وزارة التعليم العالي والبحث العلمي

هندسة تكنولوجيا الامن السيبراني المرحلة الثانية – الفصل الأول أسس الالكترونيك

Lecture 1

Assist. Lect. Alaa.B.Obaid

What is Electronics Fundamentals ?

Why we study this course in Cyber Security Technology Engineering Department ?

TYPES OF MATERIALS

- Materials are divided into three types according to their conductivity:
  - Conductors – Copper
  - Insulators – Wood
  - Semiconductors – Silicon (Si), Germanium (Ge)
- The term conductor is applied to any material that will support a generous flow of charge when a voltage source of limited magnitude is applied across its terminals.
- An insulator is a material that offers a very low level of conductivity under pressure from an applied voltage source.
- A semiconductor is a material that has a conductivity level some-where between the extremes of an insulator and a conductor.

- The property that determined the type of the material is called **Resistivity (ρ)**. Where the Resistivity (ρ) measures the resistance of a material towards the flow of charges.

$$\rho = \frac{RA}{L} = \frac{\Omega(cm^2)}{cm} = \Omega - cm$$

- The resistivity of conductors < 10^{-6}
- The resistivity of insulators > 10^{12}
- The resistivity of Silicon = 50×10^3
- The resistivity of Germanium = 50

INTRINSIC MATERIALS

- Semiconductors are divided into three types according to their purity: Intrinsic materials and Extrinsic materials
- **Intrinsic materials** are those semiconductors that have been carefully refined to reduce the impurities to a very low level—essentially as pure as can be made available through modern technology.
- The most widely used semiconductors are Silicon (Si) and Germanium (Ge) because they can be manufactured to a very high purity level.
- The free electrons in the material due only to natural causes are referred to as intrinsic carriers.

- At the room temperature, intrinsic germanium material will have approximately 2.5×10^{13} free carriers per cubic centimeter.
- At the room temperature, intrinsic silicon material will have approximately 2.5×10^{10} free carriers per cubic centimeter.
- According to the number of free carriers per cubic centimeter, the germanium is a better conductor at room temperature.

Stability in Intrinsic semiconductors

Semiconductors (elements of Group 4 in the periodic table) try to reform their structure to be like the structure of noble gases in order to be more stable, where the most outer orbit of the noble gases contains 8 electrons. Figure 1,a shows the atomic structure of silicon, and Figure 1,b shows the atomic structure of Argon (a noble gas).

