Nanotechnology Course/ Ph-457 Lecture 2

Chapter 1:
Fundamentals Properties of Nanomaterials

By

Dr. Marwah Jawad Kadhim

Conductors, Semiconductors and Isolators

❖ Conductivity

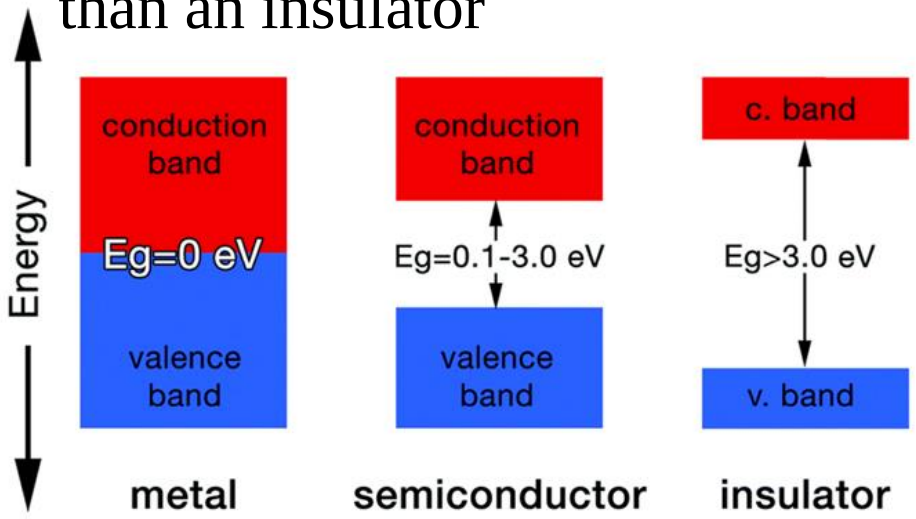
An electrical conductor is a substance in which electrical charge carriers, usually electrons, move easily from atom to atom with voltage application.

- **Metals are good conductors**
- **A saturated salt-water solution acts as a fair conductor.**
- Gases are normally poor conductors because the atoms are too far apart to allow a free exchange of electrons. However, if a sample of gas contains many ions, it can act as a fair conductor.

Conductors, Semiconductors and Isolators

Semiconductors are crystalline or amorphous solids with distinct electrical characteristics. They have higher resistance than typical resistance materials but are much lower than insulators. Their resistance decreases as their temperature increases, which is behavior opposite to that of a metal.

Semiconductors have band gap values less than 3 eV and insulators have band gap values greater than 3 eV. **ZnO** is normally considered a broader band gap semiconductor rather than an insulator



Morab et al., Coatings (2023), 13(9):1657

Conductors, Semiconductors and Isolators

❖ Atomic Structures

- Atomic Number

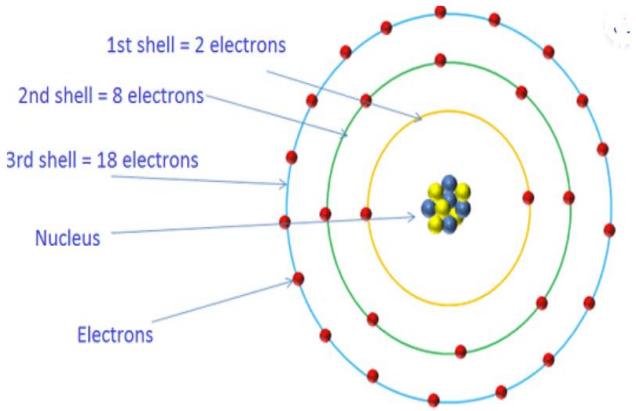
✓ Elements in the periodic table are arranged according to atomic number

✓ Atomic number = NO. of protons=NO. of electron

- Electron Shells and Orbits

✓ In an atom, the orbits are grouped into energy bands/ shells

✓ Energy increases as the distance from the nucleus increases.



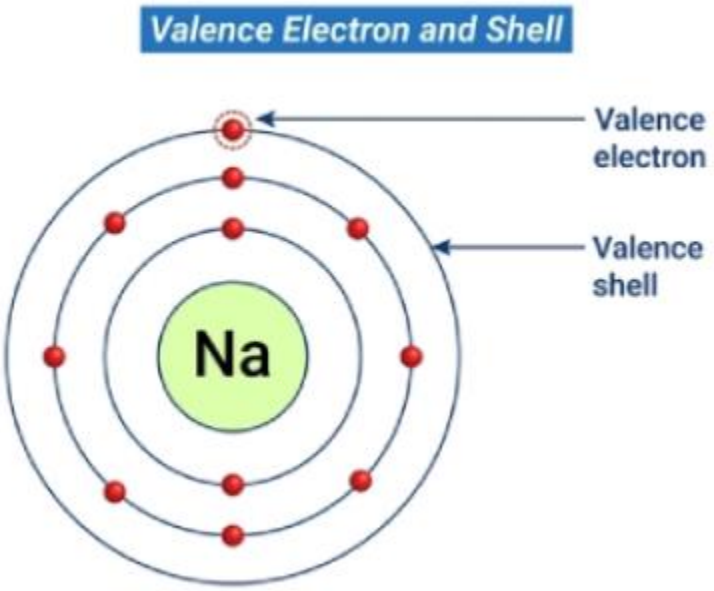
Conductors, Semiconductors and Isolators

- Valence Electrons

✓ Electrons in the valence shell are called valence electrons.

