MATERIAL CHEMISTRY

Materials chemistry involves the use of chemistry for the design and synthesis of materials with interesting or potentially useful physical characteristics, such as magnetic, optical, structural or catalytic properties. It also involves the characterization, processing and molecular-level understanding of these substances

Non- elemental semi conducting material

Stoichiometric semi conductors:

- The crystal structure and band structures similar to that of silicon and germanium are developed by the combination of group III and group V elements and group II and group VI elements named as stiochiometric semi conductors.

Example : Ga-As semiconductor

Characteristics of stoichiometric semiconductors:

- They can be used at wide range of temperatures
- It is possible to alter the energy gap of these semi conductors by substituting one of the elements in its composition by an element of higher atomic number

  Ex: In GaP, if P is replaced by As ,the energy gap reduces from 2.24 to 1.35
- They can be doped to n or p type semiconductors

CONTROLLED VALENCY SEMICONDUCTORS:

The limitation of defect semiconductor is overcome by preparing controlled valency semiconductor.

- In order to control the concentration of Ni^{3+} ions in NiO and hence its conductivity, a calculated amount of lithium oxide (Li_2O) is reacted with nickel oxide (NiO) and oxygen to form compounds, $Li_X Ni^{+2}_{1-2X} Ni^{+3}_X O$, which exhibit temperature dependent conductivities.

- For example: $Li_{0.05}Ni_{0.95}O$ can be employed in a wide range of temperature upto about 200 ^{0}C.

Chalcogen photo semiconductors:

- Oxygen ,sulphur,selenium and tellurium are collectively called chalcogens or Ore forming elements because a large number of metal ores are oxides or sulphides

Characteristics

- They behave as semiconductors or photo conductors either alone or by combining with other elements

- Conductivity of pure chalcogens increase with increase in atomic mass

- Selenium is an excellent photo conductor.Its conductivity increases enormously on exposing to light,hence it is used in photo copying process(XEROX).

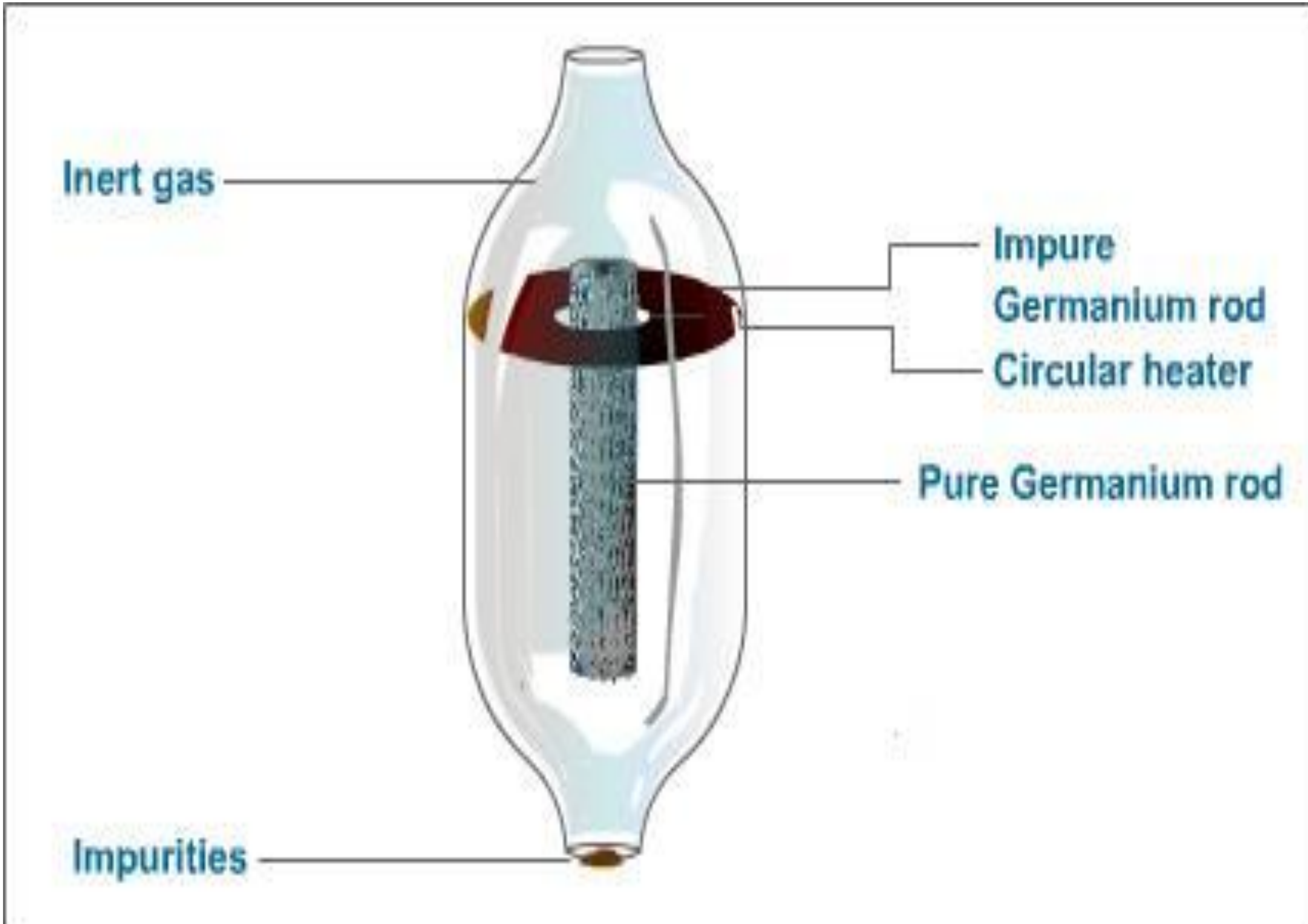
Preparation of semiconductor:

