

Chapter 1

Introduction to Electronics

www.electronicsohize.com

June 12, 2024

Electronics: Principles, Concepts and Practices

Table of contents

1. Electronics
2. The Atom
3. Bohr's Atomic Model
4. Periodic Table
5. Energy Levels and Bands
6. Material Classifications
7. Conductors



Intro

1. Understanding the atom is a crucial starting point when delving into the story of modern electronics.
2. The study of atoms and their behavior provides the foundation for comprehending the behavior of materials and their electrical properties.
3. The story of the atom begins in the early 20th century with groundbreaking discoveries in the field of quantum mechanics.
4. Scientists such as Max Planck, Albert Einstein, Niels Bohr, and Erwin Schrödinger made significant contributions to our understanding of the atom's structure and behavior.



The Atom

The Atom

Atom

The atom is the smallest unit of matter that retains the complete property of an element. Atoms are made up of three basic particles namely; protons, electrons and neutrons.

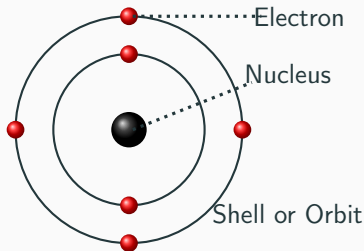


Figure 1: Atomic Structure



Atoms continued ...

- Electrons are negatively charged.
- The outer region of the atom consists of electron orbits.
- These orbits contain electrons.
- The outermost orbit can only have a maximum of 8 electrons.
- The electrons in the outermost orbits are known as valency electrons.

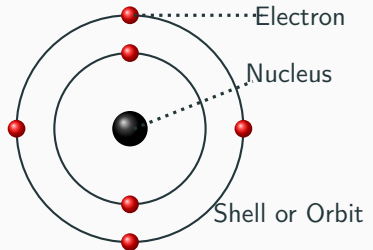


Figure 2: Atomic Structure



The valence electrons determines the physical, chemical and most essential for us, the electrical properties of materials. As a rough rule:

1. When the number of valence electrons is less than 4, the material is usually a metal and a conductor. Examples are sodium, magnesium and aluminium which have 1, 2 and 3 valence electrons respectively
2. When the number of valence electrons is greater than 4, the material is usually a non-metal and an insulator. Examples are nitrogen, sulphur and neon, which have 5, 6 and 8 valence electrons respectively.
3. When the number of valence electrons equal 4, the material has both metal and non-metal properties and is usually a semi-conductor. Examples are carbon, silicon and germanium.



Bohr's Atomic Model

Bohr's Atomic Model

Bohr assumptions may be summarized in simple terms as follows:

1. The atom has a massive positively charged nucleus consisting of protons and neutrons orbited by negatively charged electrons;
2. The electrons move round the nucleus in circular orbits that have a discrete size and energy and are balanced to do so due to the centrifugal force of pull between the nucleus and electrons;
3. Electrons revolve around their discrete permitted orbits and do not radiate out electromagnetic energy unless when forced or excited from the permitted orbits; and
4. If E_1 and E_2 are the energies corresponding to two orbits before and after a transition, then the frequency f of the emitted photon is

$$E_2 - E_1 = \Delta E = hf \quad (1)$$

where h is the Plank's constant and $E_2 > E_1$.



Periodic Table

Periodic Table

Figure 3 shows a typical Periodic Table with eight groups corresponding to the number of valence electrons. For example, Si is the chemical symbol for silicon, with atomic number 14, and found in group 4 as it has four valence electrons.

1	2	3	4	5	6	7	8
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ag
19 K	20 Ca	31 Ga	32 Ge	33 As			
		49 In		51 Sb			



Figure 3: Periodic Table

Energy Levels and Bands

Energy Levels and Bands

Energy Level: A discrete value from a set of quantize values of total energy for a subatomic particle confined by a force to a limited space.

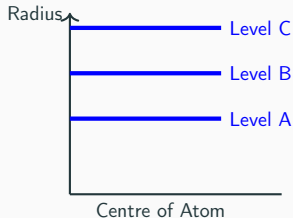


Figure 4: Energy level illustration

Energy bands consisting of a large number of closely spaced energy levels. This arises from the closely packed atoms of typical crystalline materials.

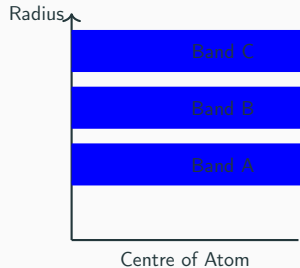


Figure 5: Energy band illustration



Energy Levels and Bands

There are three (3) crucial energy bands in solid materials.

1. The **valence band** is the range of energies possessed by the valence electrons.
2. The **conduction band** refer to the range of energies possessed by free electrons which have been excited and detached from their loose bonds to become conducting electrons
3. **Forbidden energy gap** refers to the spatial separation between conduction and valency band. As the name implies, no electron stays in the forbidden energy gap.

For different materials, the forbidden gap varies. The more the forbidden energy gap, the tighter the valence electrons are bond to the nucleus.



Material Classifications

Material Classification based on Energy Band

The classification includes, insulators, semi-conductors and conductors as shown in fig.6.