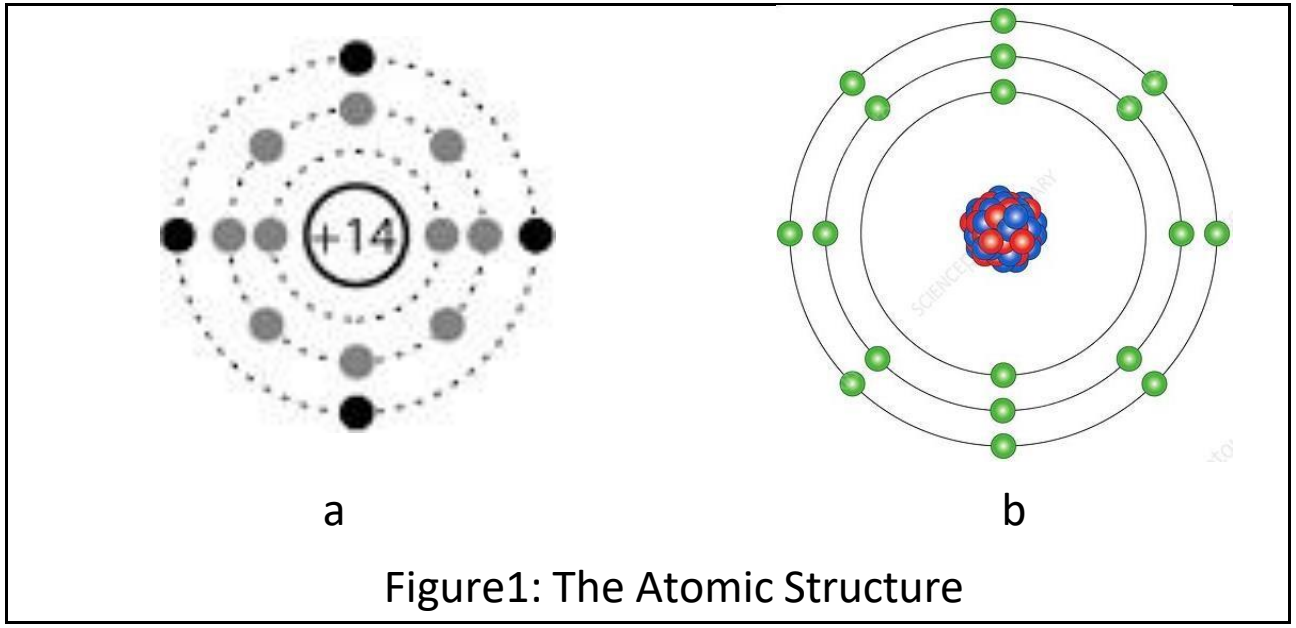


Figure1: The Atomic Structure

In order to copying the structure of noble gas, atoms of a semiconductor will share their four electrons (electrons that lies in the most outer orbits) with each others to obtain eight electrons in their most outer orbit as shown in figure 2

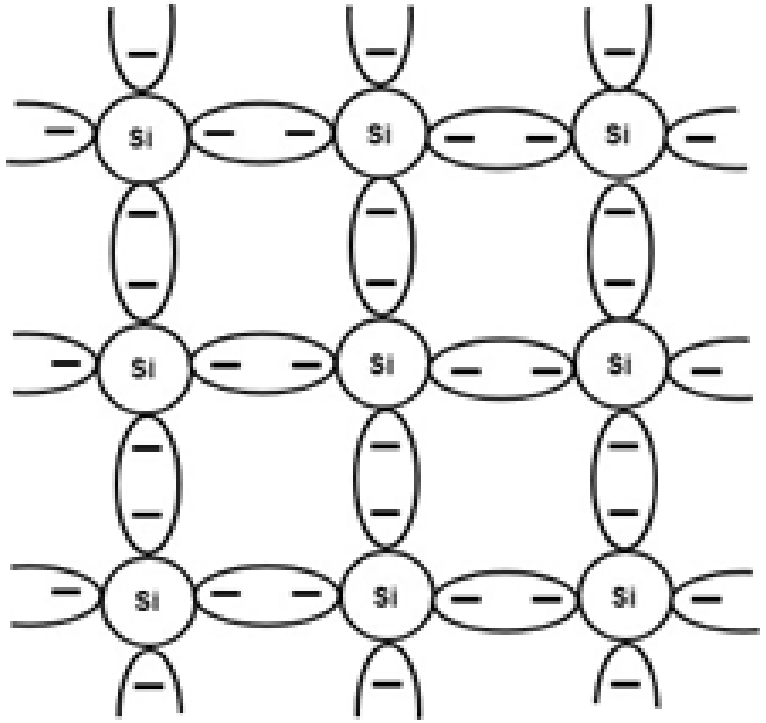


Figure 2: Crystal Lattice of Silicon

Energy Levels

- Figure 2,a shows the atomic structure of The Silicon and Figure 2,b Shows the atomic structure of The Germanium.

