CONTENTS

- Introduction
- Semiconductor materials
- Covalent bonding and Intrinsic material
- Energy levels
- Extrinsic materials

INTRODUCTION

- Basics of semiconductor material.
- Importance of semiconductor material to electronics devices.



Figure. Electronics gadgets by using semiconductors

- Miniaturization limited by
  - Quality of semiconductor
  - Network design technique
  - Limits of manufacturing and processing equipments

SEMICONDUCTOR MATERIALS : Si, Ge, GaAs

- Germanium, Silicon and GaAs
- Semiconductors are special class of elements having a conductivity between insulator and conductor
- Classes of semiconductor material:
  - Single crystal: Germanium and Silicon
  - Compound : cadmium sulphide (CdS), Gallium arsenide (GaAs), Gallium Nitride (GaN), Gallium arsenide phosphide (GaAsP).
- After the discovery of diode in 1939 and the transistor in 1947 the Germanium is commonly used material.
- As Germanium available in pure form due to its refinery process and available in large quantity.

- However transistors constructed from Germanium are suffered low levels of reliability due to its sensitivity to temperature change.
- And due to which scientists have come up with silicon transistor in 1954 which is less sensitive to temperature.
- Silicon is one of the most abundant material on earth.
- As time moves on electronics became highly sensitive to speed .
- Computers operating at higher and higher speeds And communication system were operating at higher level of performance.
- As a result of this in early 1970 new GaAs transistor was developed..
- The new transistor speed is 5 times greater than silicon transistor.
- But more difficult to manufacture as compared to Silicon and Germanium.

COVALENT BONDING AND INTRINSIC MATERIAL

- Every atom is made up of protons and neutrons in nucleolus and electrons are revolving around them.
- Silicon has 14 orbiting electrons Germanium has 32 electrons Gallium has 31 electrons and Arsenic has 33 orbiting electrons.

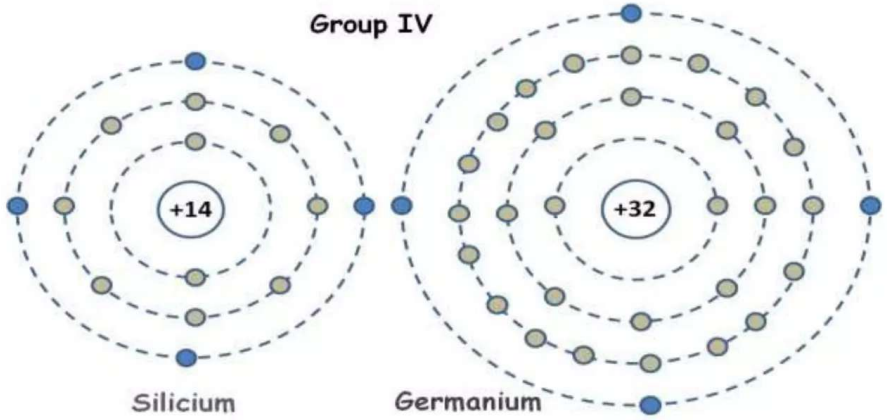


Figure. Atomic structure of Silicon (Silicium) and Germanium

- Electrons in outermost orbit is called as valence electrons.
- Atoms having 4 valence electrons is called as tetravalent, those having 3 valence electrons called trivalent and those having 5 valence electrons is called as pentavalent.

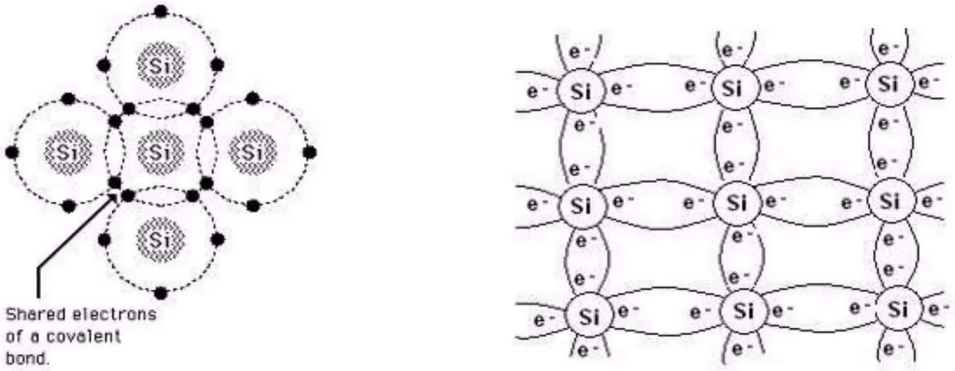


Figure. Covalent bonding of silicon atom

This bonding of atom, strengthened by the sharing of electrons, is called covalent bonding.

