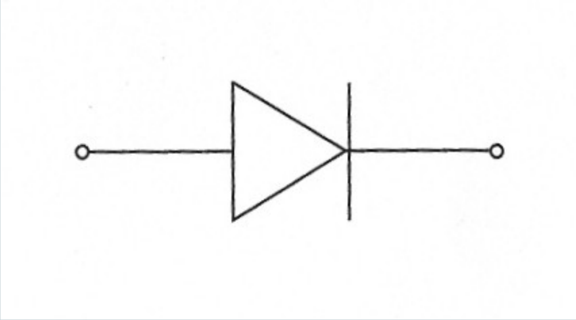
Electronic devices created by bringing together a *p*-type and *n*-type region within the same semiconductor lattice. Used for rectifiers, LED etc



Diodes

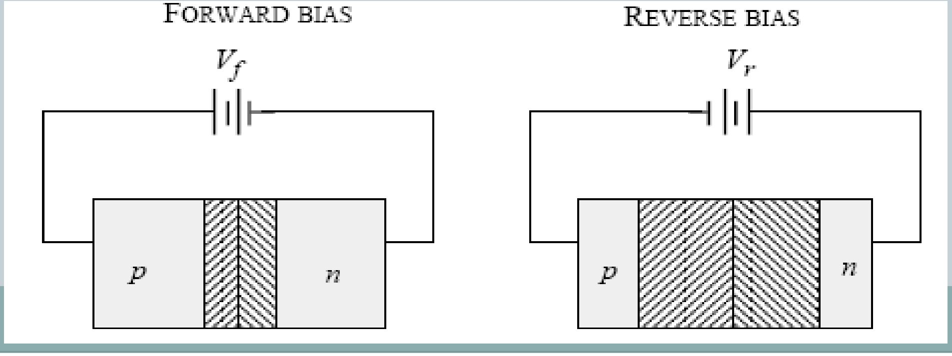
It is represented by the following symbol, where the arrow indicates the direction of positive current flow.





Forward Bias and Reverse Bias

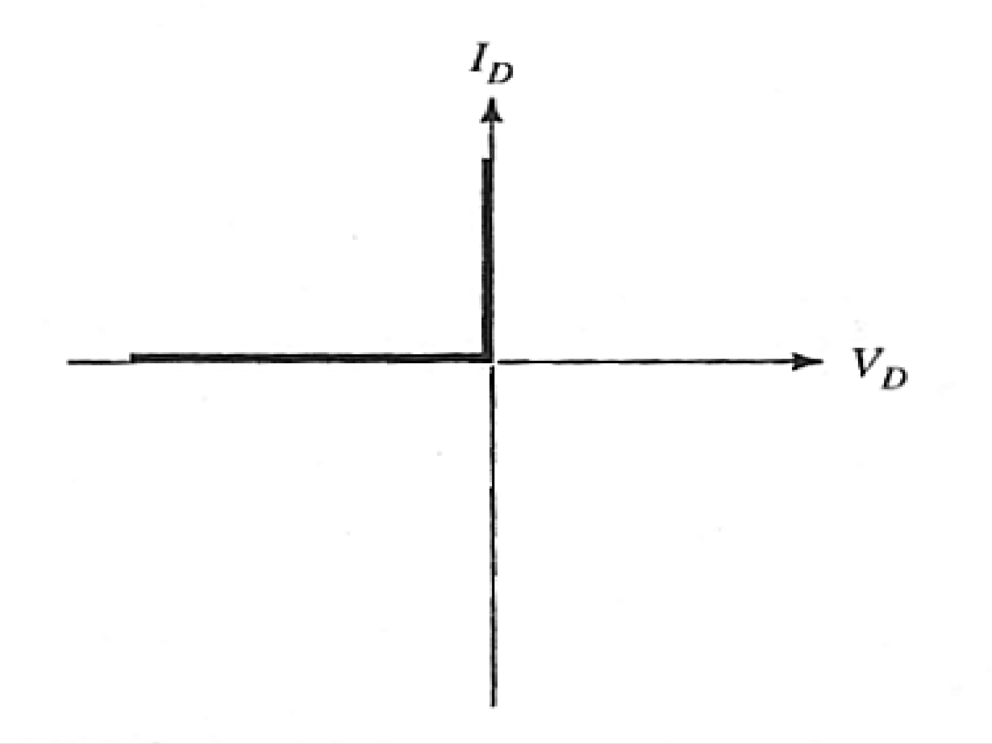
- Forward Bias : Connect positive of the Diode to positive of supply…negative of Diode to negative of supply
- Reverse Bias: Connect positive of the Diode to negative of supply…negative of diode to positive of supply.