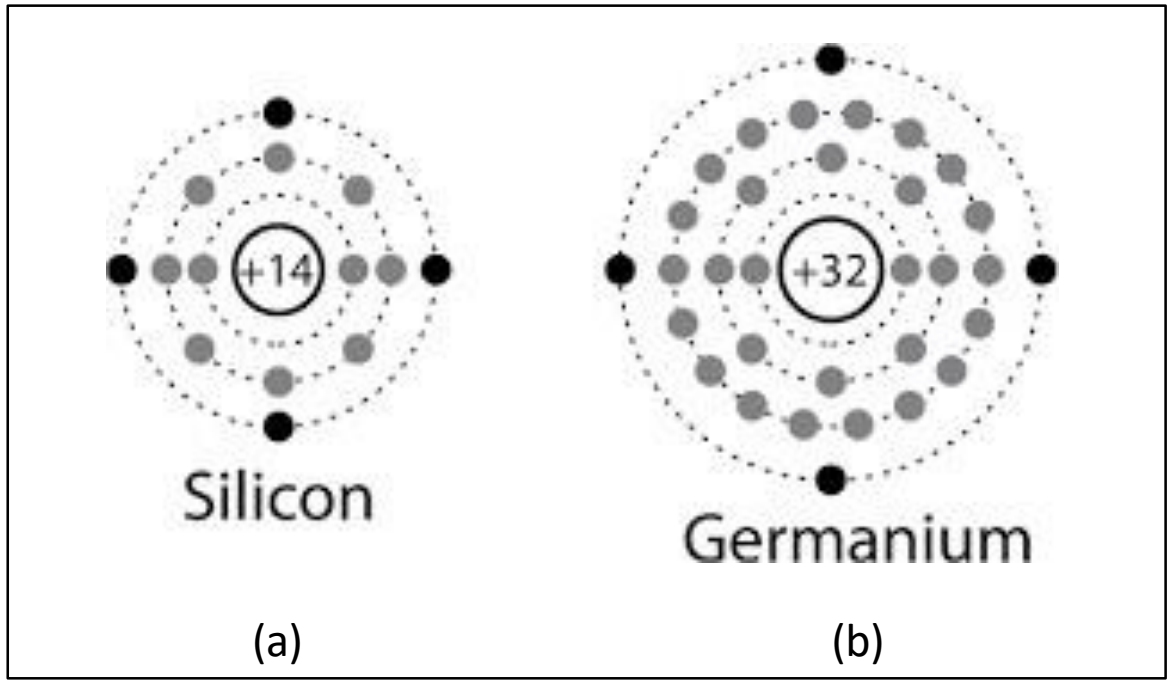


Figure (3)

- We will focus on the most outer orbit of the atom because the position of the electron will decide whether this material will allows electric current to pass through or not.
- The most outer orbit consist of two regions: conduction band and the valence band.

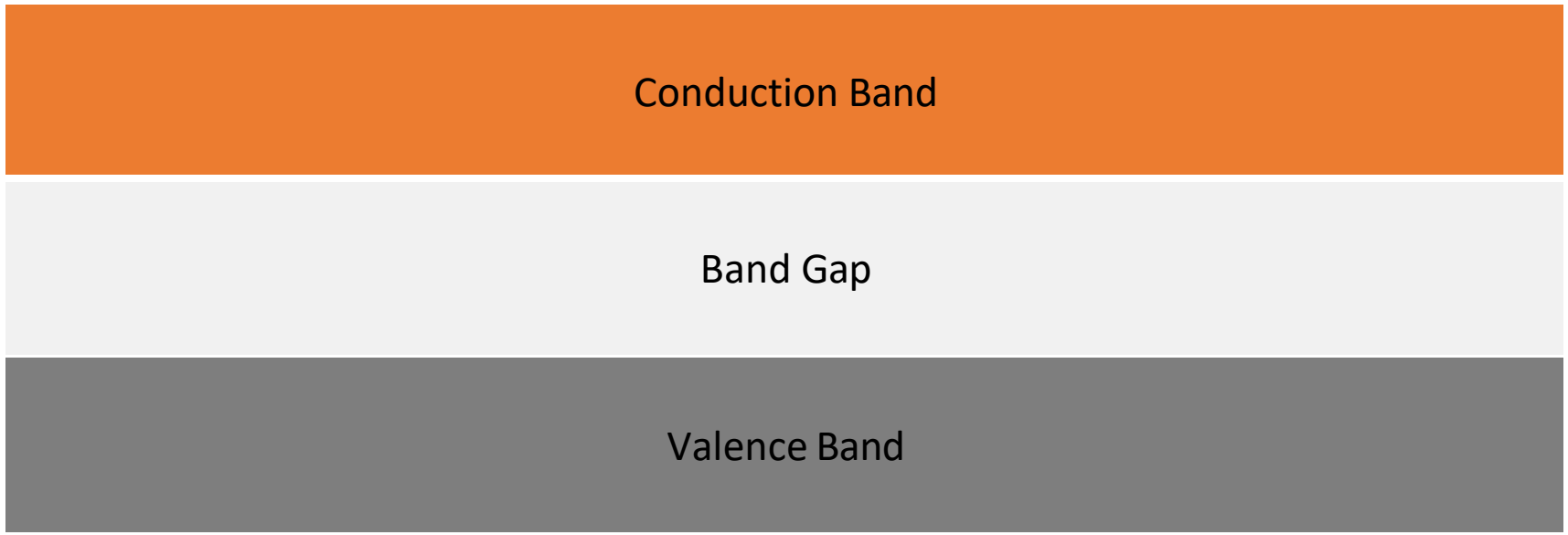


Figure 4

- Figure 5 shows the bands of most outer orbit for conductor, insulator, and semiconductor