- In a pure Silicon or Germanium crystal the four electrons of one atom forms bonding arrangement with four adjoining atoms shown in figure.

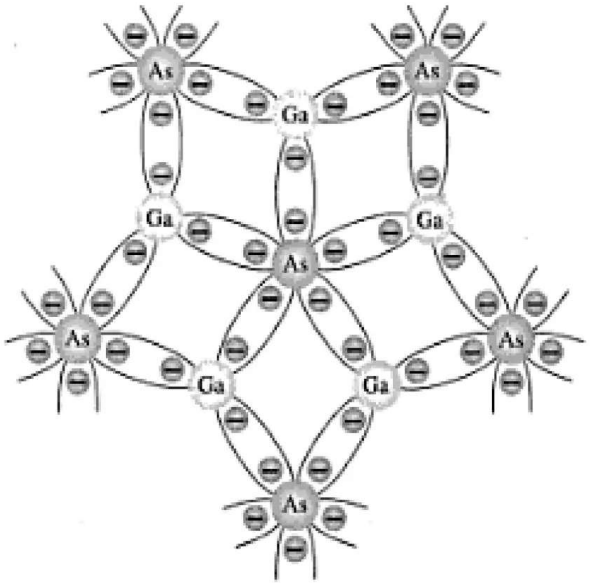


Figure. Covalent bonding of GaAs atom

⦿ The figure show the covalent bonding between two different atom

⦿ Gallium is having 3 valence electrons and Arsenide is having 5 valence electrons

⦿ Which will result in stronger bonding between two atoms.

⦿ The free electrons in a material is due to only external causes are referred to as intrinsic carriers.

⦿ At room temperature there are approx. 15 billion free carriers in 1 cm cube of intrinsic silicon material.

Semiconductor	Intrinsic Carriers (cubic cm)
GaAs	1.7x10^6
Silicon	1.5x10^10
Germanium	2.5x10^13

Table. Intrinsic carriers

⦿ Germanium has more than twice intrinsic carriers than the GaAs and silicon is as in middle range.

⦿ relative mobility factor (μn) decides ability of free electrons moves through the material.

Semiconductor	Relative mobility factor
Silicon	1500
Germanium	3900
GaAs	8500

ENERGY LEVELS

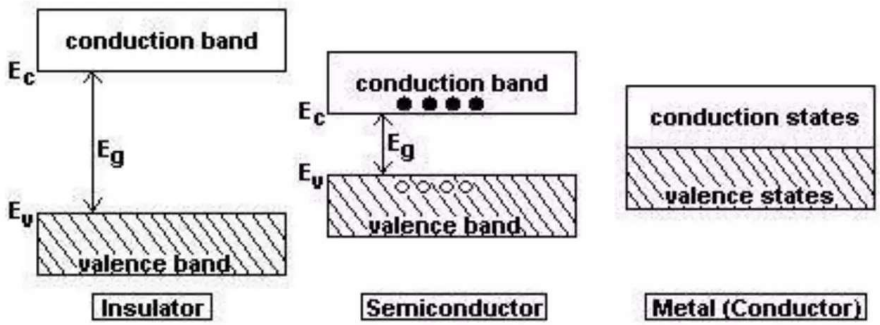


Figure. Energy levels of materials

⦿ For every material they are having valence band and in order to conduct the electrons must be flow from valence band to conduction band

⦿ Figure show the valence band and conduction band of insulator, semiconductor and conductor i.e metals.