Characteristics of Diode

- Diode always conducts in one direction.
- Diodes always conduct current when "Forward Biased" (Zero resistance)
- Diodes do not conduct when Reverse Biased
  (Infinite resistance)

I-V characteristics of Ideal diode



I-V Characteristics of Practical Diode

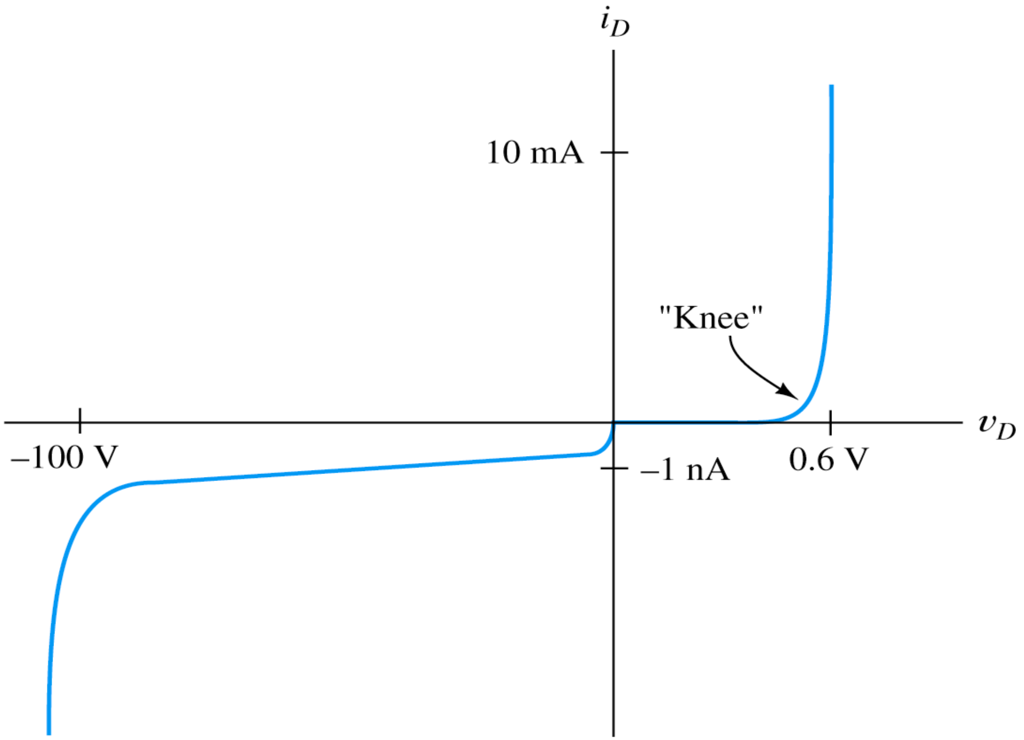
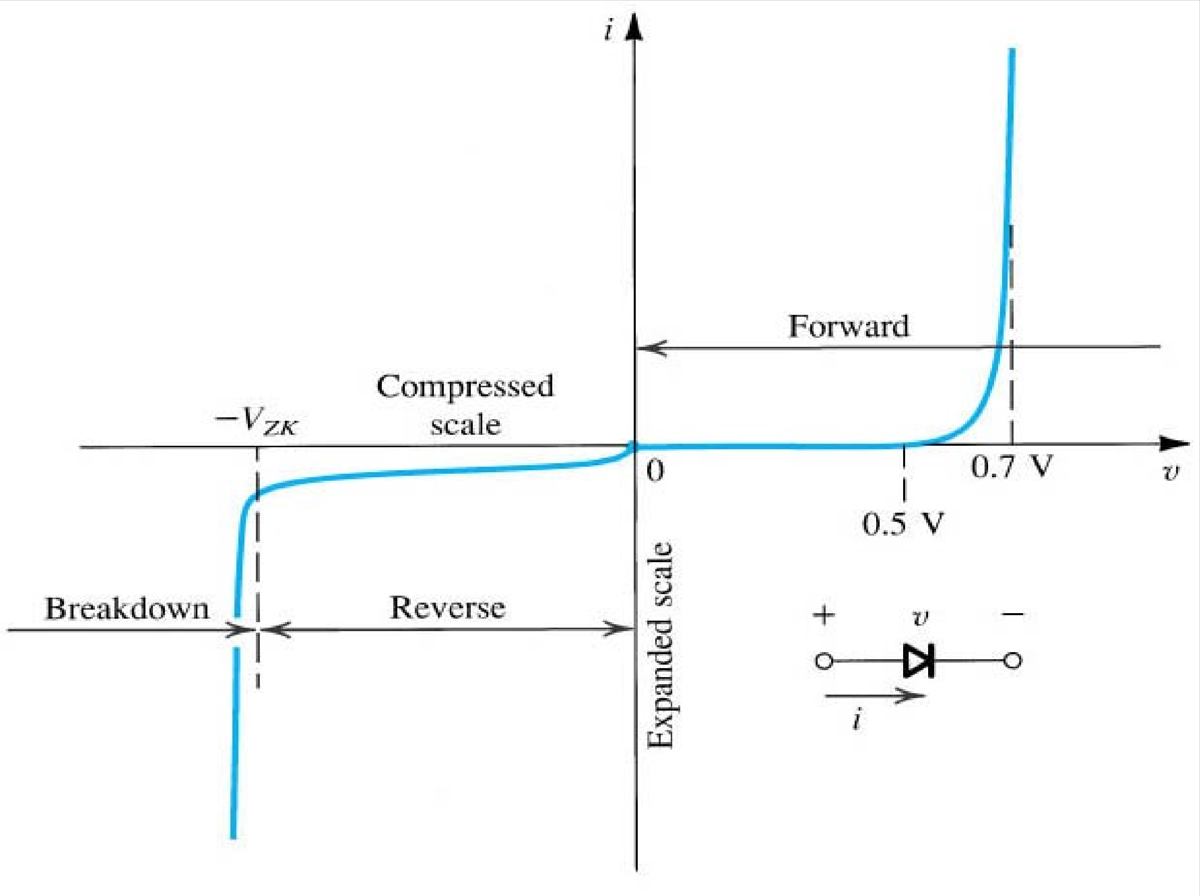


