Superconductivity

The sudden disapperance of electronical resistance in material below a certain temperature is known as **superconductivity**..The materials that exhibit superconductivity are called **superconductor.**

The characteristic temperature at which a metal becomes superconducting depends on-

1. The strength of magnetic field.
2. Whether the field is applied externally or is the result of current used to measure the resistance.

Types of Semiconductors

On the basis of biasing on the magnetic behaviour, superconductors are classified into two categories namely type-I and type-II superconductors.

1. **Type -I Superconductor :** In this type of superconductor the magnetic field is totally excluded from the interior of the superconductor below a certain magnetic field called critical field (H_C). But at the critical magnetic field, the material losses superconductivity abruptly. Now the magnetic field penetrate fully with the material, *i.e.* the material is in normal state such type of superconductor are termed as type-I super conductor. Ex. Lead, Tin, Mercury.

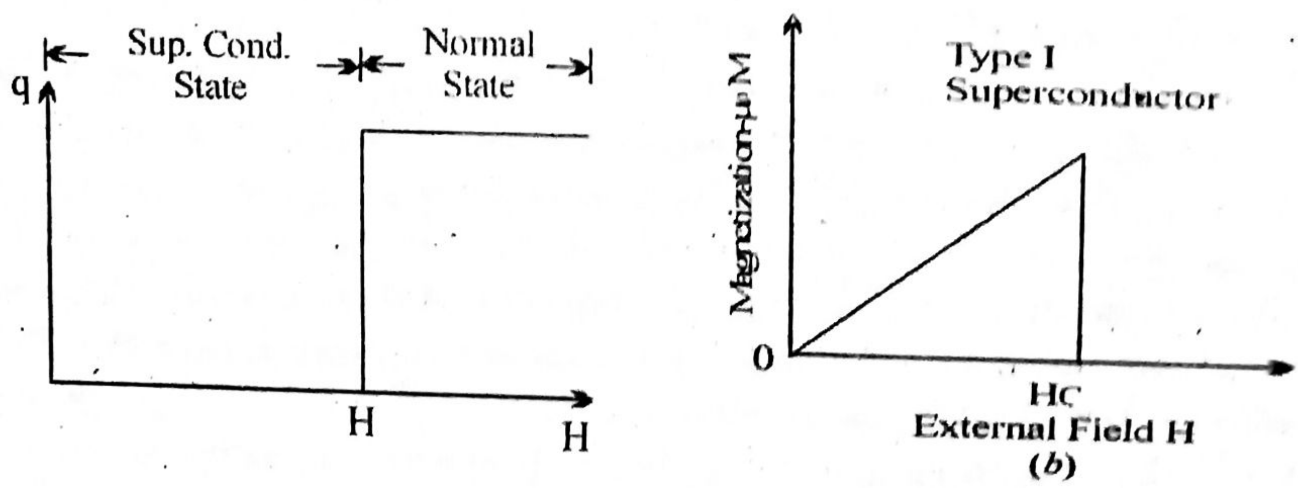


Fig . 4.9

Type-I superconductor are called **soft superconductor** because the superconductivity is destroyed very easily at low H_C value.

2. **Type - II superconductor :** This type of superconductor are charaterized by the exislence of two critical field, *i.e.*, lower critical field Hc_1, and upper critical field Hc_2.

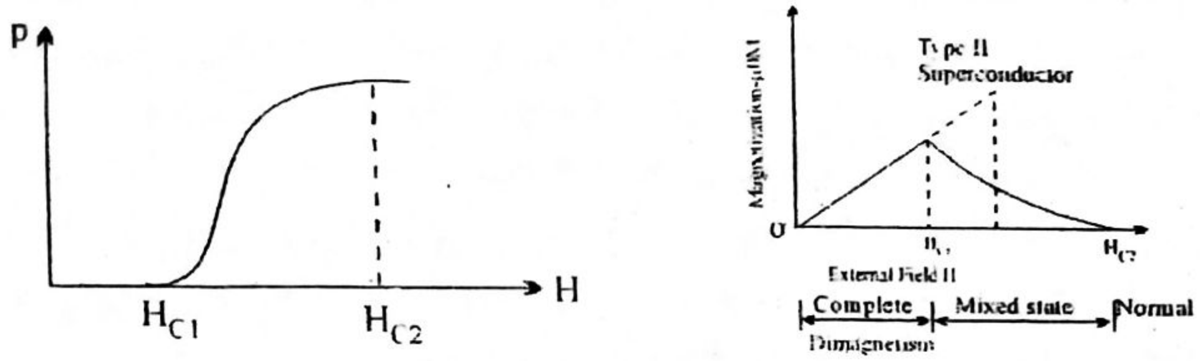


Fig. 4.10

For this group of superconductor below Hc_1 the specimen is superconducting. At Hc, the flux start pencrating into untill the upper critical field Hc_2 is reached the specimen is in mixed state and exhibit superconducting eletrical propertiy. At Hc_2 the magnetization vaishes and the specimen turns to normal conducting state.

