INTRODUCTORY ELECTRONICS

Electronics is a branch of science that deals with the study of semiconductors and their electrical conductivity.

SEMICONDUCTORS

Semiconductors are classes of elements in group (IV) of the periodic table. Major examples of semiconductors are silicon and germanium.

The electronic theory that satisfactorily the difference between insulators, semiconductors and pure conductors (or metals) is called the Energy Band Theory

The lowest available band in a solid is called the Valence band. This band is completely filled with electrons. The highest band known is called the conduction band. There is another band in between the conduction band and the valence band. This band is called the forbidden gap or forbidden band. No electron can occupy (or stay in) the forbidden band.

ENERGY BAND DIAGRAM (THEORY) FOR INSULATORS

The conduction band in insulators is completely empty. No electron can occupy (or stay in) the forbidden band. The forbidden gap in insulators is so high that no amount of energy can excite electron from the valence to pass through it to get to the conduction band. Since insulators have no electrons in their conduction bands, they therefore can’t conduct electricity.

ENERGY BAND IN SEMICONDUCTORS

In semiconductors, the forbidden gap in semiconductors is narrow therefore electrons can be excited from the valence band to the conduction band. At zero Kelvin, the electrons do not possess thermal energy hence the valence the valence band remains filled with electrons. At zero kelvin, there are no electrons in the conduction band hence semiconductors don’t conduct electricity at zero kelvin. At room temperature (or at an increased temperature), some of the electrons at the valence band become excited and are moved, jumped or promoted to the conduction band leaving behind some vacancies called holes. The number of holes in the valence band must be equal to the number of electrons in the conduction band.

Now, since there are electrons in conduction band, semiconductors can conduct electricity.

The electrons and holes in semiconductors are the charge carriers in semiconductors

ENERGY BAND IN METALS

In metals, there are no forbidden gaps instead, the valence band and the conduction band overlap. As a result of this overlap, there are (many) electrons in the conduction band which makes metals very good conductors of electricity.

SEMICONDUCTOR THEORY

It should be noted that the type of bond in semiconductors is the covalent bond

Semiconductor elements (silicon and germanium) have resistivity of about one million times that of metals

$$\rho_s \cong 1000000\rho_m$$

Each semiconductor element has four electrons in its outermost shell and is surrounded by four other atoms of its kind. For example, a silicon atom has four electrons in its outermost shell and is surrounded by four other silicon atoms in a tetrahedral arrangement.

At zero kelvin, all the electrons are bonded to the nucleus (i.e. there is no free electron). At room temperature (or an increased temperature), one of the electrons is set free leaving behind a hole. An electron from a neighboring silicon atom is attracted by the hole and this neighboring atom will have a hole. Electrons will also be attracted by another neighboring atom leaving a new atom with a hole. As the temperature is increased more electrons escape and more holes are created.

Electrons and holes are therefore observed to be drifting (or moving) in opposite direction. At all times, the number of electrons emitted is equal to the number of holes created.

CURRENT IN SEMI CONDUCTORS

When a battery is connected to a semiconductor, current will be seen to be flowing in same direction as holes while the electrons will be flowing in opposite direction.

However, in metals, the only charge carriers are (free) electrons and they move in opposite direction to the current.

The following points should be noted of pure semiconductors (intrinsic semiconductors)

The number of holes is equal to the number of free electrons

The charge carriers are electrons and holes

The drift velocity of electrons is greater than that of the holes

Electrons and holes drift in opposite direction

EFFECT OF TEMPERATURE ON SEMICONDUCTORS

When semiconductors are heated, a large number of electrons will move from the valence band to the conduction band giving rise to many electron-hole pairs. The higher number of conduction electrons and holes make semiconductors good conductors at higher temperatures. Semiconductors have low resistance at high temperature and have higher resistance at low temperatures.

Semiconductors are said to have a negative temperature coefficient for resistance since a higher temperature means a lower resistance.

$$R_f = R_i(1 - \propto \Delta\theta)$$

$$R_f = R_i - R_i \propto \Delta\theta$$

$$R_i - R_f = R_i \propto \Delta\theta$$

$$R_i \propto \Delta\theta = R_i - R_f$$

$$\propto = \frac{R_i - R_f}{R_i \Delta\theta}$$

$$\propto = \frac{R_i - R_f}{R_i(\theta_f - \theta_i)}$$

$$\propto = \frac{-\Delta R}{R_i \Delta \theta}$$

However metals have a positive temperature coefficient for resistance

DOPING IN SEMICONDUCTORS

This is defined as the process of adding impurities (or foreign atoms) to semiconductors in order to increase their conductivities. The impurities must be group (III) or group (V) elements.

N-TYPE SEMICONDUCTORS

This is a negative type semiconductor. It is an extrinsic (or impure) semiconductor.

This is formed by adding a group (V) (or pentavalent) element to a semiconductor.

$$Pure(intrisic)\,semiconductor + Group(V)\,element = N - type\,semiconductor(extrinsic)$$

When a group (V) element such as Arsenic which has five electrons is introduced into a silicon lattice, an extra electron is observed since only four of its electrons are used for bonding. The fifth electron will wonder (roam). Introducing many arsenic atoms will lead to the generation of many free electrons in addition to the few holes that are thermally generated (generated by heat).