Figure 10.2 Volt–ampere characteristic for a typical small-signal silicon diode at a temperature of 300 K. Notice the change of scale for negative current and voltage.

I-V Characteristics



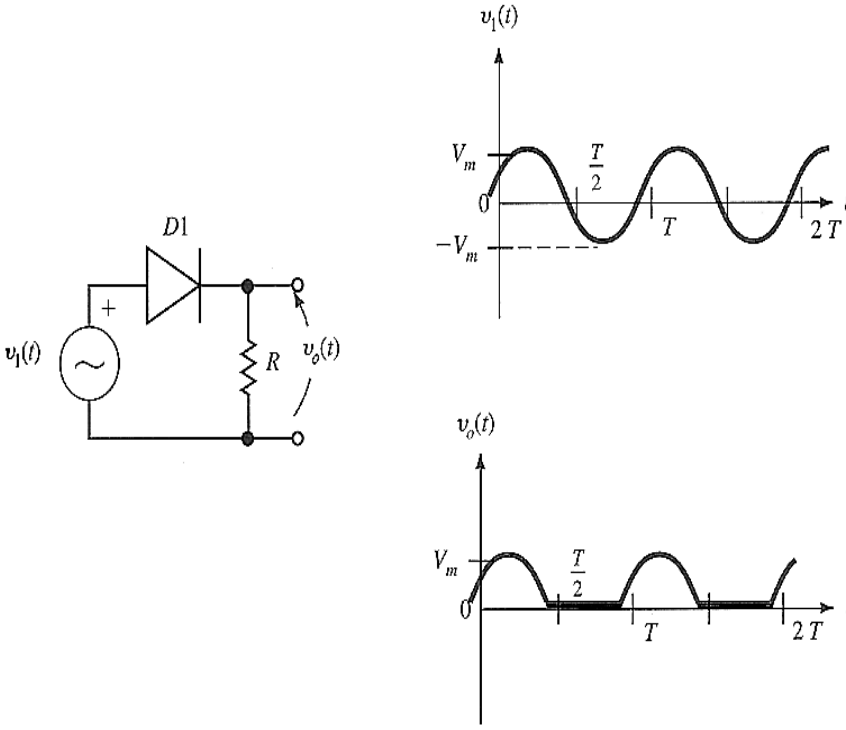
The diode *i*–*v* relationship with some scales expanded and others compressed in order to reveal details

Rectification

- Converting ac to dc is accomplished by the process of rectification.
- Two processes are used:
  - Half-wave rectification;
  - Full-wave rectification.