Since the superconductivity is rutained till fair large magnitic field is reached, hence the superconductor are called **hard superconductor.** Ex.- Nb - Ti, Nb_3 Sn.

Applications of Superconductivity

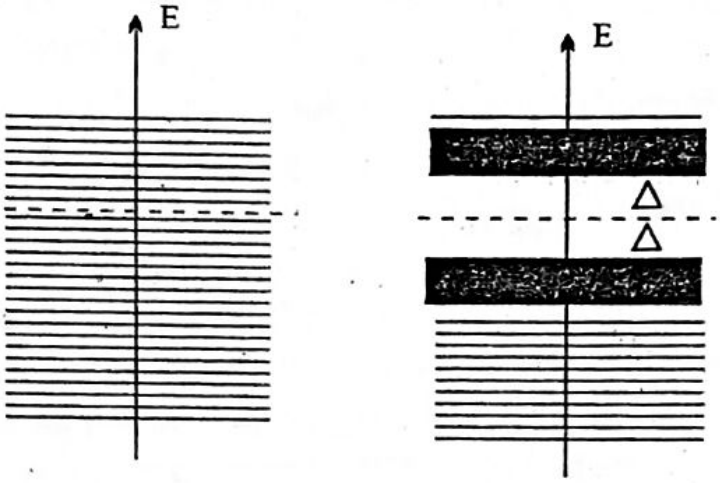
1. superconductor are used to amplifging very small current and voltage.
2. Fligh magnetic field is require in many area of research and diagonostic equipments superconductor solonoids produce very strong magnetic field. They are small in size and does not need power. They are less expensive.
3. They are employed in switching device.
4. In the conduction of very sensitive elecrical measuring instrument like galvanometer.

(a) BCS Theory of Superconductivity

John Bardeen, Leon, N. Cooper and John Robert Sheriffer developed in 1957 the quantum theory of superconductivity. When an electron approaches an ions in the lattice, there is a coulmb attraction between the electron and the lattice ion. This produce a distortion in the lattice. The distortion causes an intense in the density of ions in the regoin of distortion. A free electron exerts a small attractive force on another electron through phonon which are quanta of lattice viberation. A pair of free electron thus coupled through a phonon is a called a **cooper pairs**. At normal tepmerature the attractives force is too small and pairing of electron does not lake place. Each cooper pair consist of two electron of opposite moments.

The BCS theory gives two important,results namely existence of energy gap and flux guantization.

1. Energy Gap : The electron of a cooper pair have a lower energy than two unpaired electron therefore the energy spectrum of electron exhibit an energy gap. The cooper pair occupy the lower state the energy gap prevent the pair from breaking.



(a) (b)

Fig. 4.12

A finite energy 2Δ must be expanded to dissociate a cooper pair. For a superconductor at 0 k, the width of gap is proportional to critical temperature .Thus,

$$\boxed{2\Delta = 3.52\, k\, T_C}$$

The energy gap is generally of the order of 10^{-3} eV.

At tyemperature close to absolute zero, a superconductor does not absorb energy until the energy quantaof incident radiation is equal to or greater than 2Δ.The absorption then grows fast to a value typ[ical for the normal metal, because electrons can not absorb photons and go to higher state that lie above the gap.

2. Flux quantization : In 1957 A. A. Abrikosov predicted the existence of magnitic flux quanta. Accordingly a closed superconducting loop can enclose magnetic flux only in integral multiples of a fundamental quantum of flux. Thus the magnetic flux enclosed by superconducting ring ϕ is given by

$$\phi = n\frac{h}{2e}$$

$$\phi = n\ \phi_0 \qquad\qquad n = 1,2,3,....$$

Where , $\phi_0 = \frac{h}{2e}$ is the flux guantum and is called **fluxon**. The value of flux quantum is -

$$\phi_0 = 2.07\times10^{-15}\ \text{Weber}$$

The quantization of magnetic flux is a special property of superconductor.