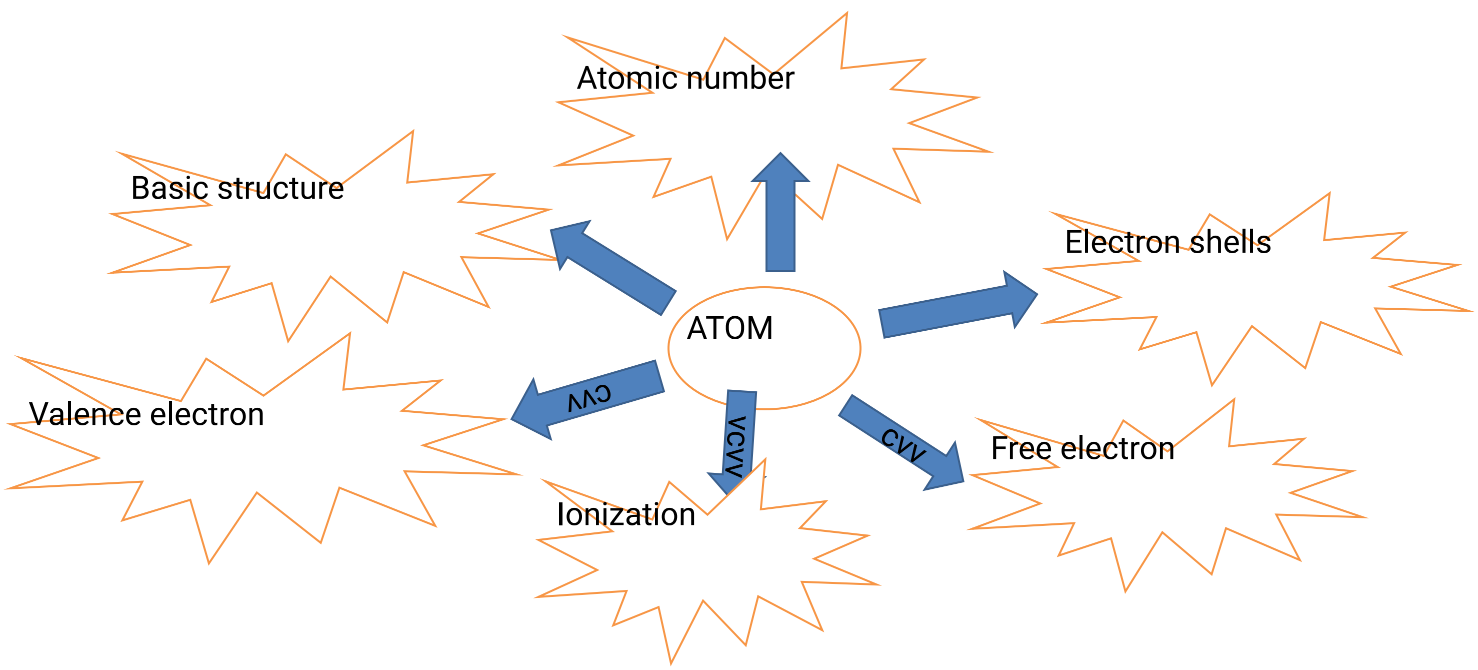
INTRODUCTION to SEMICONDUCTORS

. LECTURE'S CONTENT

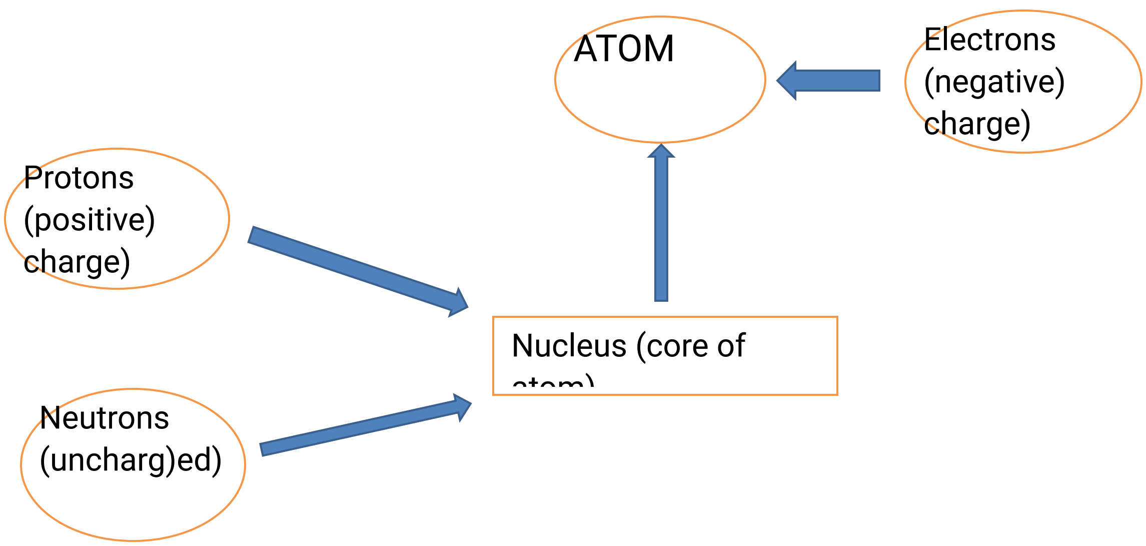
1.1 Atomic structure
1.2 Semiconductor, conductors and insulators
1.3 Covalent bonding
1.4 Conduction in semiconductors
1.5 N-type and P-type semiconductors

1.1 Atomic Structure



1.1 Atomic Structure

smallest particle of an element contain 3 basic particles:



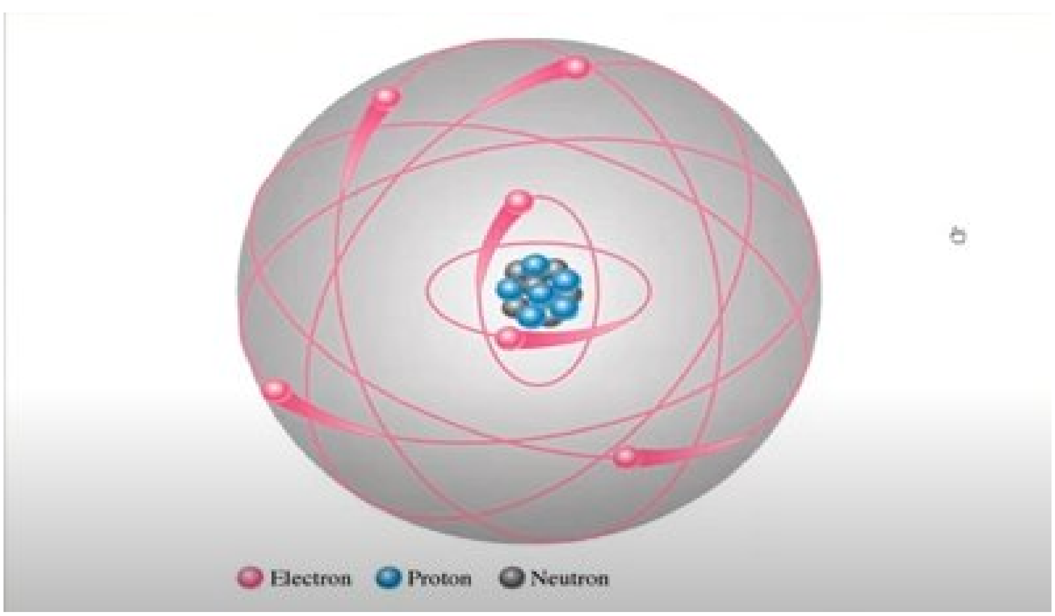


Figure Bohr model of an atom

1.1 Atomic Structure (cont.)

Atomic Number Element in periodic table are arranged according to atomic

number Atomic number = number of protons in nucleus

Electron Shells and Orbits

- Electrons near the nucleus have less energy than those in more

- distant orbits. Each distance (orbits) from the nucleus corresponding to a certain energy level.

- In an atom, the orbits are group into energy bands - shells
- Diff. in energy level within a shell << diff. in energy between shells.

Valence Electrons

- Electrons with the highest energy levels exist in the outermost shell and loosely bound to the atom. The outermost shell
- Electron in the valence shell called valence electrons.

1.1 Atomic Structure (cont.)

Atomic Number Element in periodic table are arranged according to atomic

number Atomic number = number of protons in nucleus

Electron Shells and Orbits

Electrons near the nucleus have less energy than those in more

distant orbits. Each distance (orbits) from the nucleus corresponding to a certain energy level.

In an atom, the orbits are group into energy bands - shells Diff. in energy level within a shell << diff. in energy between shells.

Valence Electrons

Electrons with the highest energy levels exist in the outermost shell and loosely bound to the atom. The outermost shell - Electron in the valence shell called valence electrons.

Ionization

- When atoms absorb energy (e.g heat source) - losing valence electrons called ionization.

- Escape electron called free electron.

The Number of Electrons in Each Shell

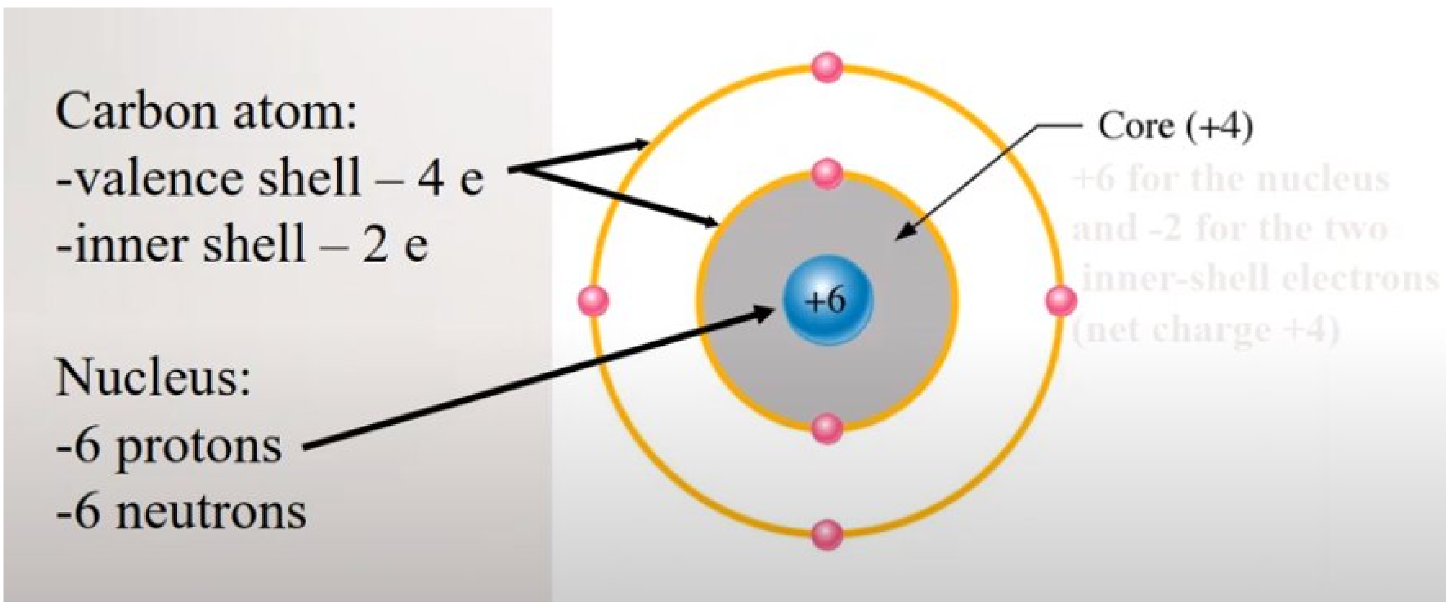
- The maximum number of electrons (N) in each shell is calculated using formula below:

- N = number of shell

- Example for 2nd shell

1.2 Semiconductors, Conductors, and Insulators

- Atom can be represented by the valence shell and a core
- A core consists of all the inner shell and the nucleus



1-2 Semiconductors, Conductors, and Insulators (cont.)

Conductors

- material that easily conducts electrical current.