To prepare ultra pure materials the following steps are involved

- i)**Preparation of ultra pure Si or Ge :**Germenium tetrachloride is used as starting material ,which contains arsenic impurity ,which is removed as $AsCl_3$ and separated by distillation
- a) **Distillation**: It is a process where separation is carried out by taking the difference of boiling points as advantage. Ge is taken in a series of stills with a layer of HCl over it and heated it ,While passing chlorine through it. The vapours produced were collected and passed into a fractionating column. The distilled vapours are collected in a ice bath.

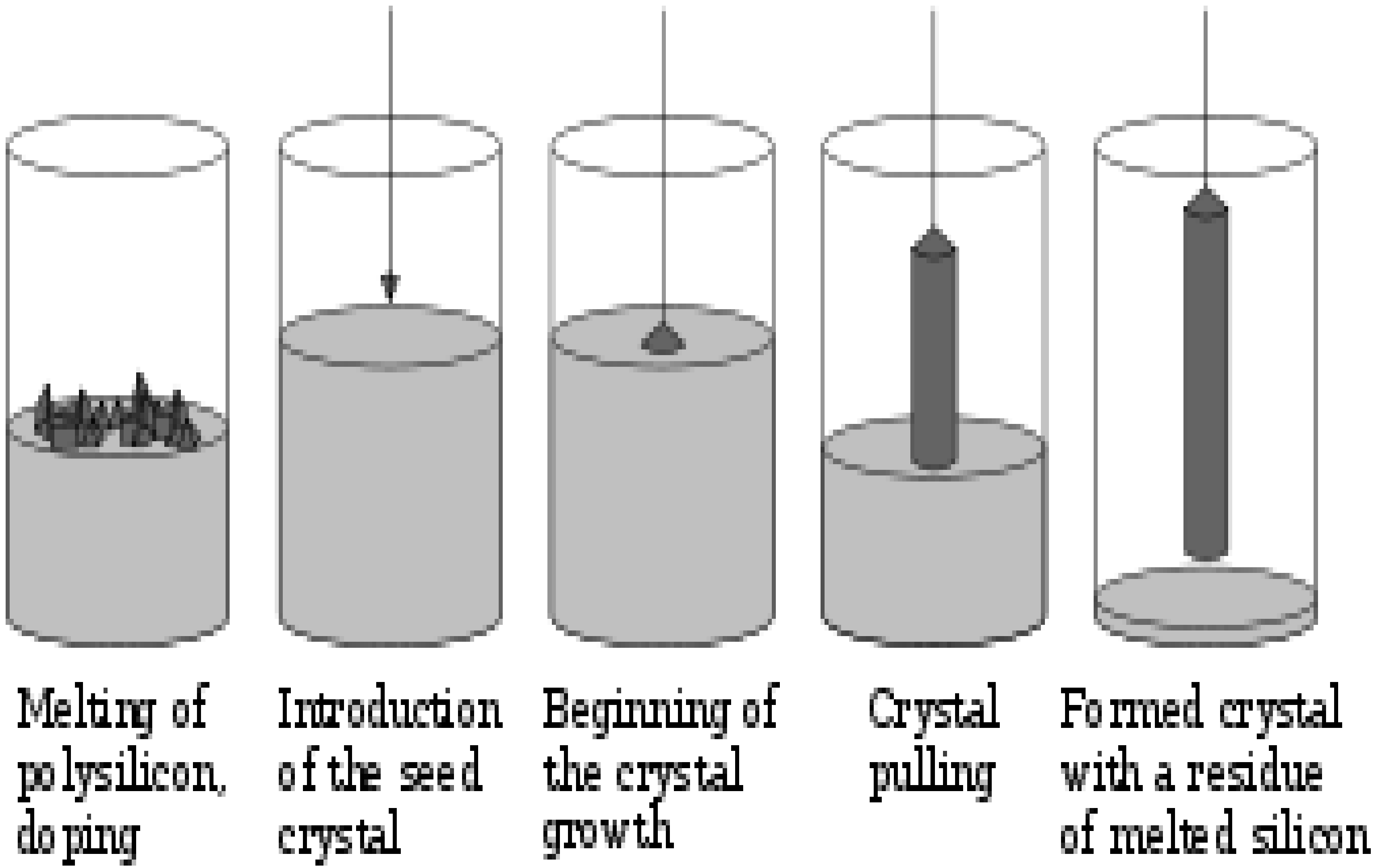
b)**Zone refining**: It is based on principle that the impurities present in a metal are more soluble in molten metal than in solid metal. For the purification of Ge vertical zone refiner is used. A rod of Ge to be purified is clamped and heated by RF coil to about 1000 ^{0} C in a reducing atmosphere. The heater moves from top to bottom very slowly. As it moved down, impurities also moves with molten part of material.

