Pearson BTEC Levels 4 Higher Nationals in Engineering (RQF)

Unit 19: Electrical and Electronic Principles

Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

Semiconductor Action

Contents

INTRODUCTION

Describe the basis of semiconductor action, and its application to simple electronic devices

Semiconductor material:

> **Characteristics of semiconductors; impact of doping, p-type and n-type semiconductor materials, the p-n junction in forward and reverse bias.**

Simple semiconductor devices:

> **Characteristics and simple operation of junction diode, Zener diode, light emitting diode, bipolar transistor, Junction Field Effect Transistor (FET) and Metal Oxide Semiconductor FET (MOSFET). The bipolar transistor as switch and amplifier.**

SIMULATOR DOWNLOADS

[MicroCap]

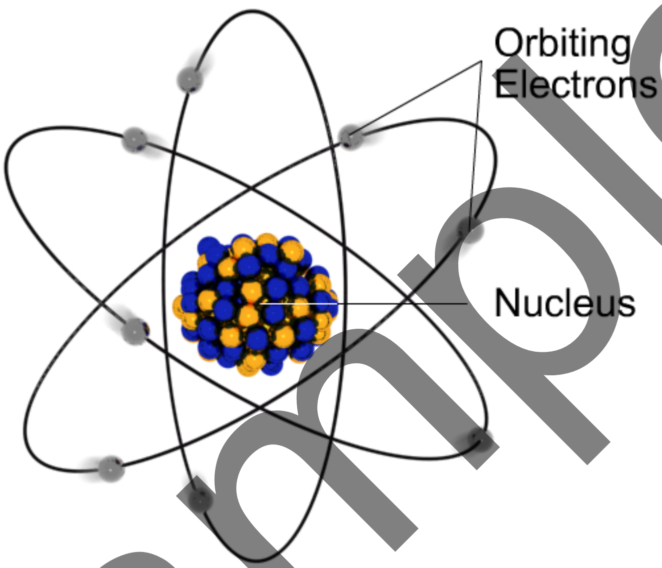
[TINA-TI]

Semiconductor material:

Materials are generally categorised as being either electrical conductors or insulators. However, a category of material exists that can behave as either a conductor or an insulator, depending on external conditions. These materials are called **semiconductors**. This property can be very useful in electronics, and semiconductor materials are used in devices such as diodes and transistors.

Atomic Structure

All materials are made from atoms that consist of a positively charged nucleus with negatively charged electrons orbiting around it. The electrons orbit the nucleus in a number of concentric shells.

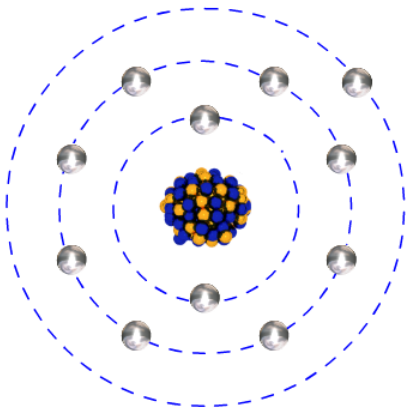


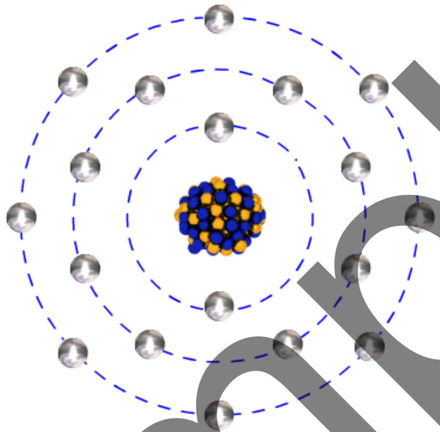
In any atom there are the same number of electrons orbiting as protons in the nucleus, so that it is electrically neutral. It is the electrons in the outermost shell and how they interact with the outermost electrons in adjoining atoms that determines the conductivity of the material.

Conductors and Insulators

A good **conductor** has one electron in the outer shell of each atom. This electron is held loosely in place and can easily be pulled free. It is these free electrons that move through a material when a potential difference exists, causing an electrical current.

An **insulator** has many electrons in the outer shell of each atom that form a strong bond with adjacent atoms. These electrons cannot easily be pulled free, so electrical conduction doesn't occur.