• The best conductors are single-element material (e.g copper, silver, gold, aluminum)

• Only one valence electron very loosely bound to the atom- free electron

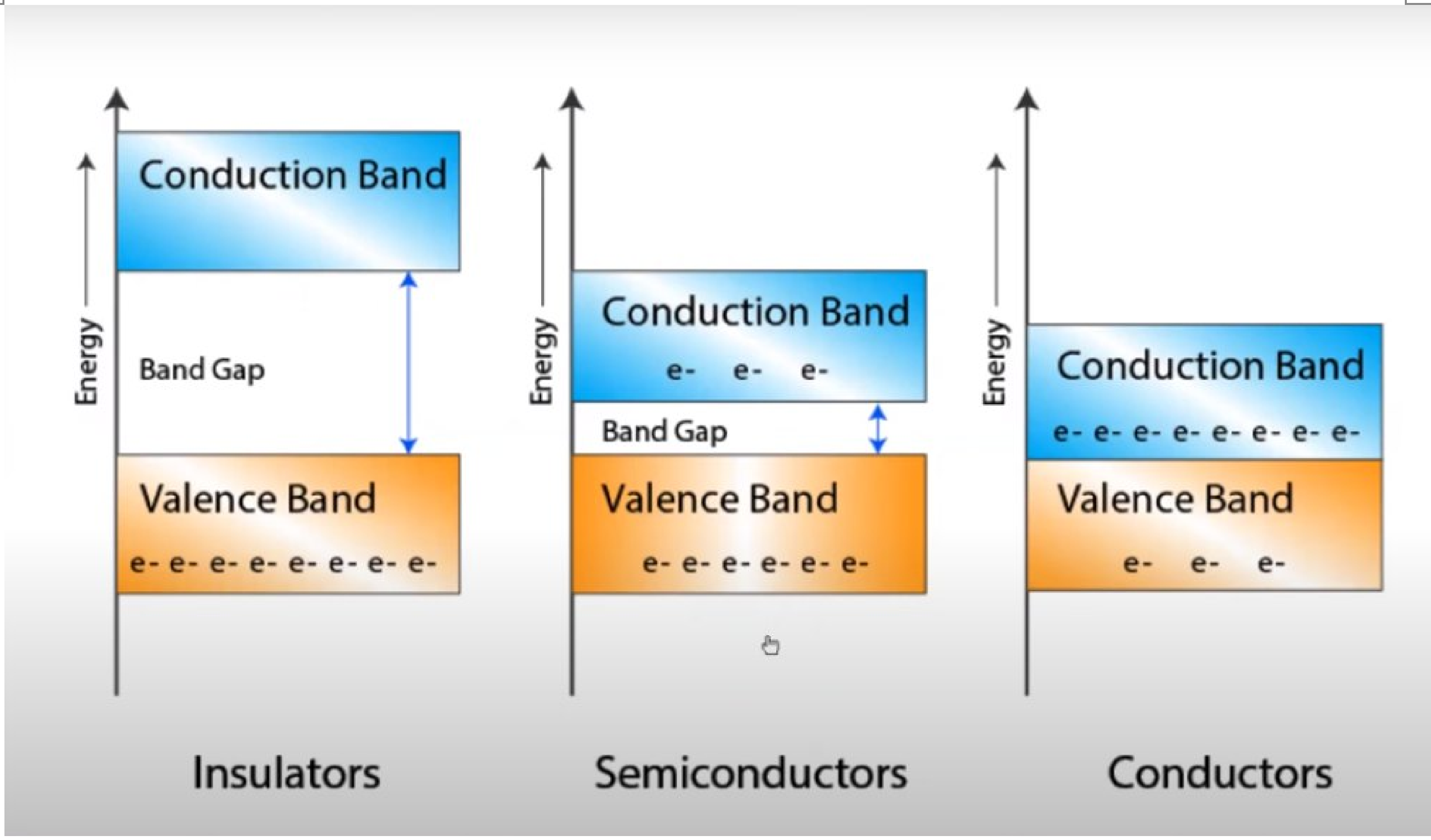
Insulators

• material does not conduct electrical current

• valence electron are tightly bound to the atom - very few free electron

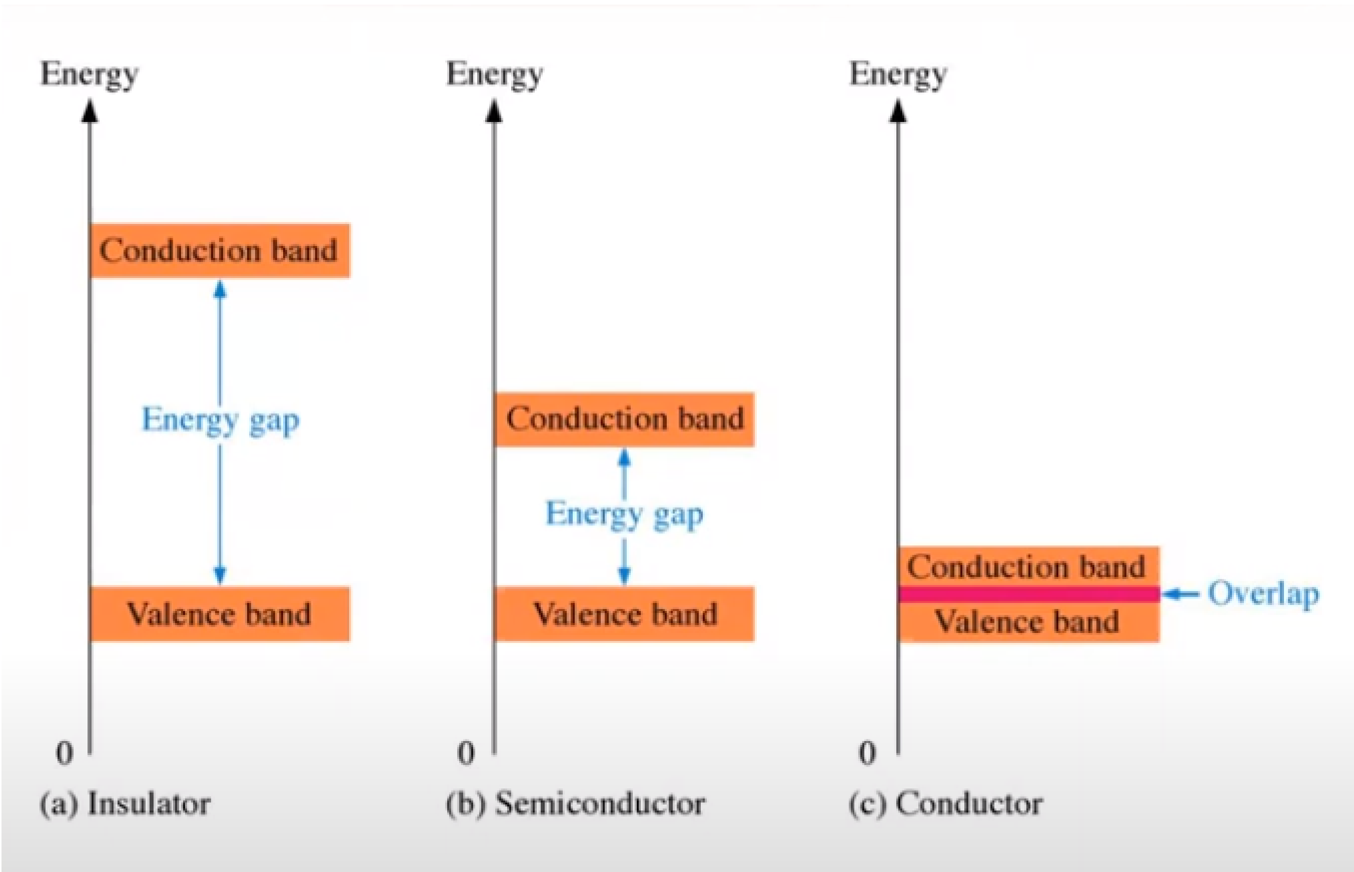
Semiconductors

• material between conductors and insulators in its ability to conduct electric current
- In its pure (intrinsic) state is neither a good conductor nor a good insulator
- most common semiconductor-silicon(Si), germanium(Ge), and carbon(C) which contains four valence electrons.


Energy
Conduction Band
Band Gap
Valence Band
e- e- e- e- e- e- e- e-