Pure Ge rod solidifies at upper portion


Inert gas
Impure
Germanium rod
Circular heater
Pure Germanium rod
Impurities

Preparation of Ultrapure silicon: The vapours of trichlorosilane are fed into tubular furnace fitted with a highly pure silicon rod and heated at 950 ^{0} C,at this temperature ,the vapours of trichlorosilane decompose leaving behind pure silicon on the surface of the highly pure silicon rod.

- ii)**Preparation of single crystals of Si and Ge**(Czochralski crystal pulling technique):
- In this method single crystal are grown in such a way that during crystal growth atoms reproduce the same atomic arrangement as that of the seed crystal.The process begins when the chamber which contains a crucible with silicon dioxide is heated at 1500 ^{0} C ,at which it produces molten silicon.The shaft rotates in anti clock wise direction and crucible rotates in clock wise direction.The rotating rod is then drawn upwards slowly about 25mm per hour.Annealing process condition were adopted to remove oxygen.This complete method can be applied for the preparation of Ge also.


Melting of polysilicon, doping
Introduction of the seed crystal
Beginning of the crystal growth
Crystal pulling
Formed crystal with a residue of melted silicon

- Doping:Introducing an impurity in to the semiconducting crystal is called “doping”.It can be done by epitaxy diffusion implantation technique.

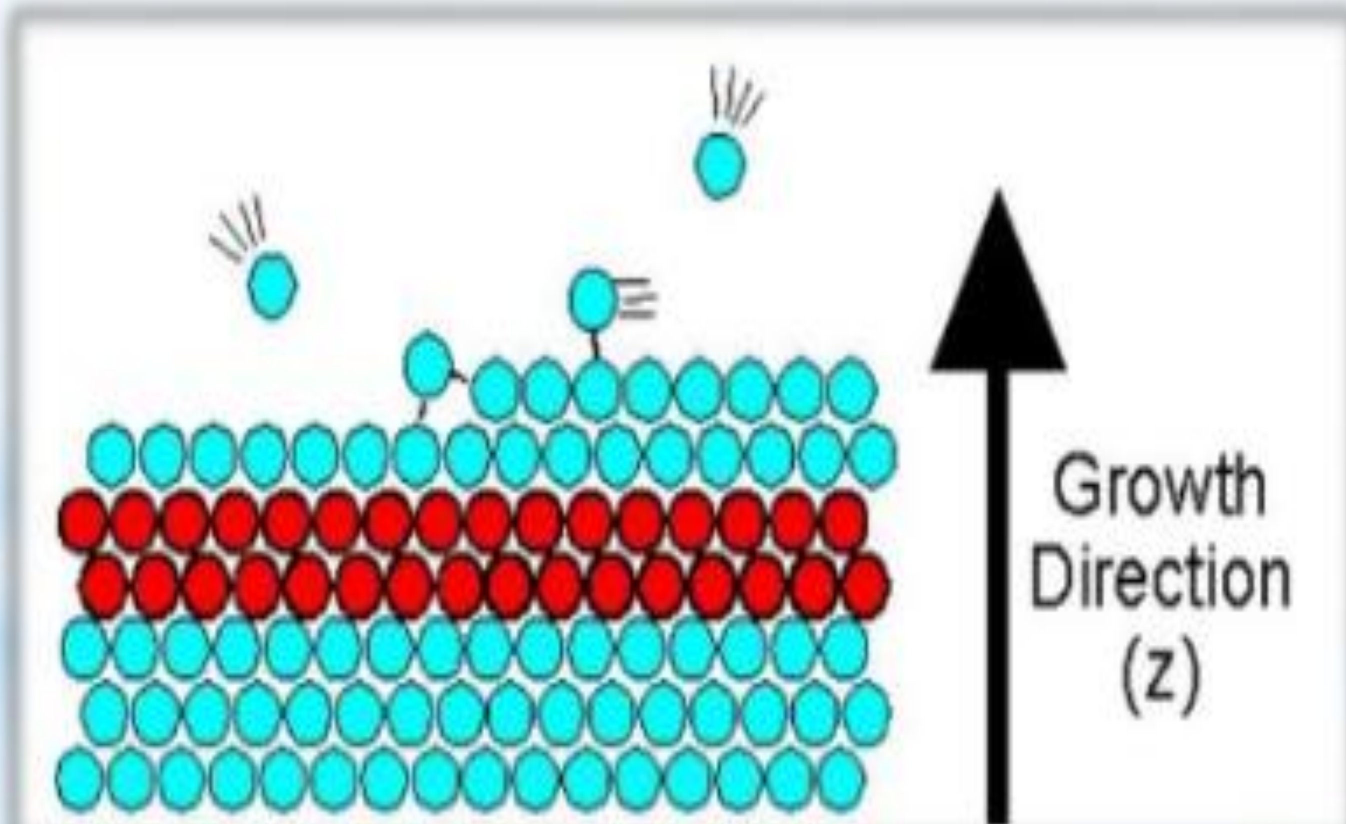
a)EPITAXY(Epi- over, taxis-ordered manner):It is a process of deposition of crystalline over layer on a crystalline substrate which acts as seed crystal.

