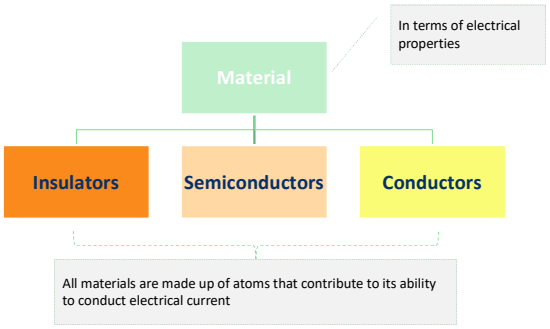
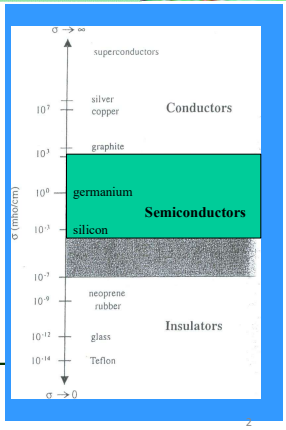
Semiconductors, conductors and insulators



1

Semiconductor

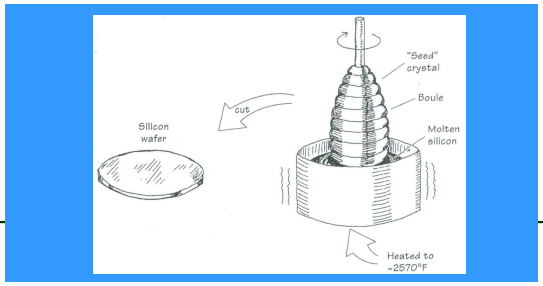
- Materials that permit flow of electrons are called conductors (e.g., gold, silver, copper, etc.).
- Materials that block flow of electrons are called insulators (e.g., rubber, glass, Teflon, mica, etc.).
- Materials whose conductivity falls between those of conductors and insulators are called semiconductors.
- Semiconductors are "part-time" conductors whose conductivity can be controlled.



2

Semiconductor

- Silicon is the most common material used to build semiconductor devices.
- Si is the main ingredient of sand and it is estimated that a cubic mile of seawater contains 15,000 tons of Si.
- Si is spun and grown into a crystalline structure and cut into wafers to make electronic devices.



3

Semiconductor Materials

Materials commonly used in the development of semiconductor devices:

- **Silicon (Si)**
- **Germanium (Ge)**
- **Gallium Arsenide (GaAs)**

4

Doping

The intrinsic semi-conductive materials are improved by adding materials in a process called doping.

There are just two types of doped semiconductor materials:

***n*-type *p*-type**

- ***n*-type materials contain an excess of conduction band electrons.**
- ***p*-type materials contain an excess of valence band holes.**

5

N-Type and P-Type Semiconductors

N-Type Semiconductor

- Is formed by adding **pentavalent** (**5valence $\bar{e}$**) impurity atoms.
- To **increase the number of free electrons**.
- 1 **extra electrons becomes a conduction electrons** because it is **not attached to any atom**.
- Pentavalent atom **gives up (donate) an electron** – call a ***donor atom***.

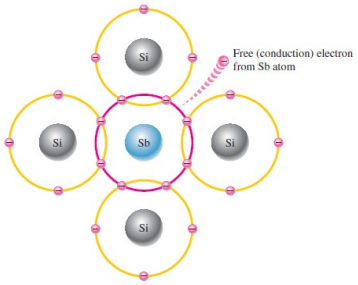


Figure 8: Pentavalent impurity atom in a silicon crystal structure. An antimony (Sb) impurity atom is shown in the center. The extra electron from the Sb atom becomes a free electron.

6

N-Type and P-Type Semiconductors

N-Type Semiconductor

- No. of conduction electrons can be controlled by the no. of impurity atoms.
- Since **most of the current carriers are electrons**, semiconductor doped with pentavalent atoms is an ***n-type*** semiconductor.
- The **electrons** are called the ***majority carriers***, while the **holes** is ***minority carriers***.

7

N-Type and P-Type Semiconductors

P-Type Semiconductor

- Is formed by adding **trivalent** (**3valence $\bar{e}$**) impurity atoms.
- To **increase the number of hole**.
- A**hole is created** when each trivalent atom is added.
- Because the **trivalent atom can take an electron**, it is often referred to as an ***acceptor atom***.
- No. of holes can be controlled by the no. of trivalent impurity atoms.
- Since **most of the current carriers are holes**, semiconductor doped with trivalent atoms is an ***p-type***semiconductor.
- The **holes**are called the ***majority carriers***, while the **conduction electrons**is ***minority carriers***.

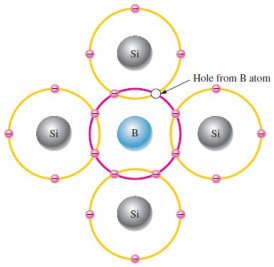


Figure 9: Trivalent impurity atom in a silicon crystal structure. A boron (B) impurity atom is shown in the center.

8

Majority and Minority Carriers

Two currents through a diode:

Majority Carriers

- **The majority carriers in *n*-type materials are electrons.**
- **The majority carriers in *p*-type materials are holes.**

Minority Carriers

- **The minority carriers in *n*-type materials are holes.**
- **The minority carriers in *p*-type materials are electrons.**

9