Insulators
Energy
Conduction Band
e- e- e-
Band Gap
Valence Band
e- e- e- e- e- e-
Semiconductors
Energy
Conduction Band
e- e- e- e- e- e- e- e-
Valence Band
e- e- e-
Conductors

1-2 Semiconductors, Conductors, and Insulators (cont.)

Energy Bands



- Energy gap-the difference between the energy levels of any two orbital shells
- Band-another name for an orbital shell (valence shell-valence band)
- Conduction band -the band outside the valence shell where it has free electrons.

1-2 Semiconductors, Conductors, and Insulators (cont.)

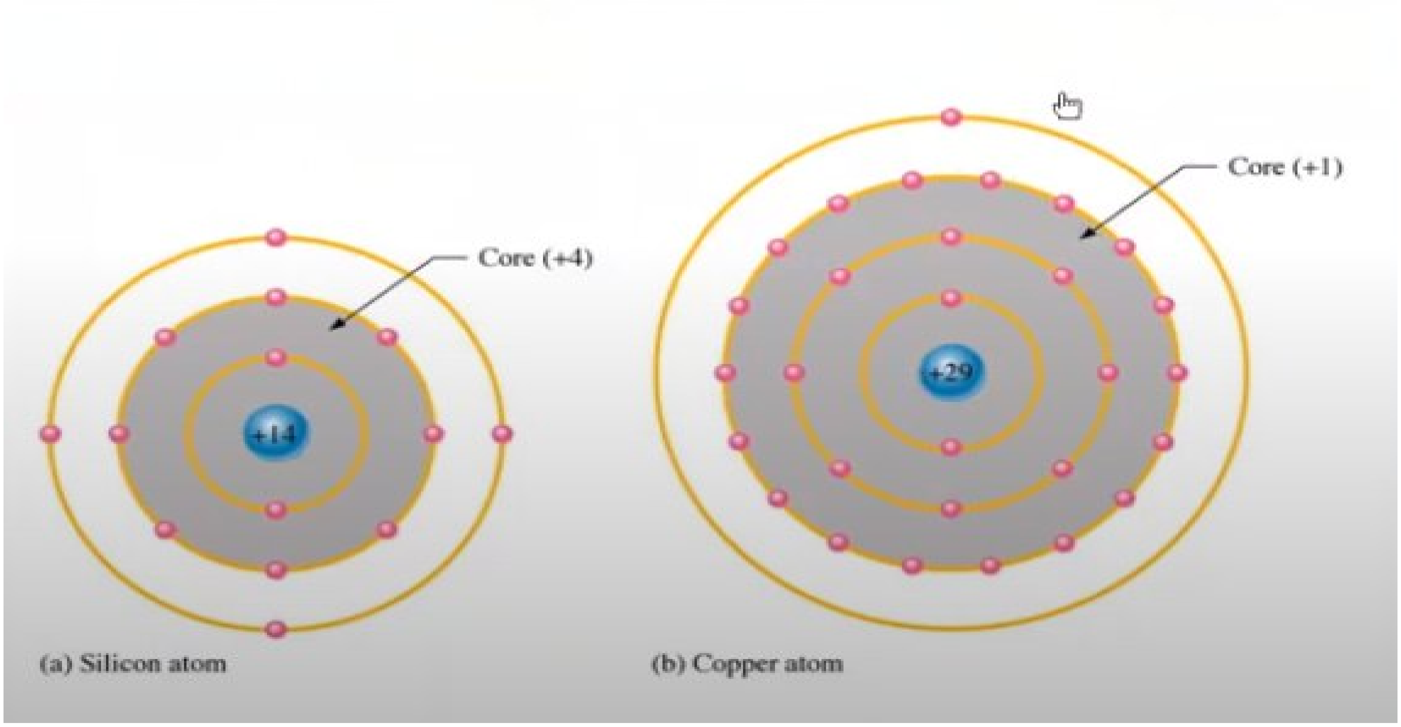
Comparison of a Semiconductor Atom & Conductor Atom

A Silicon atom:

- 4 valence electrons
- A semiconductor
- Electron conf.: 2:8:4

A Copper atom:

- Only 1 valence electron
- A good conductor Electron
- Electron conf.:2:8:18:1



(a) Silicon atom (b) Copper atom

14 protone 29 protons

14 nucleus
29nucleus

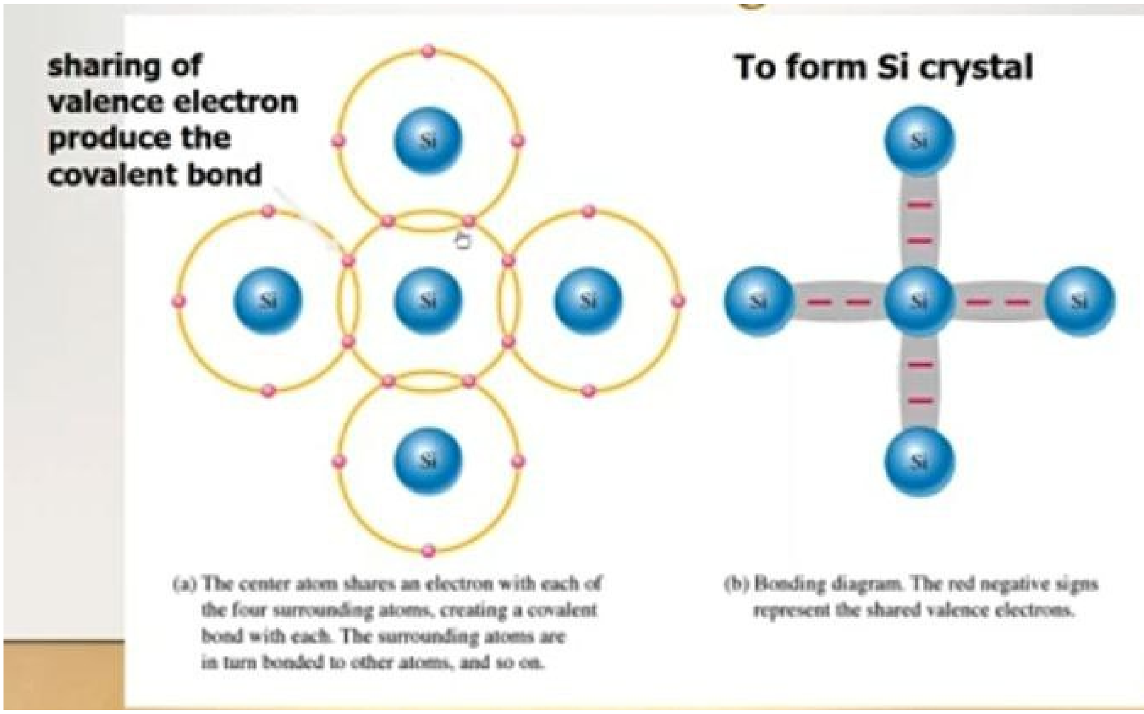
10 electrons 28electrons 2
electrons

in inner shell inner shell

1-3 Covalent Bonding

Covalent bonding-holding atoms together by sharing valence electrons

- sharing of valence electron produce the covalent bond



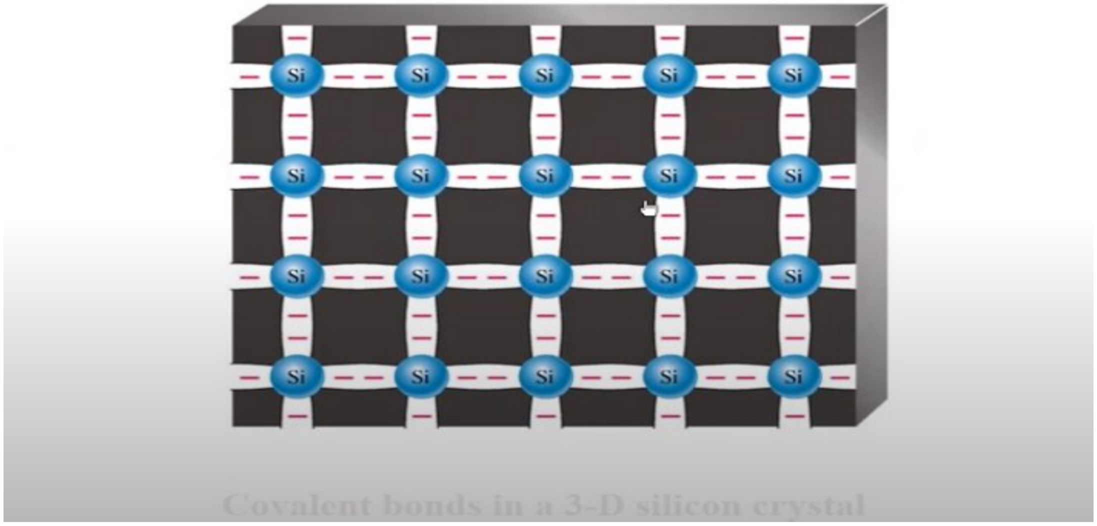
1-3 Covalent Bonding (cont.)

Result of the bonding:

1. The atom are held together forming a solid substrate.
2. The atoms are all electrically stable, because their valence shells are complete.
3. The complete valence shells cause the silicon to act as an insulator-intrinsic (pure) silicon. In other word, it is a very poor conductor

1-3 Covalent Bonding (cont.)

- Covalent bonding in an intrinsic or pure silicon crystal. An intrinsic crystal has no impurities.