- It is broadly divided in to two catergories
- Homoepitaxy -The film and the substrate are the same material. -Epitaxially grown layers are purer than the substrate and can be doped independently o f it
- Heteroepitaxy- Film and substrate are of different materials and the film can be doped

<u>Applications of Epitaxial Growth</u> • Nanotechnology

- semiconductor fabrication
- high quality crystal growth(silicon –germanium, gallium-nitride)
- To deposit organic molecules onto crystalline substrate.

EPITAXY GROWTH



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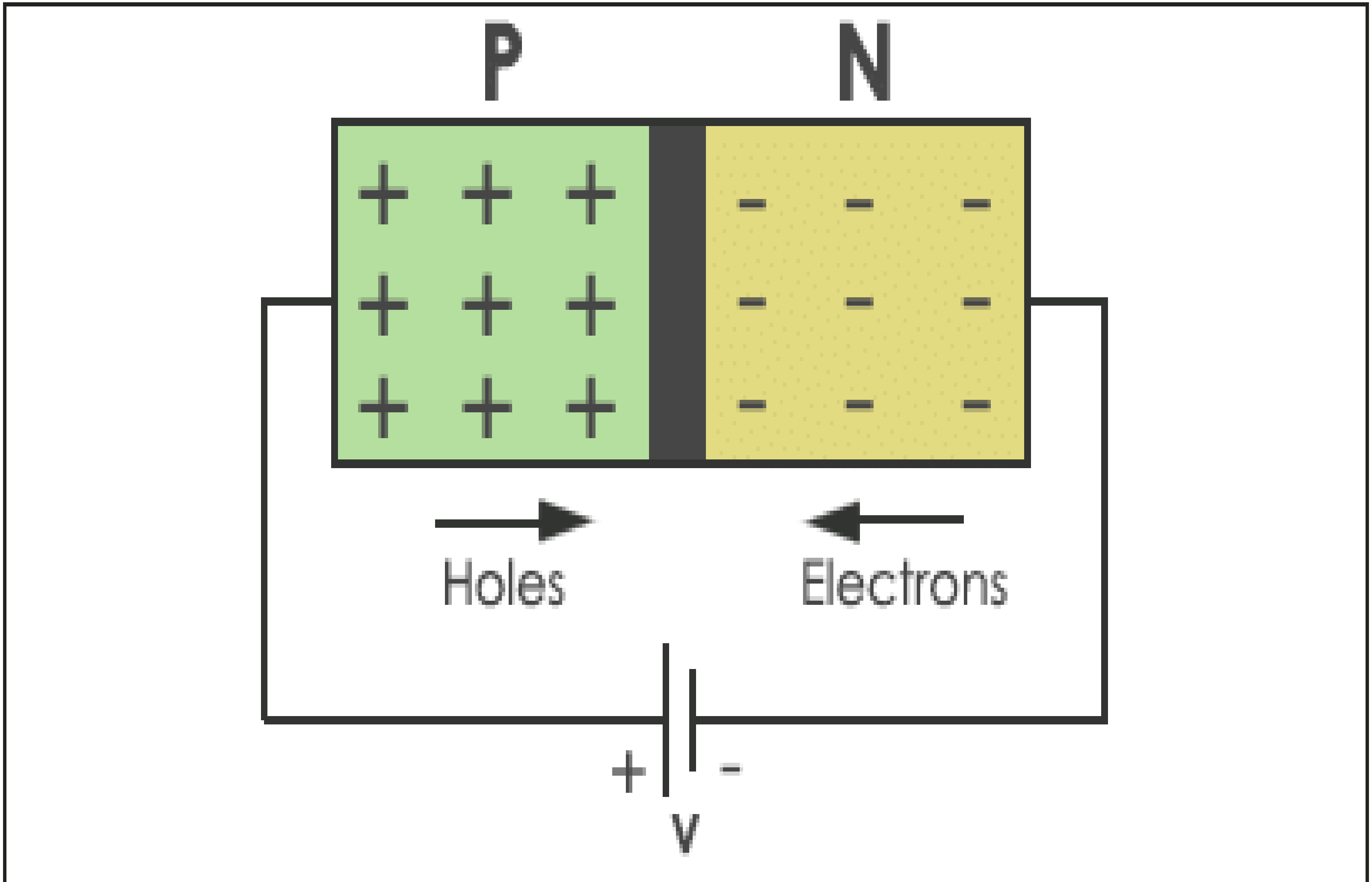
b)Diffusion: An epitaxy layer can be doped during deposition by adding impurities to source gas (impurity examples Arsine,phospine).The impurity changes the deposition rate.At high temperatures the chemical vapour deposition may allow dopants to diffuse into growing layer from layer to the other layer in the wafer(Example: preparation of pn – semiconducting material)