Half-wave Rectification

- Simplest process used to convert ac to dc.
- A diode is used to clip the input signal excursions of one polarity to zero.



Shockley Equation

$$i_D = I_s\left[\exp\left(\frac{v_D}{nV_T}\right) - 1\right]$$

$$V_T = \frac{kT}{q}$$

$$V_T \cong 26\,\text{mV}$$

I_s is the saturation current ~10 $^{-14}$

V_d is the diode voltage

n – emission coefficient (varies from 1 - 2)

$k = 1.38 \times 10^{-23}$ J/K is Boltzmann's constant

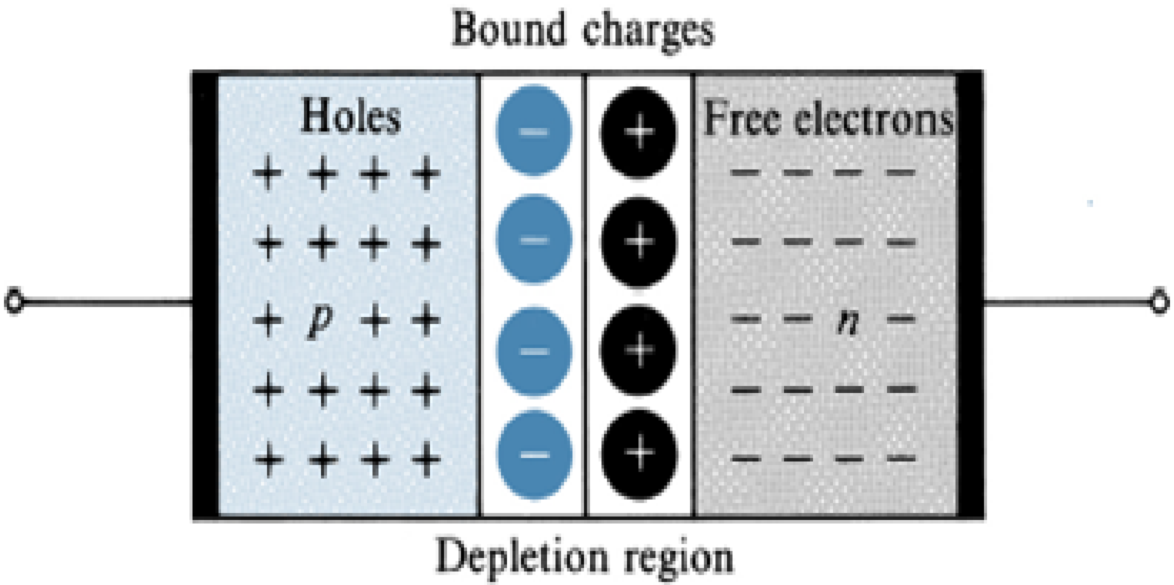
$q = 1.60 \times 10^{-19}$ C is the electrical charge of an electron.

At a temperature of 300 K, we have

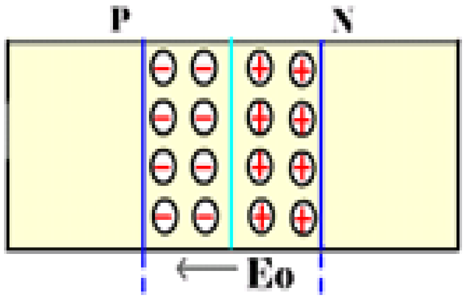
PN Junction

- N-type materials: Doping Si with a Group V element, providing extra electrons (n for negative) .
- P-type materials: Doping Si with a Group III element, providing extra holes (p for positive).