⦿ In insulator the energy gap(Eg) is very high so electrons can't move from valence band to conduction band and they are bad conductors

⦿ In semiconductor the energy gap(Eg) is very less in order to conduct the electrons.

⦿ And in conductors the two bands are overlapping so they directly conduct.

⦿ Electron volt is nothing but W=QV where v is voltage and W is energy and Q is charge on electron, so 1 Electron volt is nothing but substituting the charge of 1 electron and potential difference of 1volt results in 1 electron volt.

⦿Eg= 0.67eV (Ge)

⦿Eg= 1.1 eV (Si)

⦿Eg= 1.43 eV (GaAs)

⦿ As electrons in the valence band of Silicon must absorb more energy than the valence band of Germanium to become free carriers, similarly GaAs required more energy than the valence electrons of Germanium and Silicon on order to get in conduction band.

EXTRINSIC MATERIAL

⦿ extrinsic material is obtained by doping process

⦿Adding impurities in semiconductor material is called as Doping.

⦿Impurities are added to obtain change in the covalent bonding of semiconductor material for obtaining better electrical properties .

⦿ there are two types of extrinsic material : n-type and p-type material.

⦿ N-type material

⦿When pentavalent impurities are added to silicon base material then the N-type material is obtained. Like Antimony ,Arsenic and Phosphorous.

⦿ Pentavalent stands for atoms are having 5 valence electrons i.e 5 electrons in the outermost orbit.

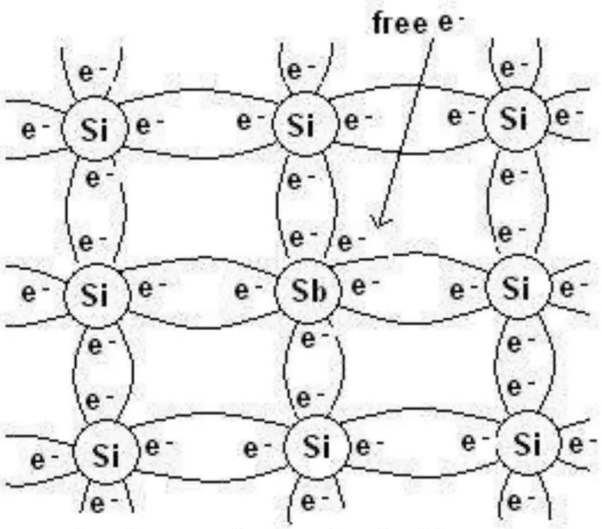


Figure. Antimony impurity in N-type material

- As silicon is having 4 valence electrons and antimony is having 5 valence electrons.
- when we doped antimony atom in silicon atom the 4 valence electrons are get with 4 valence electrons' of silicon and 1 electron remains free at each doping level so called “donor atom”
- Normally doping is done at 1 part per million . i.e 1 atom of antimony with 1 million atom of silicon which results in 100000:1 carrier concentration

⦿ P-type material

⦿ The p-type material is formed by doping pure silicon atom with impurities having 3 valence electrons (Trivalent impurities)

⦿ Boron, Gallium and Indium are trivalent impurities .

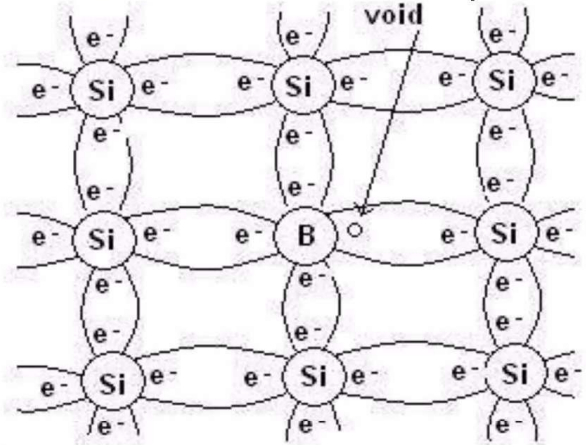


Figure. Boron impurity in P-type material

⦿Boron is having 3 valence electrons and silicon is having 4 valence electrons hence the insufficient number of electrons are there complete covalent bond

⦿Since resulting vacancy will readily accept a free electrons.