1-4 Conduction in Semiconductor

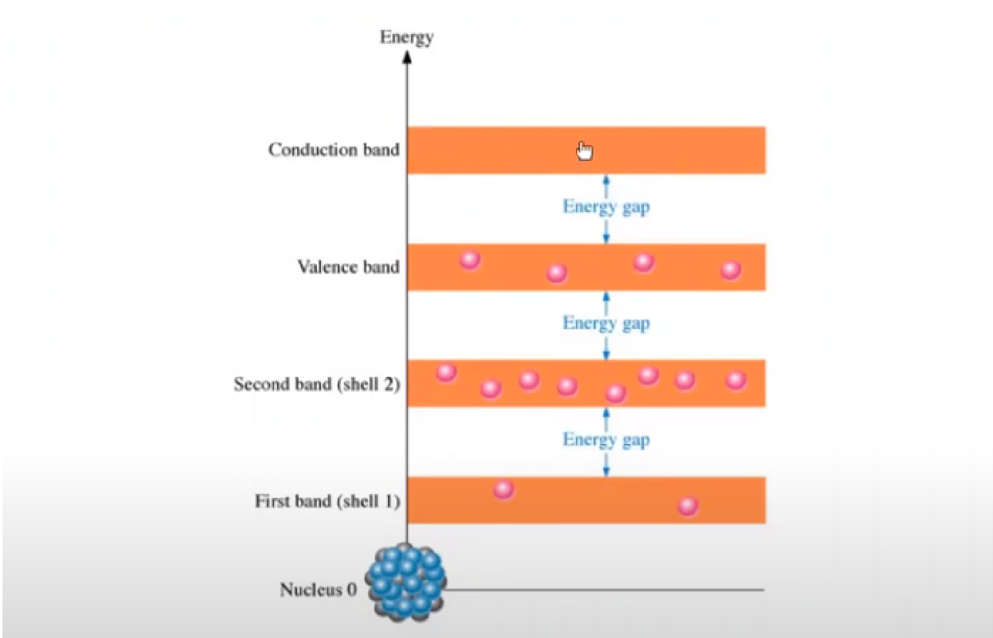


Figure Energy band diagram for a pure (intrinsic) silicon crystal with unexcited (no external energy such as heat) atoms. There are no electrons In the conduction band. This condition occurs only at a temperature of absolute 0 Kelvin.

1-4 Conduction in Semiconductor (cont.) Conduction Electrons and Holes

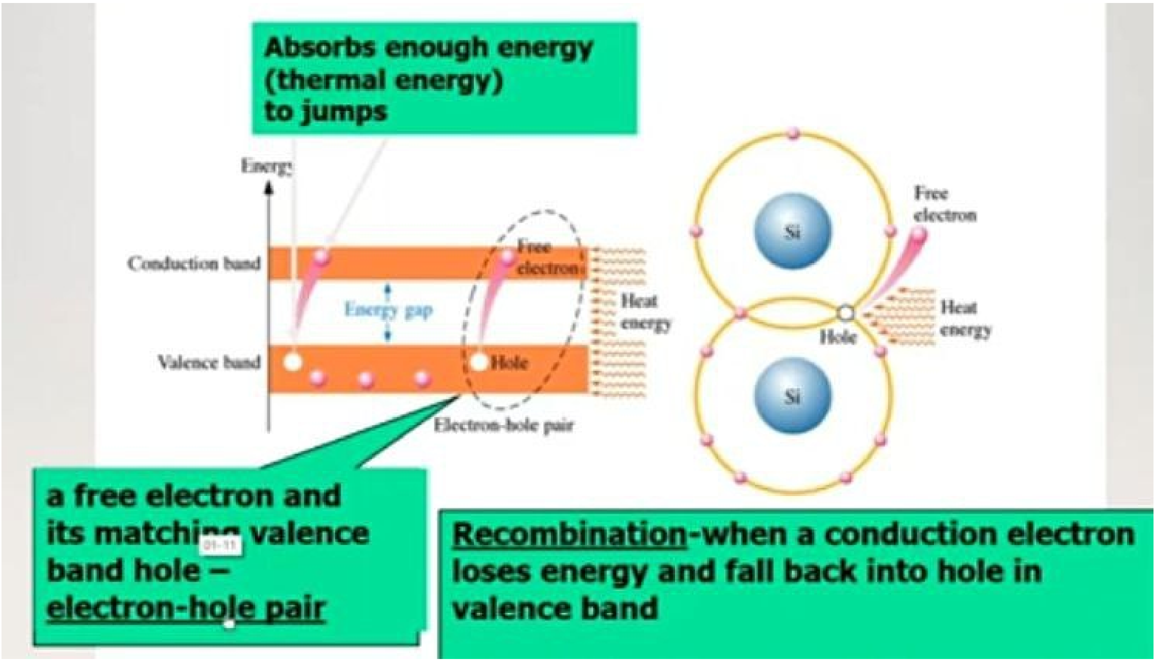


Figure Creation of electron-hole pairs in a silicon crystal. Electrons in the conductor band are free (also called conduction electrons).

1-4 Conduction in Semiconductor (cont.) Conduction Electrons and Holes

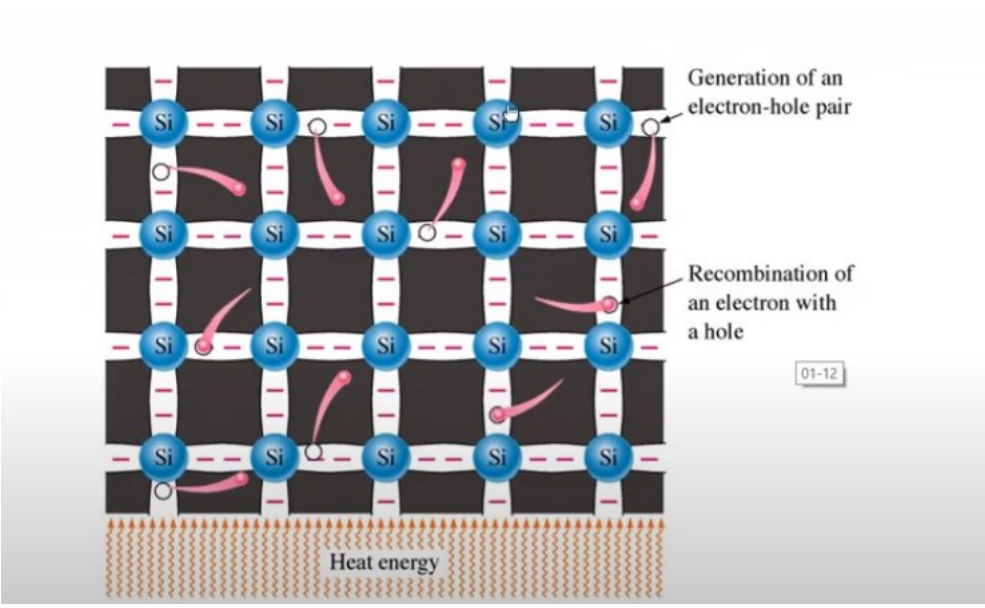


Figure Electron-hote pairs in a silicon crystal. Free electrons are being generate continuously while some recombine with holes.