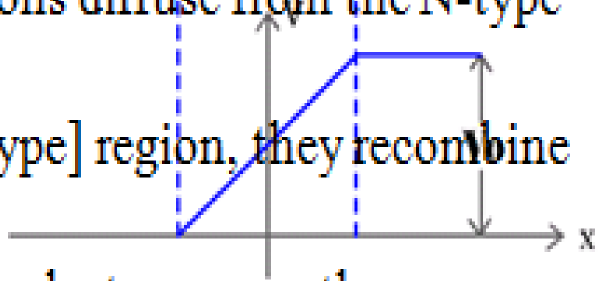
What happens when P-type meets N-type?



PN Junction



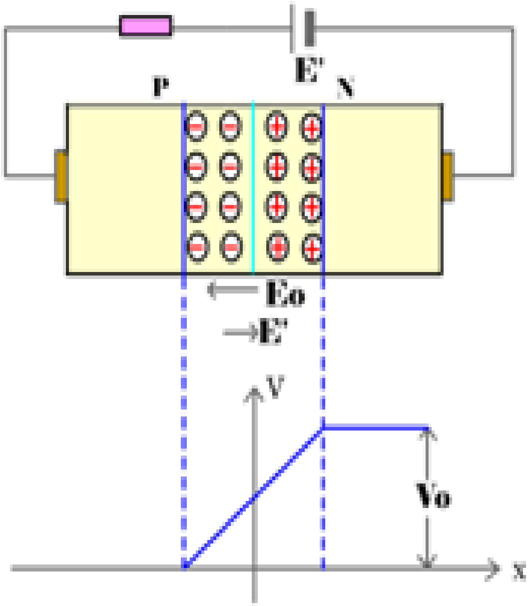
What happens when P-type meets N-type?



- Holes diffuse from the P-type into the N-type, electrons diffuse from the N-type into the P-type, creating a diffusion current.
- Once the holes [electrons] cross into the N-type [P-type] region, they recombine with the electrons [holes].
- This recombination "strips" the n-type [P-type] of its electrons near the boundary, creating an electric field due to the positive and negative bound charges.
- The region "stripped" of carriers is called the space-charge region, or depletion region.
- V_0 is the contact potential that exists due to the electric field. Typically, at room temp, V_0 is 0.5~0.8V.
- Some carriers are generated (thermally) and make their way into the depletion region where they are whisked away by the electric field, creating a drift current.

PN Junction

Forward bias: apply a positive voltage to the P-type, negative to N-type.



Add more majority carriers to both sides

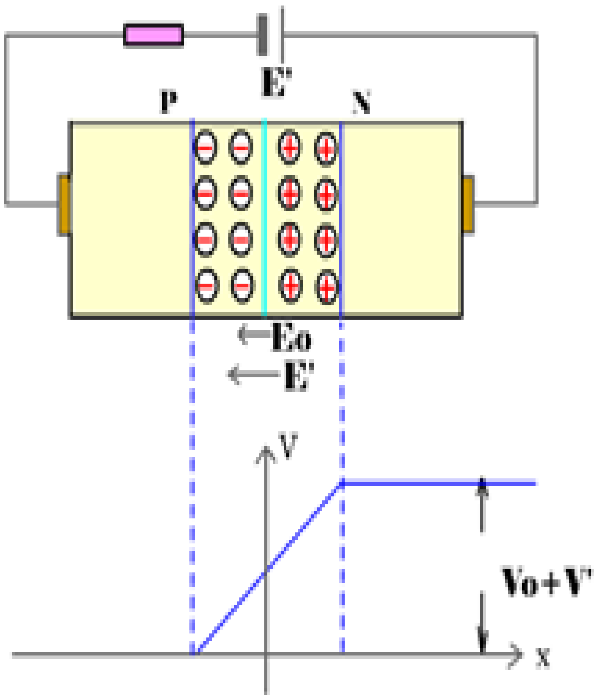
→shrink the depletion region→ lower V_0

→diffusion current increases.

- Decrease the built-in potential, lower the barrier height.
- Increase the number of carriers able to diffuse across the barrier
- Diffusion current increases
- Drift current remains the same. The drift current is essentially constant, as it is dependent on temperature.
- Current flows from p to n

PN Junction

Reverse bias: apply a negative voltage to the P-type, positive to N-type.



- Increase the built-in potential, increase the barrier height.
- Decrease the number of carriers able to diffuse across the barrier.
- Diffusion current decreases.
- Drift current remains the same
- Almost no current flows. Reverse leakage current, I_S, is the drift current, flowing from N to P.