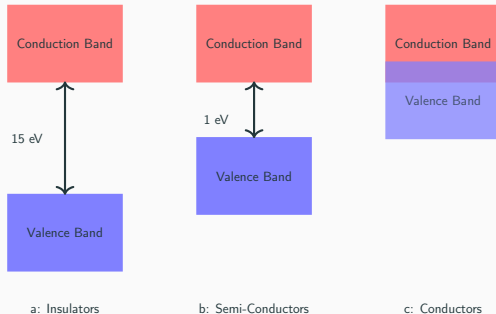


Figure 6: Energy Band



Material Classification ...

1. Insulators or dielectrics do not readily conduct an electric current when external sources are applied. From the energy bands perspective, we may explain that for insulators, the valence band is full while the conduction band is empty. The energy gap (forbidden energy band) is large.
2. Semiconductors are materials that have conductivity between that of an insulator and that of most metals. From the energy bands perspective, the energy gap between the conduction and valence band is relatively small.
3. Conductors are materials that permit electrons to flow freely from particle to particle. From the energy gap perspective, conductors have overlapping conduction and valence band.



Conductors

Conductors

Refer to Fig. 7, showing a conductor of length L . Let the mass of the mobile charge carrier q^+ be m .

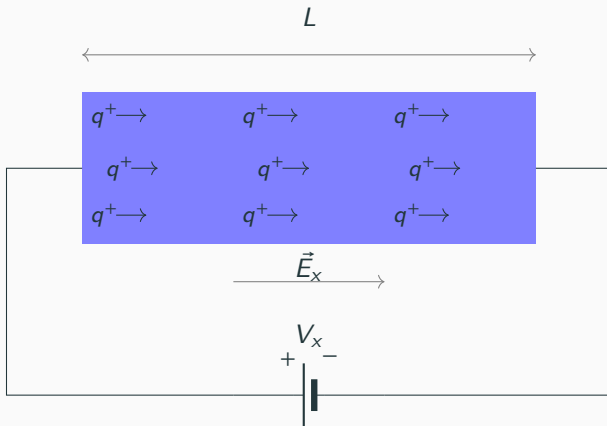


Figure 7: Applying voltage to a conductor



Conductors

This electric field will exert a force $\vec{F}_x$ on the mobile charges, given by

$$\vec{F}_x = q\vec{E}_x \quad (2)$$

In classical physics, the applied force causes the charge particle q to accelerate, expressed as

$$\vec{F}_x = m\vec{a}_x = m\frac{d}{dt}v_x(t) \quad (3)$$

By combining Equations (2) and (3) and integrating with respect to time t , we can obtain the velocity of the charged particle as

$$v_x(t) = \frac{q\vec{E}_x t}{m} \quad (4)$$

We can only speak in terms of the average velocity v for specified time interval τ , given as

$$v(t) = \frac{q\vec{E}\tau}{m} \quad (5)$$



Conductors

Consider a specific section of the conductor, as shown in Figure 8. The area of this section is denoted by A , and its length is $L = v(t) \times \Delta\tau$. We can define $\Delta\tau$ as the relaxation time, which represents the time between two successive electron collisions within the conductor. Volume flow, denoted by N is given by

$$N = (n) \times (v(t)\Delta\tau A) \quad (6)$$

where n is charge per unit volume.

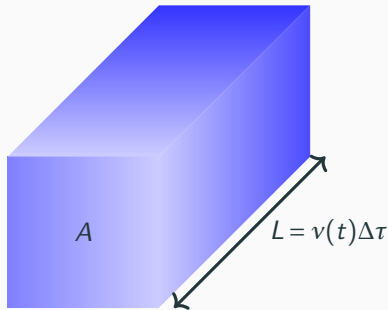


Figure 8: Cross section of the conductor



Conductors

Current flow I , is

$$I = \frac{Q}{\Delta t} = \frac{qN}{\Delta \tau} \quad (7)$$

$$I = qnv(t)A \quad (8)$$

Substituting for $v(t)$ using Equation (5) gives,

$$I = \frac{q^2 n \tau \vec{E}_x A}{m} \quad (9)$$

From a field point of view, we speak in terms of current density J for the cross-sectional area A

$$J = \frac{I}{A} = \left(\frac{q^2 n \tau}{m} \right) \vec{E} = \sigma \vec{E} \quad (10)$$

here σ is the conductivity of the material. Equation 10 may be expressed in voltage and current as

$$I = V \left(\frac{A\sigma}{L} \right) \quad (11)$$



This equation can be further rearranged as

$$V = I \left(\frac{L}{\sigma A} \right) = IR \quad (12)$$

where R is the resistance of the conductor sample

$$R = \frac{L}{\sigma A} = \frac{\rho L}{A} \quad (13)$$

and ρ is the resistivity of the material which is the inverse of the conductivity ($\rho = 1/\sigma$).



Equation 12 reminds you of _____?



Equation 12 reminds you of **Ohms Law!**



Homework:
**Check with the class rep for the weekly
numerical task!**



Interestingly, we have shown the derivation of ohm's law. We bring the discussion on conductors to an end here. Note that the model used here is based on an assumption of two charged particles wherein one is fixed and the other is mobile. This is entirely not the case when we discuss semi-conductors in the next chapter. The focus onward shall be semi-conductors.



Recommendation:

See worked examples in reference material!

WWW.ELECTRONICSOHIZE.COM

