DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB103J -SEMICONDUCTOR PHYSICS

Module-II

Lecture-IX- SLO1,SLO2

Metal-semiconductor junction
Ohmic Contact and Schottky Junction

Metal-semiconductor junction
Ohmic Contact and Schottky Junction

- The metal semiconductor junction is the oldest practical semiconductor device.
- It can be either rectifying or non-rectifying.
- The rectifying semiconductor junction is called as Schottky diode and the non-rectifying junction is called as ohmic contact.

Rectifying Junction or Schottky Junction

Whenever, the work function of n type semiconductor is smaller than that of metal or the work function of p type semiconductor is greater than that of metal, it forms rectifying or Schottky junction.

Let ϕ_m and ϕ_s be the work function of metal and n type semiconductor , respectively where $\phi_m > \phi_s$.

When metal semiconductor contact is made, the conduction electrons begin to flow from the semiconductor in to the metal until the Fermi energies on both sides of the junction becomes equal. Therefore, metal becomes negative charged and the n-type semiconductor becomes positive charged. As a result potential barrier is formed at the metal semiconductor junction equal to $\phi_m - \phi_S = eV$.

When potential is applied to the system after contact such that

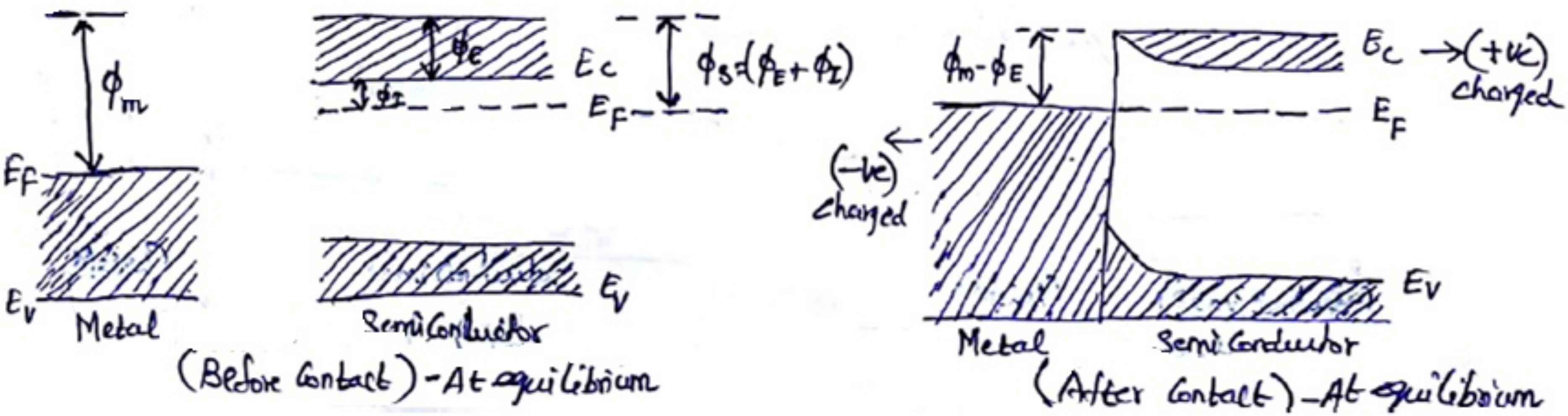
N-type is connected to positive charge and metal to negative charge, **the height of the barrier on the semiconductor side increases by (V_s +V)** and the metal remains unchanged. Therefore the junction is said to be **reverse biased** and the current flows from metal to semiconductor.

Rectifying Junction or Schottky Junction

Conversely if the voltage is reversed, so as to make semiconductor negative charge and metal positive charge, the **height of the barrier on the semiconductor side decreases by (V_s –V)** and the metal remains unchanged. Therefore the junction is said to be **forward biased** and the current flows from semiconductor to metal.

For forward bias the net current increases exponentially with applied voltage and for reverse bias, the net current is constant. Hence, the metal semiconductor contact acts like a rectifier i.e. it conducts in forward bias but not in reverse bias and hence called as rectifying contact.