Since the electrons are more in the lattice, they are referred to as Majority Carriers. The few holes that generated thermally are referred to as the minority carriers. The arsenic atom is called the donor since it donates free electrons to the lattice. The product of these reactions is called the N-Type Semiconductor (Negative type) since the number electrons is more in number since electrons are negative in nature.

P-TYPE SEMICONDUCTORS

This is formed by adding a group (III) element or trivalent atom to semiconductor. Examples of group (III) elements include Aluminum and Boron.

$$Pure\,semiconductor + Group(III)\,Element = P - type\,semiconductor$$

When a group (III) element such as a boron atom (which has three electrons) is introduced into a silicon lattice, the three electrons in the boron are bonded in the silicon lattice thereby leaving a hole in the silicon lattice. The addition of more boron will generate more holes in the lattice. When heat is then applied, electrons are generated and also more holes are generated. Since holes are more, they are called the majority carriers and the electrons generated are called the minority carriers. The group (III) element introduced is called the acceptor since it accepts electrons from neighboring atoms. The product of all this is called the P-Type semiconductor (since holes are more in number and are positive in nature).

P-N JUNCTION DIODE

By a special manufacturing process, the P-type and the N-type semiconductors can be brought together. At the junction where these two semiconductors meet (junction of contact), a large amount of holes will flow from the P-type semiconductor to the N-type semiconductor (trying to neutralize the excess in the N-type semiconductor)

Similarly, a large number of electrons will flow from the N-type semiconductor to the P-type semiconductor.

After some time, the migration will cease as a result of a potential difference that will be generated called the barrier potential difference. As these charges move from each semiconductor to the other and as this is PD is generated, these charges accumulate in a layer called the depletion layer

This joining of the two types of conductors gives a diode.

A diode can be defined as a two-terminal electronic component that conducts current primarily in one direction (and this is called asymmetric conductance): it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

A vacuum tube or thermionic diode is a vacuum tube with two electrodes, a heated cathode and a plate in which electrons can flow in only one direction from the cathode to the plate. A semiconductor diode, the most commonly used type today is a crystalline piece of semiconductor material with a p-n junction connected to two electrical terminals.

Semiconductor diodes were the first semiconductor electronic devices. The discovery of asymmetric electrical conduction across the contact between a crystalline mineral and a metal was made by a German physicist Ferdinand Braun in 1874. Today, most diodes are made of silicon but other semiconducting materials such as gallium arsenide and germanium are also used.

Diodes are conductors made of semiconductors that do not obey ohm’s law. Diodes are therefore non ohmic conductors. They do not have a linear function of an I against V graph or V against I.

A diode is a rectifier. A rectifier is a material that can convert alternating current into direct current. This is because it allows current to flow in only one direction. The process of changing AC to DC is called Rectification.

Diodes are conductors made of semiconductors that do not obey ohm’s law. Diodes are therefore non ohmic conductors. They do not have a linear function of an I against V graph or V against I.

<u>MODES OF CONNECTION OF DIODES</u>

Forward Biased Mode: In this mode of connection, the positive plate of the battery is connected to the p-side while the negative plate is connected to the n-side. Since like charges repel, the holes are further propelled pass the depletion layer and the electrons are also propelled pass the depletion layer or junction of contact. In this connection, a large amount of current flows because the source of current is the majority carriers (i.e. holes are moving from where they are maximum to where they are deficient likewise the electrons). This gives rise to high conductivity and low resistance. Also, the depletion layer narrows (or becomes smaller) because the accumulated charges are propelled to move.

Reverse Biased Mode: In this mode, the positive plate is connected to the n-side and the negative plate is connected to the p-side. In this case, the positive plate will repel the holes in the n-side (where they are minority) and the negative plate will repel the electrons (where they are minority also). The current generated is low because minority carriers are used in the generation of current. In this mode of connection, there is poor conduction and high resistance.

Also, in this mode of connection, the depletion layer widens (or increases in size).

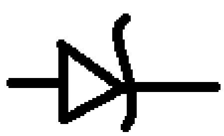
ADVANTAGES OF JUNCTION DIODES

1. They are very portable because they are quite small in size
2. They require little time to warm up
3. They require little power for their operation
4. They are very durable

ZENER DIODE

This is a special type of diode designed to reliably allow current to flow backwards when a certain set reverse voltage known as Zener voltage is reached. The zener diode was invented by Clarence Melvin Zener

Its electronic symbol is



This is a special diode used as Voltage Regulators or Stabilizers. They are also used for regulating voltages.

Zener diodes are manufactured with a great variety of zener voltages and some are even variable. Some zeners have a sharp, highly doped p-n junction with a low zener voltage, in case which the reverse conduction occurs due to electron quantum tunneling in short space between the p and n regions – this is known as the Zener effect

TRANSISTORS

A transistor is defined as a three terminal semiconductor device used as for amplifying, generating or controlling electrical signals. It can act as an amplifier or a switch in an electronic circuit. Amplifiers (Transistors) have three layers (or terminals). The three terminals are

Emitter (E): Where the current comes in or goes

Base (B)

Collector (C)

PNP Carriers: These transistors have holes as their majority carriers

NPN Transistors: They have electrons as their majority carriers.

Since electrons are faster than holes, NPN transistors are faster switches than the PNP transistors

USES OF TRANSISTORS

They are employed as amplifiers because they can control the flow of current in a circuit

They can control the flow of current

They are used as amplifiers to amplify

Signals

Current

Power

Etc.