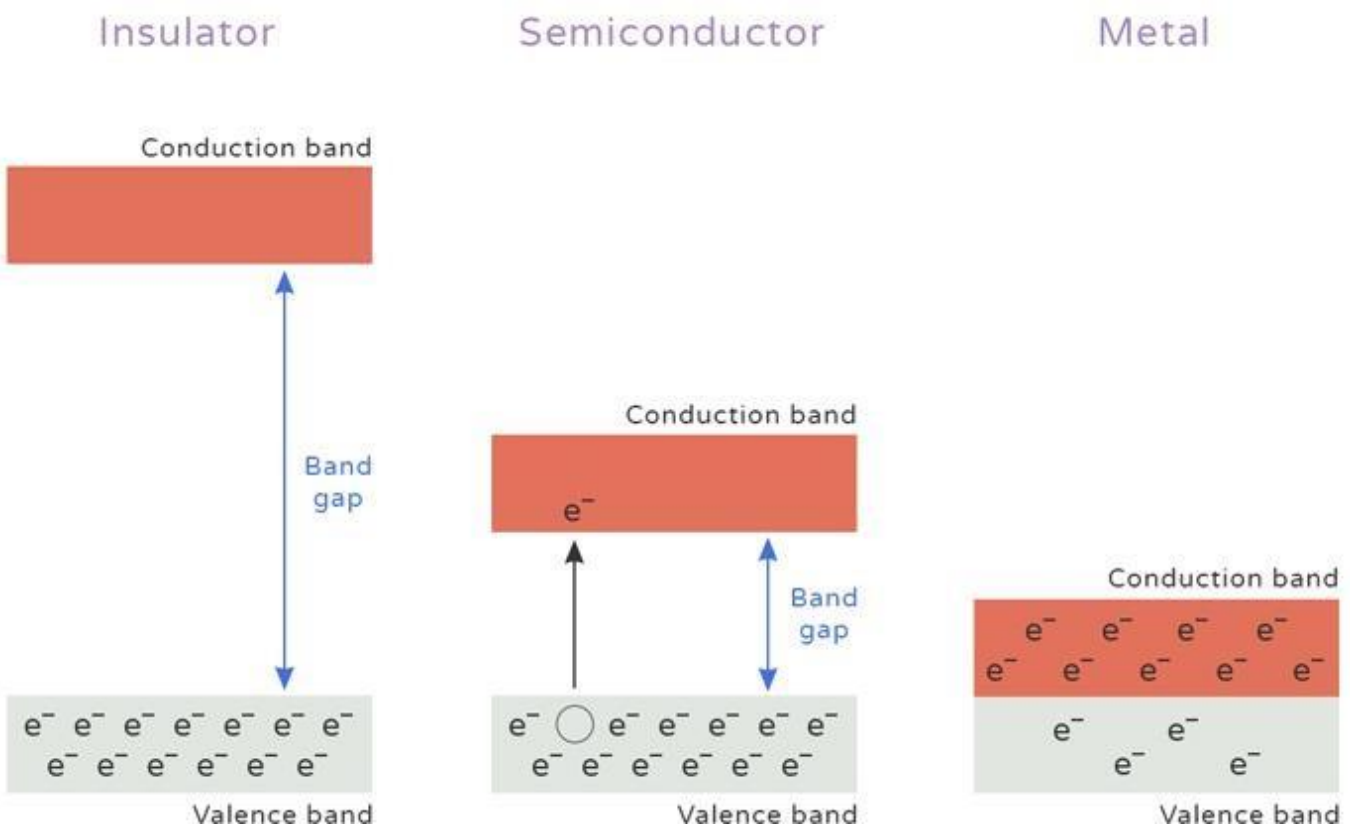


Figure 5

- Normally and except for conductors, the electrons lies in the valence band, and when they absorb power (from heat, light, electricity, pressure, ….) they will travel to conduction band.
- The amount of the energy that required for the electrons to travel from valence band to conduction band is called Energy gap (E_g)
- The Energy gap for insulators > 5 ev
- The Energy gap for insulators ≈ 1 ev

semiconductor

- The valence band and the conduction band for conductors are overlapped, so The Energy gap for it is zero

- The equation of the Energy gap:

$$W = QV \qquad eV$$

$$W = QV = (1.6 \times 10^{-19}\, C)(1V)$$

$$1eV = 1.6 \times 10^{-19}\, J$$

EXTRINSIC SEMICONDUCTORS

- In order to make the semiconductor act as conductor all the time, an atom of an element (called impurity atom) add to each 10 million atoms of a semiconductor. This process called **DOPING.** The resultant semiconductor of this process called **EXTRINSIC SEMICONDUCTORS.**
- There are two types of extrinsic material; n-type and p-type.
- N-type extrinsic semiconductor is created by adding those impurity elements that have five valence electrons (pentavalent), such as antimony, arsenic, and phosphorus.
- Diffused impurities with five valence electrons are called donor atoms.