Rectifying Junction or Schottky Junction



Rectifying Junction or Schottky Junction

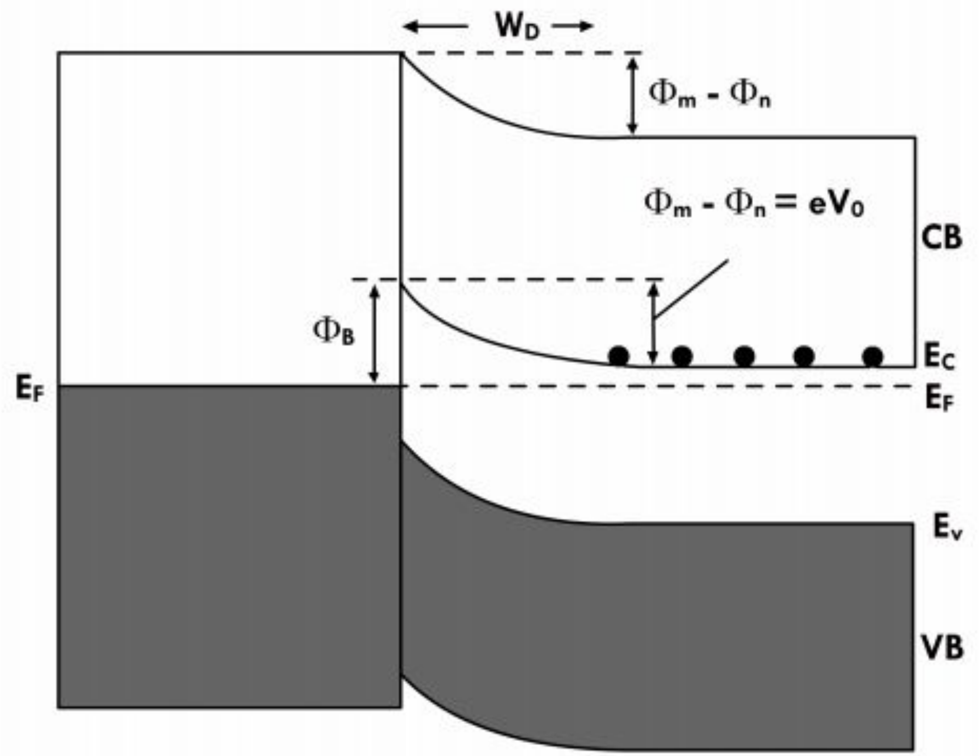


Figure 8: Schottky junction showing the band bending on the semiconductor side. Semiconductor bands bend up going from the semiconductor (positive) to metal (negative) since this is the same direction as the electric field. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

Rectifying Junction or Schottky Junction

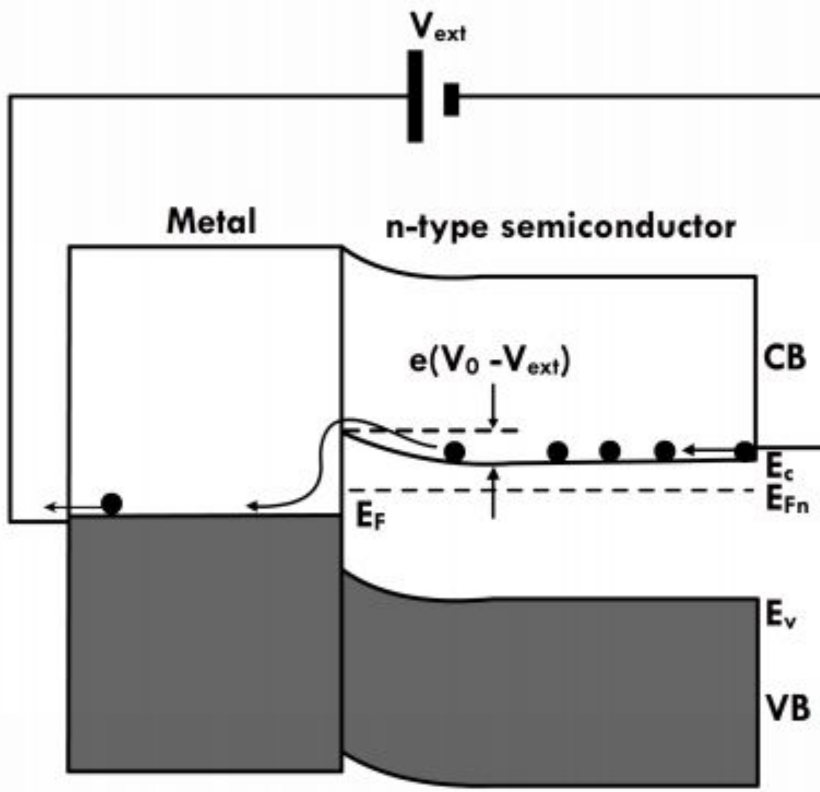


Figure 9: Schottky junction under forward bias. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