- Ion implantation technique: **Ion implantation** is a low-temperature **process** by which **ions** of one element are accelerated into a solid target, thereby changing the physical, chemical, or electrical properties of the target. **Ion implantation** is used in semiconductor device fabrication and in metal finishing, as well as in materials science research
- The process involves bombardment of high electron beam containing impurity(boron or phosphorous) with a semiconducting material
- It is useful in prevents crack propagation and an alloying of the steel surface to make it more chemically resistant to corrosion

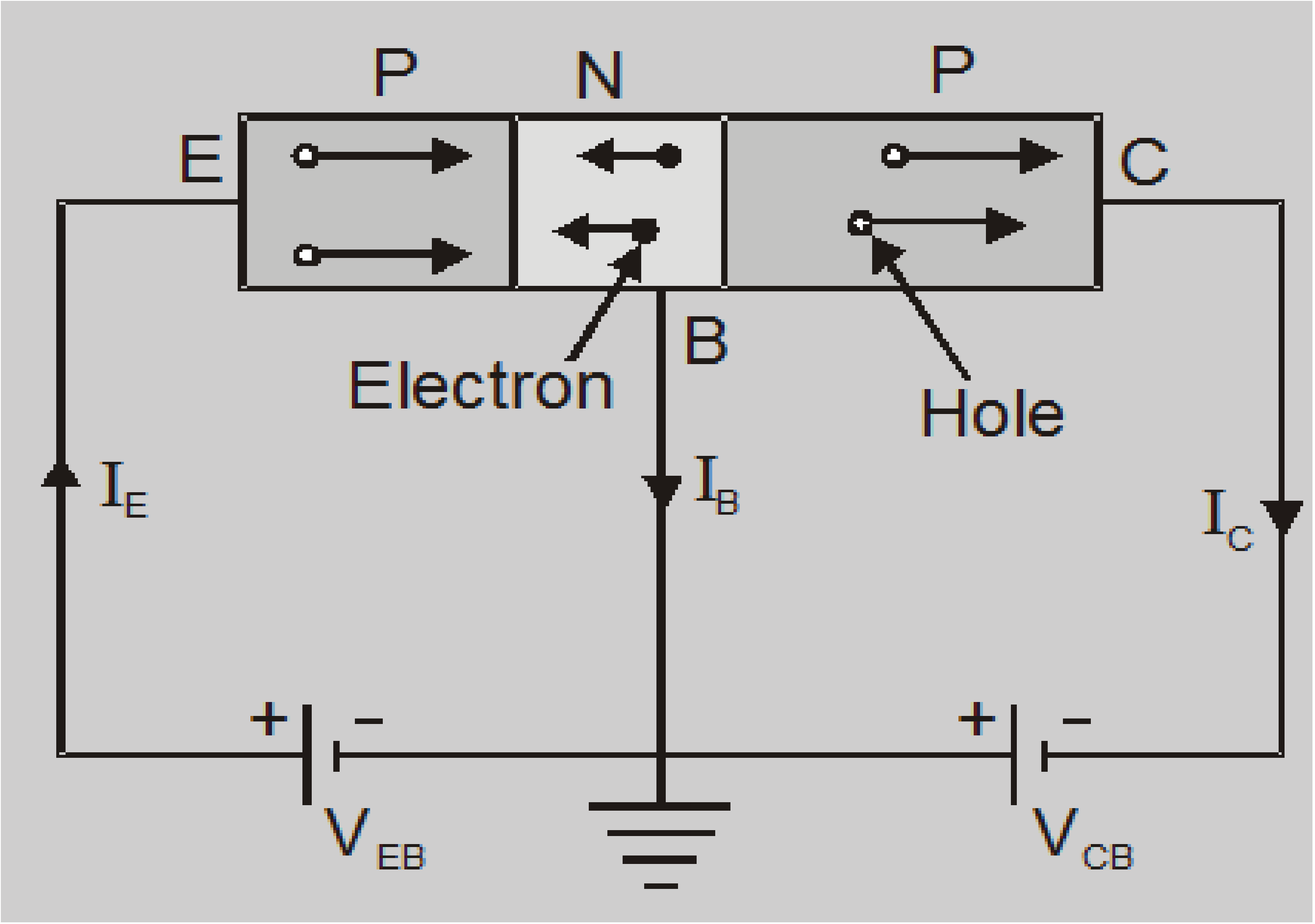
- **p-n junction as rectifier**:A transistor with two zones one p-type ,other is n-type.If p-type semiconducting region is connected to the positive terminal of the battery.From n-type region electrons migrate towards the junction,where as holes will migrate towards the junction.At p-n junction of diode ,the migrating electrons from n-type move into the vacant holes in the valence band of the p-type region.This migration of electrons and holes can continue and a current flows as long as the external voltage is there