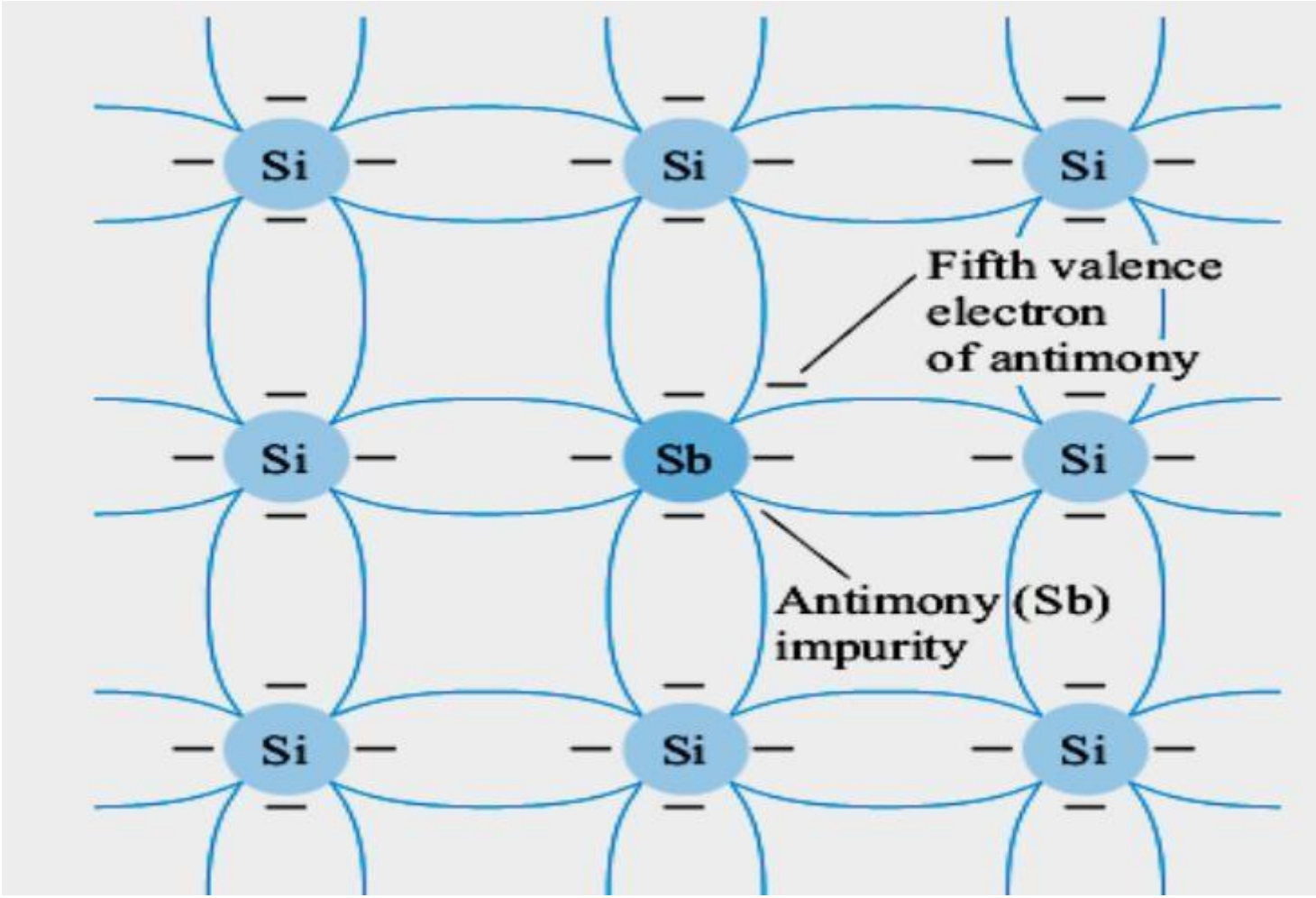


Figure 6: Crystal Lattice of silicon doped with Antimony

- The p-type material is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons.
- The diffused impurities with three valence electrons are called acceptor atoms.
- In an n-type material the electron is called the majority carrier and the hole the minority carrier. In a p-type material the hole is the majority carrier and the electron is the minority carrier.

- In the intrinsic state, the number of free electrons in Ge or Si is due only to those few electrons in the valence band that have acquired sufficient energy from thermal or light sources to break the covalent bond or to the few impurities that could not be removed.
- The vacancies left behind in the covalent bonding structure represent our very limited supply of holes. In an n-type material, the number of holes has not changed significantly from this intrinsic level. The net result, therefore, is that the number of electrons far outweighs the number of holes.

- In an n-type material, the electron is called the majority carrier and the hole the minority carrier.
- For the p-type material the number of holes far outweighs the number of electrons.
- In a p-type material the hole is the majority carrier and the electron is the minority carrier.
- When the fifth electron of a donor atom leaves the parent atom, the atom remaining acquires a net positive charge: hence the plus sign in the donor-ion representation. For similar reasons, the minus sign appears in the acceptor ion.