Rectifying Junction or Schottky Junction

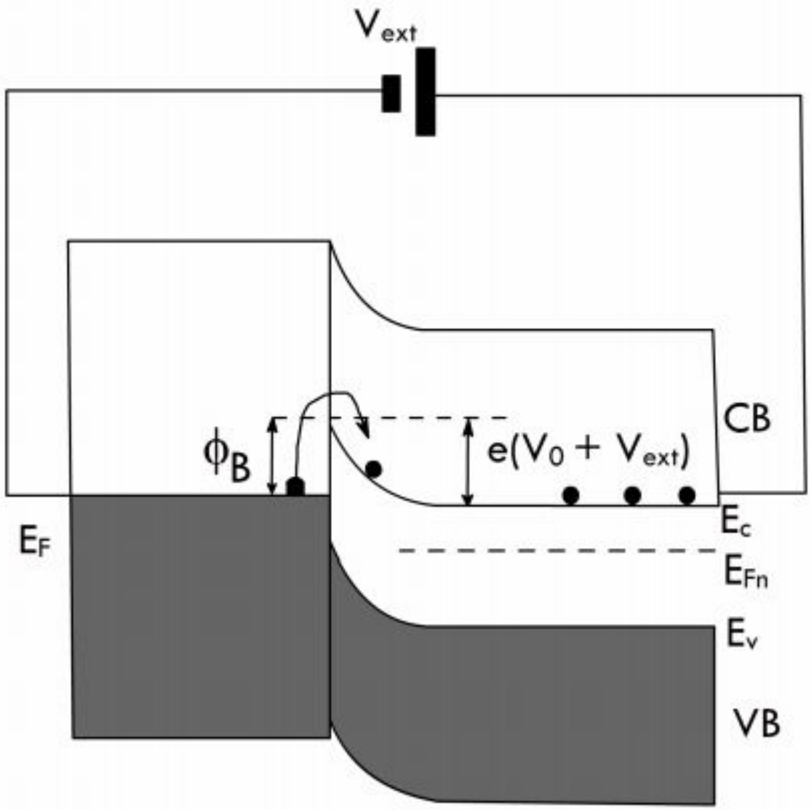


Figure 10: Schottky junction under reverse bias. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

https://nptel.ac.in/content/storage2/courses/113106065/Week%204/Lesson9.pdf

Rectifying Junction or Schottky Junction

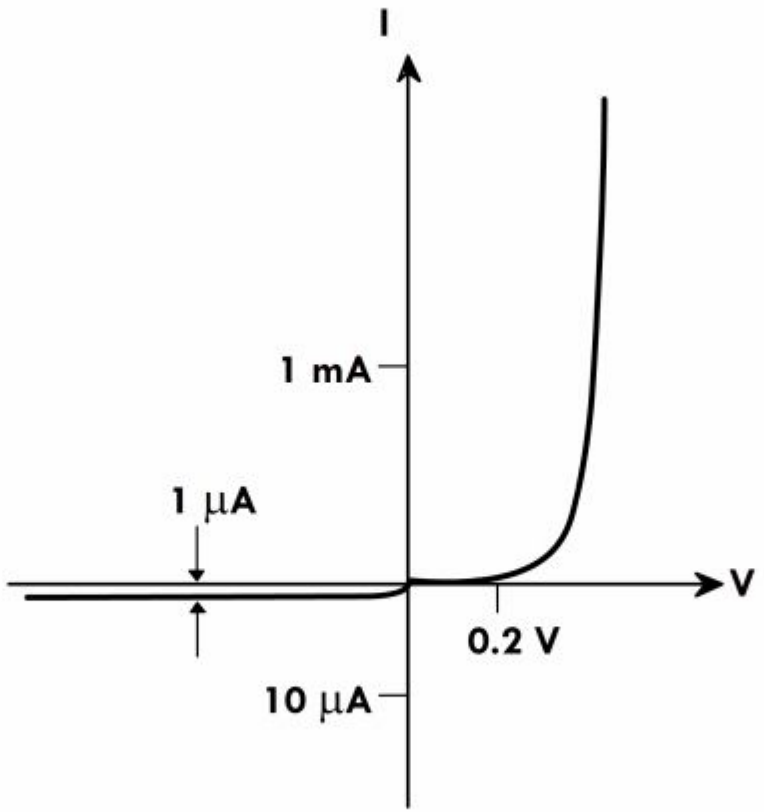


Figure 11: $I - V$ characteristics of a Schottky junction showing rectifying properties. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

Non-Rectifying Junction or Ohmic Junction

Whenever, the work function of metal is smaller than that of n type semiconductor it forms non rectifying or ohmic junction.