1-4 Conduction in Semiconductor (cont.) Electrons and Holes Current

- When a voltage is applied, free electrons are free to move randomly and attracted toward +ve end. The movement of electrons is one type of current in semiconductor and is called electron current.

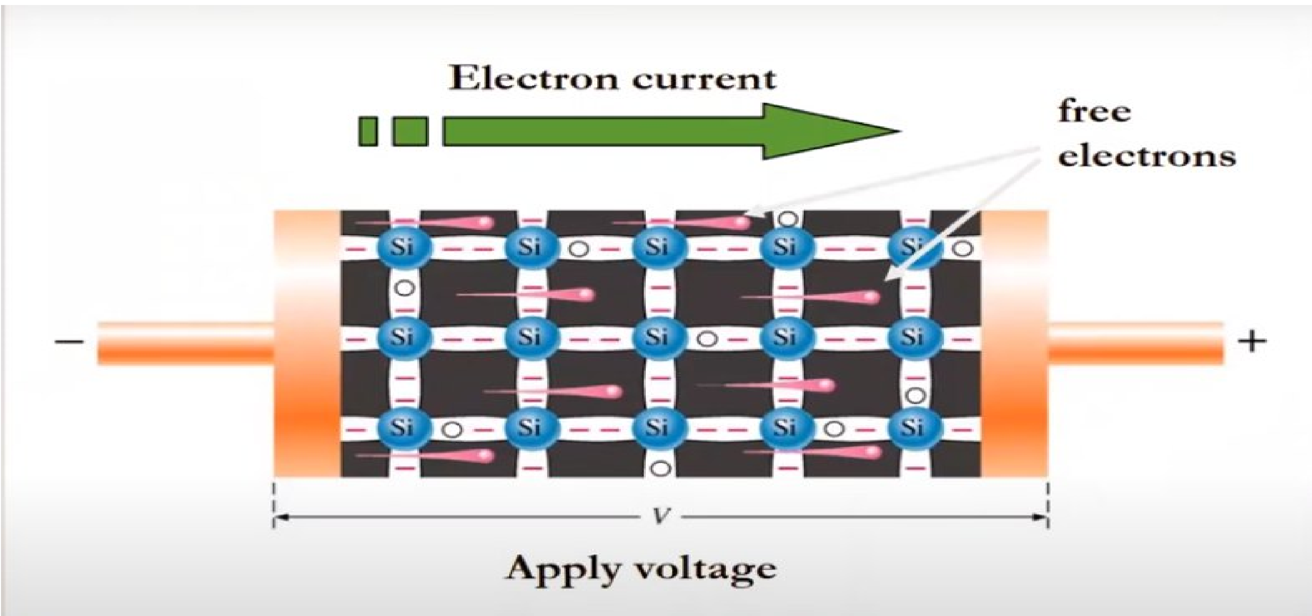
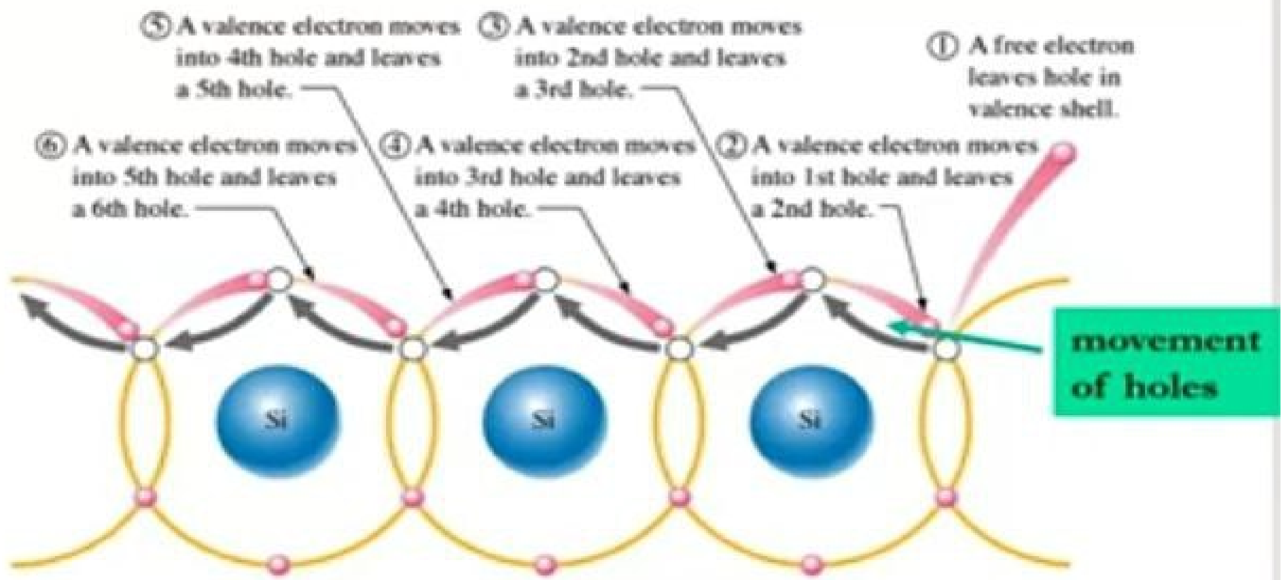


Figure Electron current in intrinsic silicon is produced by the movement of therma generated free electrons.

1-4 Conduction in Semiconductor (cont.)movement of holes



When a valence electron moves left to right to fill a hole while leaving another hole behind, the hole has effectively moved from right to left. Gray arrows indicate effective movement of a hole.

1-5 N-type and P-type Semiconductors

<u>Doping</u>

- The process of creating N and P type materials
- By adding impurity atoms to intrinsic Si or Ge to improve the conductivity of the semiconductor
- Two types of doping - trivalent (3 valence e-) & pentavalent (5 valence e-)

p-type material - a semiconductor that has added trivalent impurities n-type material - a semiconductor that has added pentavalent

impurities

Trivalent Impurities:

- Aluminum (Al)
- Gallium(Ga)
- Boron(B)
- Indium(In)

Pentavalent Impurities:

- Phosphorus (P)
- Arsenic(AS)
- Antimony(Sb)
- Bismuth (Bi)

1-5 N-type and P-type Semiconductors (cont.)