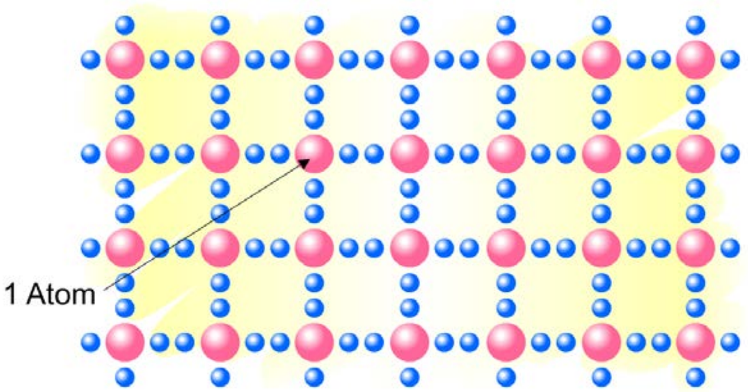
Semiconductors

Semiconductor materials have 4 electrons in the outer shell of each atom. Silicon is an example of a semiconductor material that is frequently used in electronics.

In pure silicon these outer electrons form strong bonds with adjacent silicon atoms, forming a strong crystal lattice structure.

At room temperature, heat energy will cause some of these bonds to break. This releases a very small number of electrons to move through the material, but not enough to allow a noticeable current flow in the material.

Pure silicon is therefore an insulator at room temperature.

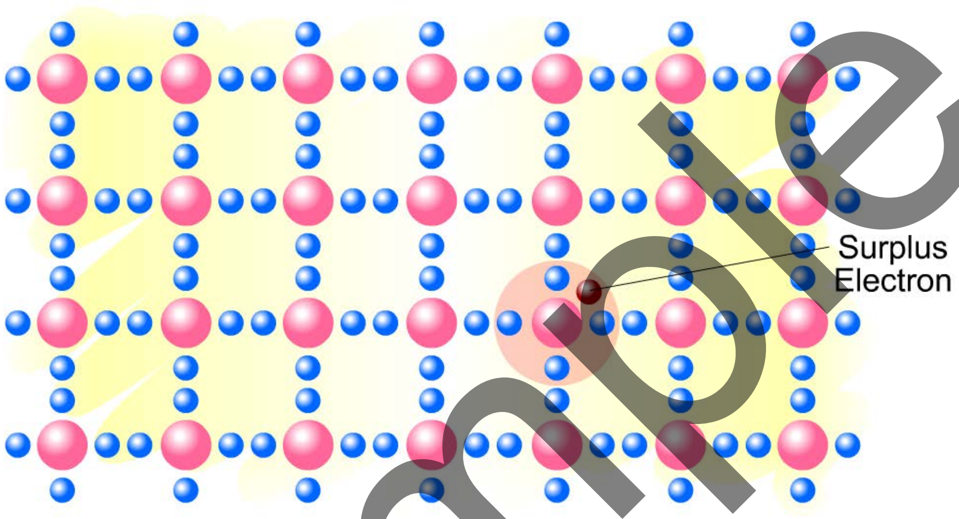


Adding Impurities

To increase the conductivity, a material can be added to the silicon to make the silicon impure. The process of adding an impurity is called **doping**. By selecting an appropriate doping material, additional charge carriers can be added to the material. The amount of impurity required to increase the number of charge carriers, and hence increase the conductivity, can be as small as 1 part per million.

N-Type Semiconductor

If a material with five outer electrons, such as arsenic, is added to silicon, four of the outer arsenic electrons will fit into the crystal lattice, but the fifth **electron** will remain free. This free electron can move very easily in the material.



Doping a material in this way creates free electrons that are **n**egative charge carriers. It is therefore known as an **n-type** semiconductor.

P-Type Semiconductor

If a material with three outer electrons, such as indium, is added to silicon, the crystal lattice will be an electron short for each impurity atom, creating a **hole** in the crystal lattice. These holes act as spaces into which electrons can move. This will give the appearance that the hole is moving through the material. The hole is said to have a positive charge since it attracts negatively charged electrons. Doping a material in this way creates holes that act like **po**sitive charge carriers. It is therefore known as a **p-type** semiconductor.