Let ϕ_m and ϕ_s be the work function of metal and n type semiconductor , respectively where $\phi_m < \phi_s$.

When metal semiconductor contact is made, the conduction electrons begin to flow from the metal to semiconductor until the Fermi energies on both sides of the junction becomes equal. Therefore, metal becomes positive charged and the n-type semiconductor becomes negative charged. As a result potential barrier is formed at the metal semiconductor junction equal to $\phi_S - \phi_m$ =eV.

When potential is applied to the system after contact such that

N-type is connected to positive charge and metal to negative charge, the electrons flow from semiconductor to metal without encountering an appreciable barrier.

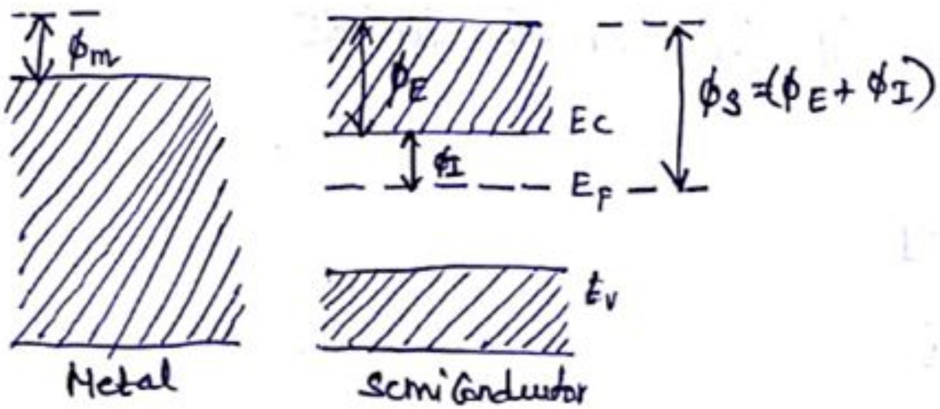
Non-Rectifying Junction or Ohmic Junction

Conversely if the voltage is reversed, so as to make semiconductor negative charge and metal positive charge, the electrons flow from metal to semiconductor without any change in barrier.

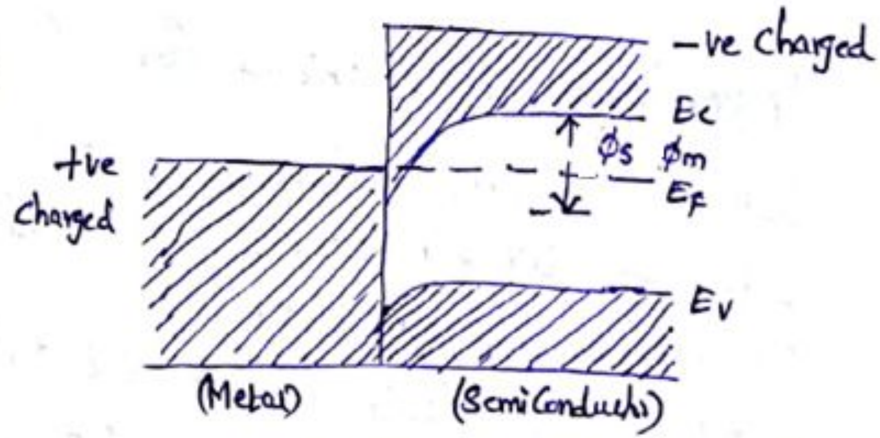
Thus in both the cases the current is directly proportional to the applied voltage in accordance with ohms law. Such contacts are called as ohmic contacts.

Thus, a Ohmic junction behaves as a resistor conducting in both forward and reverse bias. The resistivity is determined by the bulk resistivity of the semiconductor.

Non-Rectifying Junction or Ohmic Junction



Before Contact - (At equilibrium)



After Contact - (At equilibrium)