N-type semiconductor:

Pentavalent impurities are added to Si or Ge, the result is an increase of free electrons

1 extra electrons becomes a conduction electrons because it is not

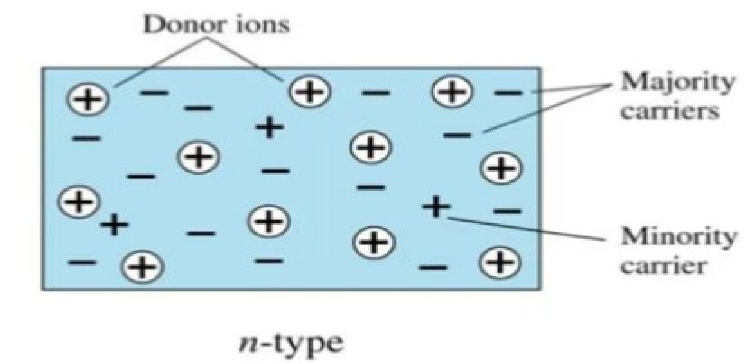
attached to any atom

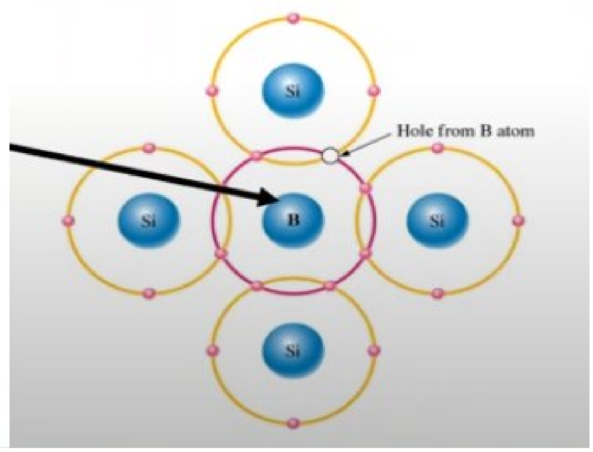
No. of conduction electrons can be controlled by the no. of impurity atoms

Pentavalent atom gives up an electron -call a donor atom

Current carries in n-type are electrons - majority carriers

Holes minority carriers (holes created in Si when generation of electron-holes pair





sb impurity atom

Pentavlent impurty atom in a Sicrysal

1-5 N-type and P-type Semiconductors (cont.)

<u>P-type semiconducto</u>r:

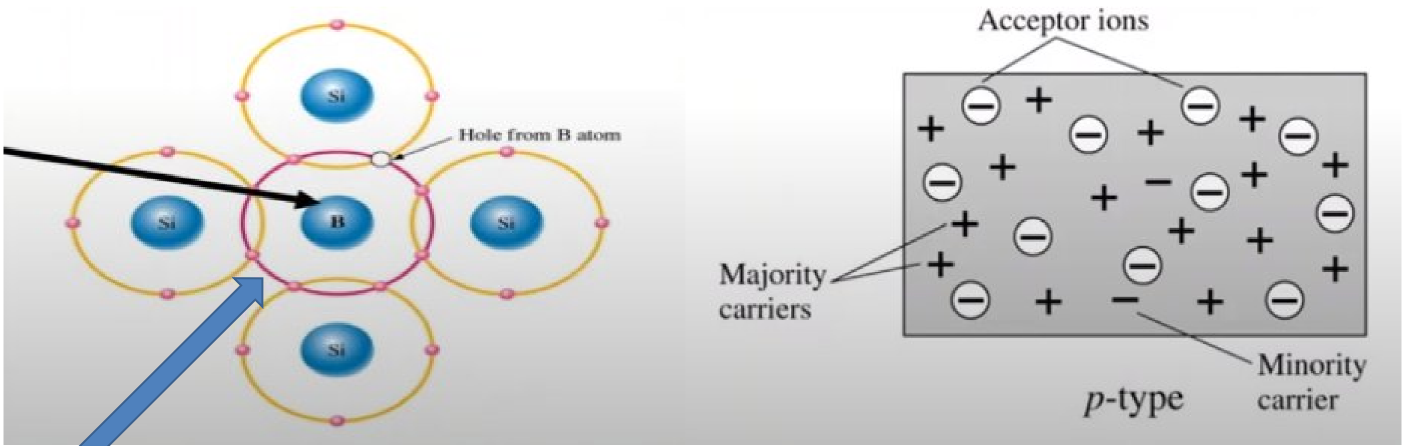
Trivalent impurities are added to Si or Ge to increase number of holes.

Boron, indium and gallium have 3 valence e- form covalent bond with 4 adjacent silicon atom. A hole created when each trivalent atom is added.

The no. of holes can be controlled by the no. of trivalent impurity atoms

The trivalent atom can take an electron- acceptor atom Current carries in p-type are holes majority carries

electrons minority carries (created during electron-holes pairs generation).



sb impurty atom

Trivalent impurity atom in a Si crystal

Summary

• An n-type semiconductive material is created by adding impurity atoms that have five valence electrons. A p-type semiconductor is created by adding impurity atoms with only three valence electrons.

• The process of adding pentavalent or trivalent impurities to a semiconductor is called doping.

• A pn junction is formed when part of a material is doped n-type and part of it is doped p-type. A depletion region forms starting at the junction that is devoid of any majority carriers. The depletion region is formed by ionization.

• The barrier potential is typically 0.7 V for a silicon diode and 0.3 V for germanium.

Review Questions

- Define doping.
- How is an n -type semiconductor formed?
- By what process are the majority carriers produced?
- By what process are the minority carriers produced?
- What is the difference between intrinsic and extrinsic semiconductors?
- What is a pn junction?
- Explain diffusion.
- Describe the depletion region.
- Explain what the barrier potential is and how it is created.

كلية المامون الجامعة

هندسة تقنيات القدرة الكهربائية

المرحلة الثالثة

1

الكترونيك القدرة

الاستاذ احمد ابراهيم