P
N
Holes
Electrons
+
-
V

- In p-n-p transistor , the charge carriers in the emitter are positive holes ,which migrate from the emitter to the base. The positive holes cross the emitter-base junction. In the n-type base region some holes combines with electrons and destroyed. Electrons flow in the reverse direction, also there is a recombination of electron with hole, called base current. Since the collector has much greater negative voltage and the base is very thin, most of the positive holes pass through the base to the collector, where they combine with electrons from the circuit.

Applications:

- Used as amplifiers
- Used as oscillator in radio ,t.v,computers,photo transistors


P
N
P
E
C
B
Electron
Hole
I_E
I_B
I_C
+
-
+
-
V_{EB}
V_{CB}

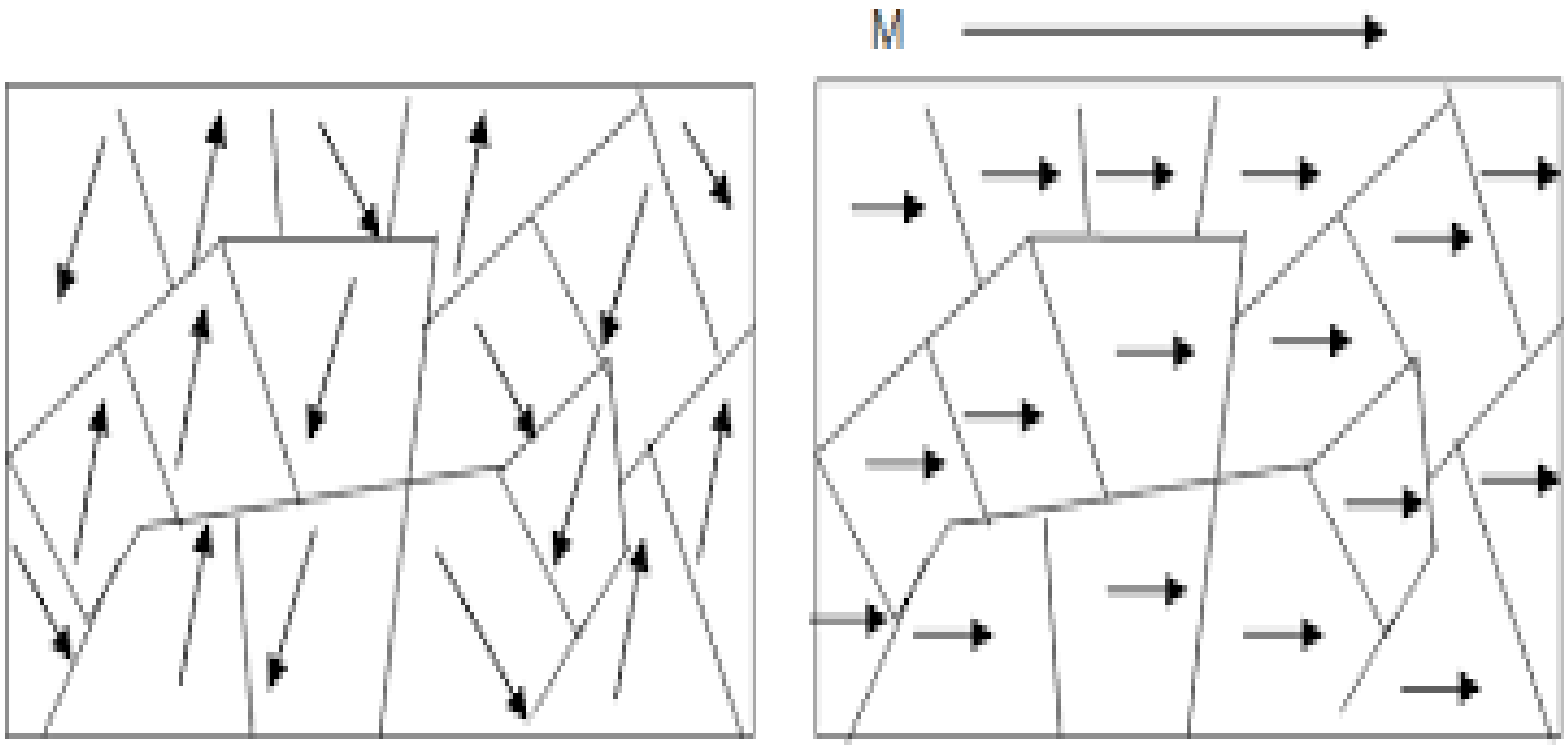
Ferro and Ferri magnetism:

Origin of magnetism: One of the fundamental property of an electron is that it has a magnetic dipole moment i.e it behaves like a tiny magnet. This dipole moment comes from the quantum mechanical spin of electrons. Magnetic field is high When the magnetic dipoles in a piece of matter are aligned in same direction

The **ferromagnetic materials** are those substances which exhibit strong magnetism in the same direction of the field, when a magnetic field is applied to it.