Non-Rectifying Junction or Ohmic Junction

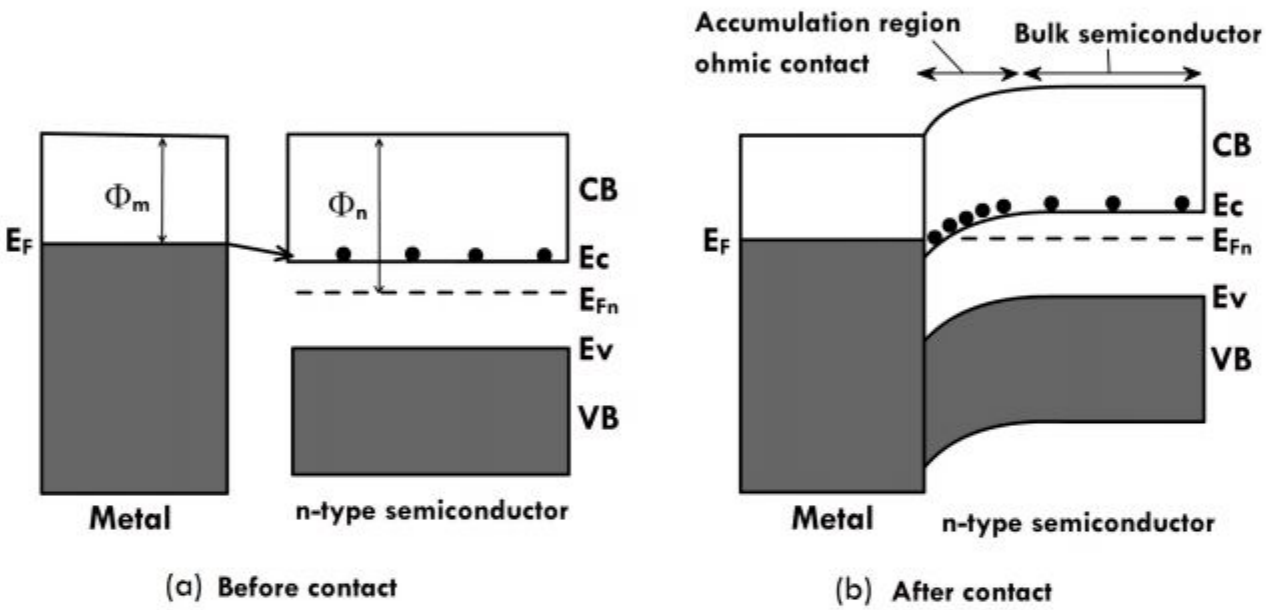


Figure 13: Ohmic junction (a) before and (b) after contact. Before contacts the Fermi levels are at different positions and they line up on contact to give an accumulation region in the semiconductor. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

Rectifying Junction or Schottky Junction

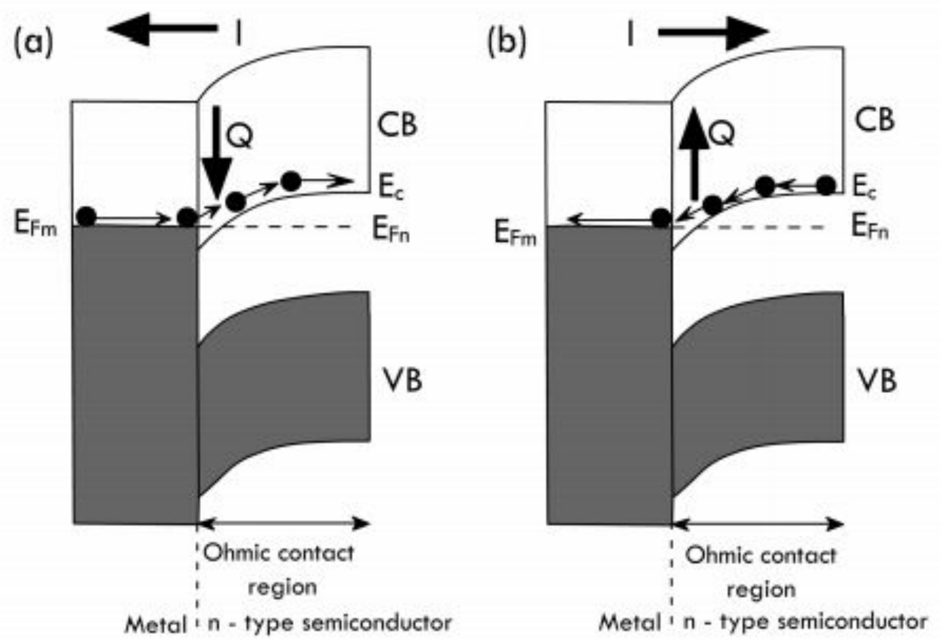


Figure 14: Current flow through an Ohmic junction can lead to heat (a) absorption or (b) release. This depends on the external bias, that determines the direction of heat flow. When electrons move from metal to higher energy levels in the semiconductor heat is absorbed and the reverse happens when electrons flow from semiconductor to metal. Adapted from *Principles of Electronic Materials - S.O. Kasap.*

THANK YOU FOR LISTENING