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Basics of Semiconductors

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Abstract: ***A semiconductor has conductivity between that of a conductor and an insulator. These are less conductive than metals, but differ from metals in that, as a semiconductor heats up, its conductivity rises. In metals the opposite effect occurs. The reason for this is, in a semiconductor, very few atoms are ionised, and so very few electrons can move, creating an electric an electric current. However, as the semiconductor heats up, the covalent bonds (atoms sharing electrons, causing the electrons to be relatively immobile) breakdown freeing the electrons. As a result, a semiconductor's conductivity rises at an increasing rate as temperature rises. Examples of semiconductors include silicon and germanium. At room temperature, silicon has a conductivity about435usm-1. Semiconductors are usually doped. This means that ions are added in small quantities, giving the semiconductor a greater or lesser number of free electrons as required. This is controlled by the charge on the ions. A semiconductor material has an electrical conductivity value falling between that of a conductor such as metallic copper and an insulator such as glass. Its resistance falls as its temperature rises; metals are the opposite. Its conducting properties may be altered.***

Keywords: Semiconductors, Resistivity, P Type, N Type-Transistors

1. Introduction

A semiconductor is a substance whose resistivity lies between the conductors and insulators. The property of resistivity is not the only one that decides a material as a semiconductor, bit it has a few properties as below:

1. The resistivity of a semiconductor is less than ana insulator but higher than a conductor.
2. Semiconductors show a negative temperature coefficient of resistance. the resistance of semiconductors decreases as the temperature increases and vice versa.
3. At zero-degree Kelvin, semiconductors behave as insulators, as temperature is increased, it works as a conductor.
4. The conductivity of semiconductors increases when impurities are added. The process of adding impurities to semiconductors is called doping.

2. Literature Survey

The first documented observation of a semiconductor effect is that of Michael Faraday (1833), who noticed that the resistance of silver sulphide decreased temperature, which was different than the dependence observed in metals. IN 1874 Karl Broun discovered and documented the first semiconductor diode effect.

The term 'semiconduction was used for the first time by Alessandro Volta in 1782. Michael Faraday was the first person to observe a semiconductor effect in 1833. Faraday observed that the electrical resistance of silver sulphide decreased with temperature. In 1874, Karl Braun discovered and documented the fist semiconductor diode effect. Braun observed that current flows freely in only one direction at the contact between a metal point and a galena crystal. In 1901, the very first semiconductor device called "cat whiskers" was patented. The device was invented by Jagadish Chandra Bose. Cat whiskers were a point - contact semiconductor rectifier used for detecting radio waves. A transistor is a devise. Composed of semiconductor material. John Bardeen, Walter Brattain and William Shockley all co-invented the transistor in 1974 at Bell Labs.

3. Problem Definition

1. What is a semiconductor, Types, Material, Physics

A semiconductor can be defined as a substance with properties of a conductor and insulator both. It can conduct electricity under certain circumstances but not always, thisphysics and property of a semiconductor makes it a good medium to use electricity in a controlled manner and where required. Conductance of a semiconductor depends onsuperinfectors such as current or voltage applied to a control electrode, or ton the intensity of irradiation by infra-red (IR), visible light, ultraviolet (UV), or X - rays. So, we can say that s semiconductor is a material that has electrical conductivity greater than an insulator but less than a conductor.

As semiconductor has a dual property - conductor and insulator of electricity. This property depends on impurities added to the semiconductor material, a pure such material is called and intrinsic. The impurities added to the material to change its electrical property are called 'dopants" and the process of adding impurities to the pure semiconductor material is called doping.

4. Types of Semiconductors

1. N-Type semiconductor - is one that carries current in the form of negatively-charged electrons. This is very similar to conduction of current in a wire.

2. P-Type semiconductors are one that carries current predominantly as electron deficiencies called holes. A hole has a positive electric charge. This charge is equal and opposite to the charge in an electron. These holes flow in the opposite direction of electrons.

5. Methodology

1. Semiconductor Materials

There are several materials and elements used to make semiconductor. The basic requirement is that the material should not be a very good conductor of electricity, nor should it be a very bad conductor of electricity. Its properties can be changed by adding or removing atoms/impurities. Semiconductor materials include Silicon, Antimony, arsenic, boron carbon, germanium, gallium arsenide, selenium, silicon carbide, sulphur, tellurium oxides of most metals.