First, we have to know what a domain is. It is actually a tiny area in ferromagnetic materials with a specific overall spin orientation due to quantum mechanical effect.

These materials that can be magnetized by an external magnetic field and remain magnetized after an external field is removed are permanent magnet

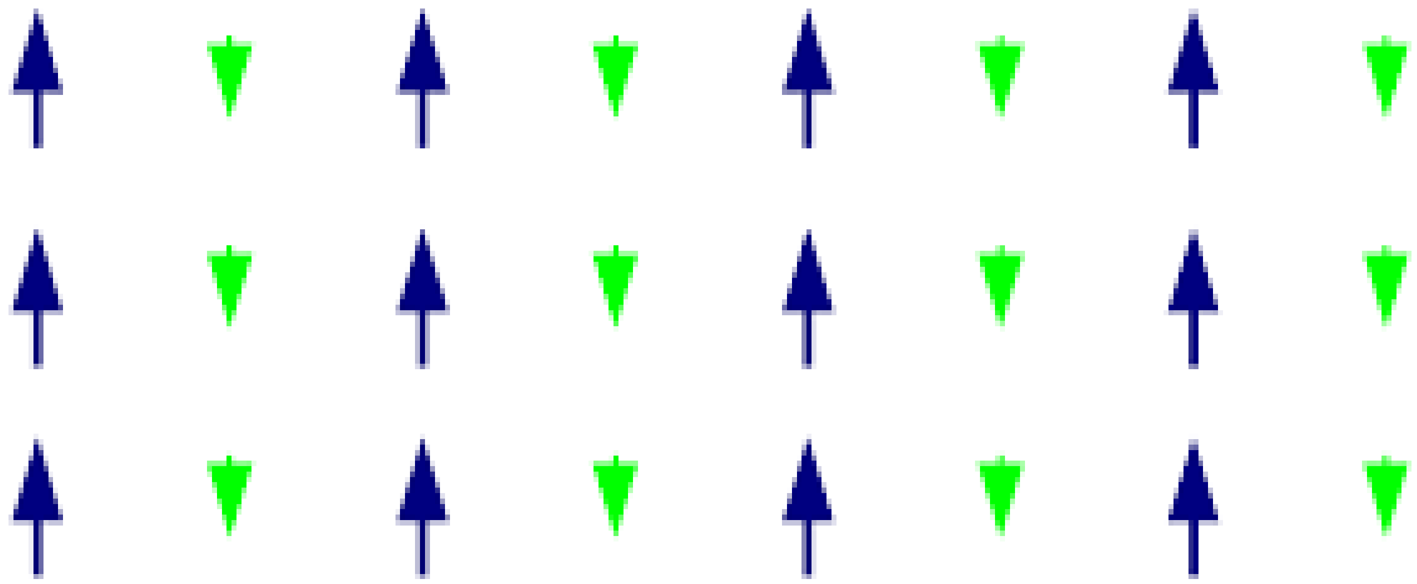


A. Random domain orientation

B. After magnetization

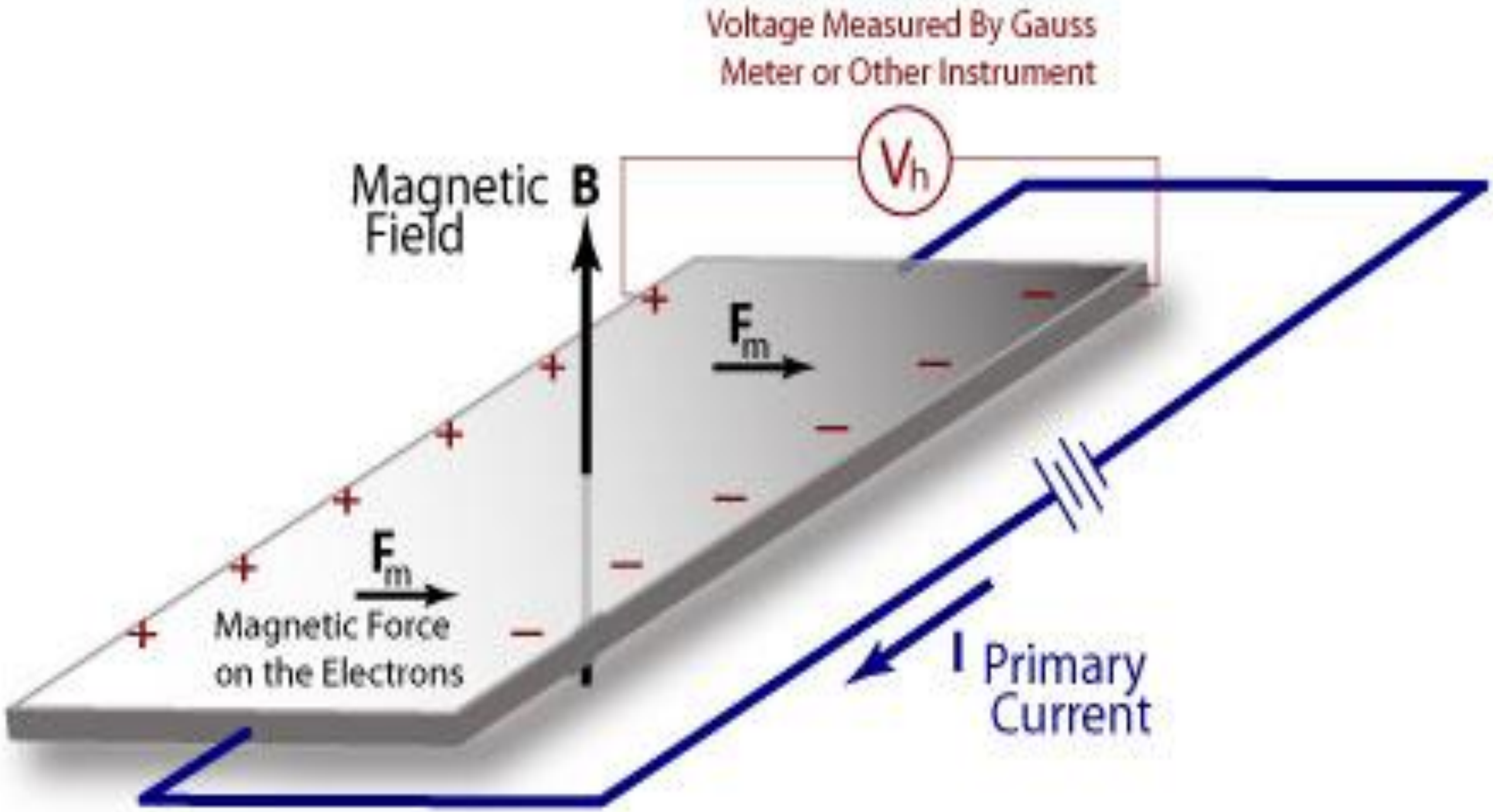
Figure 1

While incase of **ferrimagnetism ,which has** populations of atoms with opposing magnetic moments but the opposing moments are unequal **in magnitude i.e it** results spontaneous magnetization



- Hall effect: The **Hall effect** is the production of a voltage difference (the **Hall voltage**) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current

When a magnetic field is present, these charges experience a force, called the Lorentz force. When such a magnetic field is absent, the charges follow approximately straight line..At equilibrium a voltage appears at the semiconductor edges.


Voltage Measured By Gauss Meter or Other Instrument
Vh
Magnetic Field B
Fm
Fm
Magnetic Force on the Electrons
I Primary Current

Applications:

i) Hall probes are used as magnetometers to measure magnetic field

ii) Hall effect sensors have mass application and analog to digital convertors

iii)It is useful in space craft applications

Electrical insulators :