✓ Electrons with the highest energy levels exist in the outermost shell.

✓ The term valence is used to indicate the potential required to remove any one of these electrons.



Conductors, Semiconductors and Isolators

- In **conductors**, one valence electron is very loosely bound to the atom-free electron
- **Insolates** have valence electrons tightly bound to the atom – less free electrons. These bonds are difficult to break; consequently, there are no free electrons to participate in current conduction.
- **Semiconductors** contain four valence electrons. Bonds between neighboring atoms in a semiconductor are only moderately strong. Therefore, thermal vibrations may break some bonds. When a bond is broken, an electron is injected from the valence band into the conduction band. This is now a mobile negative charge carrier and the atom from which the electron emerges is left with a negative charge deficiency, i.e., a positive net charge, also called a hole.

Conductors, Semiconductors and Isolators

❖ Measuring the Band-Gap Energy E_g

The band gap E_g can be estimated using the equation: $E_g = \frac{hc}{\lambda}$

Where c, h, and λ are the velocity of light, the Plank constant, and the wavelength of the light, respectively.

H.W

What is a band gap energy if a semiconductor is transparent to light with a wavelength longer than 0.87 µm?

Conductors, Semiconductors and Isolators

❖ **Semiconductors types (Doping)**

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 Impurites:

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

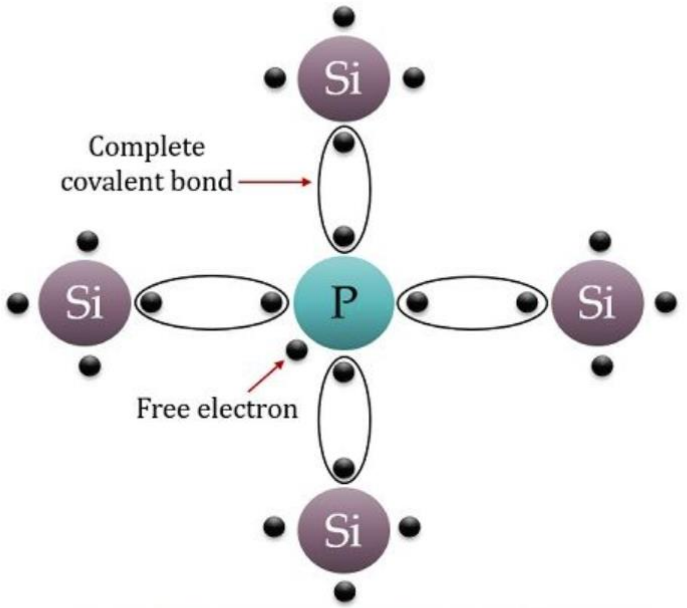
Conductors, Semiconductors and Isolators

- **N-type semiconductor**

Pentavalent impurities are added to Si or Ge, and the result is an

increase the free electrons

- Extra electrons become 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 – the majority carries
- Holes – minority carries



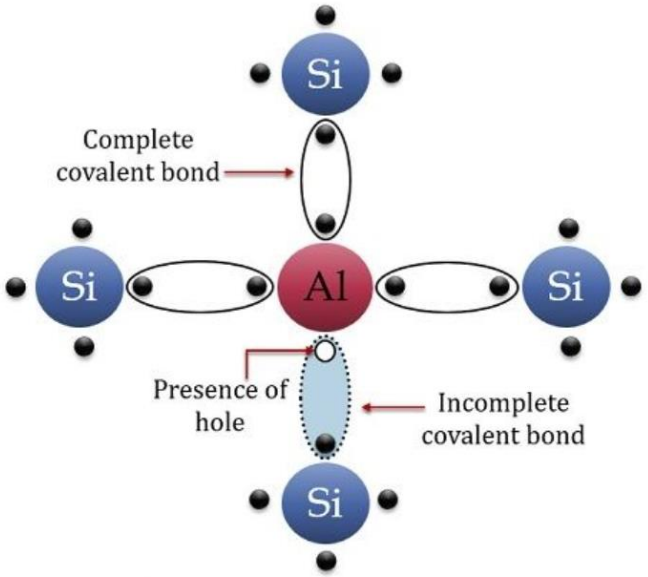
Formation of N type extrinsic semiconductor

Conductors, Semiconductors and Isolators

- **P-type semiconductor**

Trivalent impurities are added to Si or Ge to create a deficiency of electrons or hole charges

- The holes created by the doping process
- The number of holes can be controlled by the number 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



Formation of P type extrinsic semiconductor

THANK YOU