2. Diode

A diode is the simplest possible semiconductor device and is best device to learn and understand how a semiconductor works. A diode is an electric component that allows current to flow in one direction only. It is a device that consists of a p-n junction. These are used most commonly to convert AC to DC, because they pass the positive part of the wave, and block the negative part of the AC signal, or, if they are reversed, they pass only the negative part and not the positive part.

3. Transistor

A transistor is a device made of a solid piece of semiconductor material an is used to amplify and switch electronic signals. A transistor can be active in one direction and can draw more or less current through its load resistor.

4. Semiconductor manufacturing

Manufacturing semiconductors need expertise and experience. Manufacturing has to be done in a clean room environment. Chemicals to be used need to be pure and free from any impurity. The process of adding controlled impurities to a semiconductor is known as doping.

Steps involved in manufacturing semiconductors.

1. Design / Mask creation
2. Patterning
3. Wafer Fabrication
4. Device Formation / Device insulation layer Formation
5. Device Formation / Transistor Formation
6. Metallization
7. Assembly and Testing

6. Results and Discussion

1. How do semiconductors work

The most commonly used semiconductor material in the electronics industry is silicon.

After that it's a compound known as gallium arsenide. Though germanium was used extensively in the early years of semiconductor technology, it is unstable at high temperatures, so silicon became more widely used.

Semiconductor material has two current carriers, free electrons and holes. IN an intrinsic semiconductor material, free electrons are produced then the material receives sufficient thermal energy that provide valence electrons from the valence band enough energy to jump to the conduction band and turn into free electrons. When valence electrons jump to the conduction band, they leave vacancies in the valence band. These vacancies are called holes. The number of holes in the valence band is just equal to the number of free electrons in the conduction band in this undoped, intrinsic material.

A semiconductor material becomes a useful electronic component by controlling its conductivity. However, semiconductor materials, in their intrinsic state, do not conduct current well. This is because of the limited number of free electrons and holes in it. But through a process known as doping, the conductivity of a semiconductor can be increase.

Doping increases the number of current carriers by adding impurities with either more free electrons or holes to the intrinsic semiconductor material.

The number of free electrons in an intrinsic semiconductor material is increase in the doping process by adding pentavalent impurity atoms or atoms with five valence electrons such as arsenic, phosphorous, bismuth or antimony. For example, an antimony atom covalently bonds with for adjacent silicon atoms during the doping process. Only four valence electrons of the antimony atom were used to form covalent bonds with the silicon atoms, leaving an extra atom that becomes a free electron. So, by adding pentavalent impurity atoms to an intrinsic semiconductor material, the number of free electrons can be increased as well as the conductivity of the semiconductor material. Semiconductors doped with penta valent atoms are n - type semiconductors, since the majority of its current carriers are electrons. Once you add these impurities to an intrinsic semiconductor, it is considered an n extrinsic semiconductor. In order for an intrinsic semiconductor material to have more holes they are doped with trivalent impurity atoms. These are atoms with three valence electrons in their valence shell like boron indium and gallium. For example, when a boron atom covalently bonds with for adjacent silicon atoms, a hole is produced. This is because; each of the four adjacent silicon atoms requires one electron from the boron atom. But it only had three valence electrons. In this case, we can say that by adding more trivalent impurity atoms to an intrinsic semiconductor material, it increases the number of holes and improves the conductivity of the semiconductor material. Semiconductors doped with trivalent atoms are p-type semiconductors since the majority of its current carriers are holes. The doping process converts an intrinsic semiconductor material into extrinsic and produces either an n-type or a p-type semiconductor material. Combining the n-type and p-type semiconductor materials creates a boundary known as p-n junction. This p-n junction is the basis for different semiconductor devices widely used today, like diodes, transistors and thyristors.

We talked about the basics of semiconductors, the intrinsic semiconductor and its poor conductivity, how doping increases the number of current carriers in a semiconductor material and improves its conductivity. We also briefly mentioned how different semiconductor devices were created on the p-n junction.

7. Conclusion

Semiconductors are used in almost every sector of electronics. Consumer electronics, Mobile phones, laptops, games consoles, microwaves and refrigerators all operate with the use of semiconductor components such as integrated chips, diodes and transistors.

Semiconductors unlike vacuum tubes are shock-proof. Furthermore, they are smaller in size take up less space and use less power. Semiconductors are extremely sensitive to temperature and radiation when compares to vacuum tubes. Semiconductors are less expensive thana vacuum diodes and have much larger shelf life.

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