An **electrical insulator** is a material in which electric current does not flow freely. The atoms of the insulator have tightly bound electrons which cannot readily move.The main characteristics are

- high resistivity and low electrical conductivity
- High dielectric strength

A perfect insulator does not exist because even insulators contain small numbers of mobile charges (charge carriers) which can carry current. In addition, all insulators become electrically conductive when a sufficiently large voltage is applied that the electric field tears electrons away from the atoms. This is known as the breakdown voltage of an insulator.

Classification of insulators

i)Gaseous insulators :

- Air (Over head transmissionlines)
- Nitrogen (used in transformers,capacitors)
- Carbondioxide (capacitors, transformers)
- Electronegative gas ex: Sulphur hexafluoride (used in capicitors)

Fig - A : Transmission line with tower and other accessories

ii) Liquid insulator :

Mineral oils,askarels, silicon fluids , organic ester liquids (used in capacitors, transformers as coolant)

iii) Solid insulators:

- paper, pressboard,fibrous insulators,amber,shellac, polyethylene ,poly styrene,polyvinyl chloride ,POLYESTER RESINS ,epoxy resins , poly tetrafluoroethylene (used in capacitor and cable insulations

$143 : Oct 2014 (#146) : Bill & Jill

$121 : Oct 2014 (#146) : Bill & Jill

$99 : Feb 2014 (#144) : Bill & Jill

$275 : May 2017 (#149) : Bill & Jill