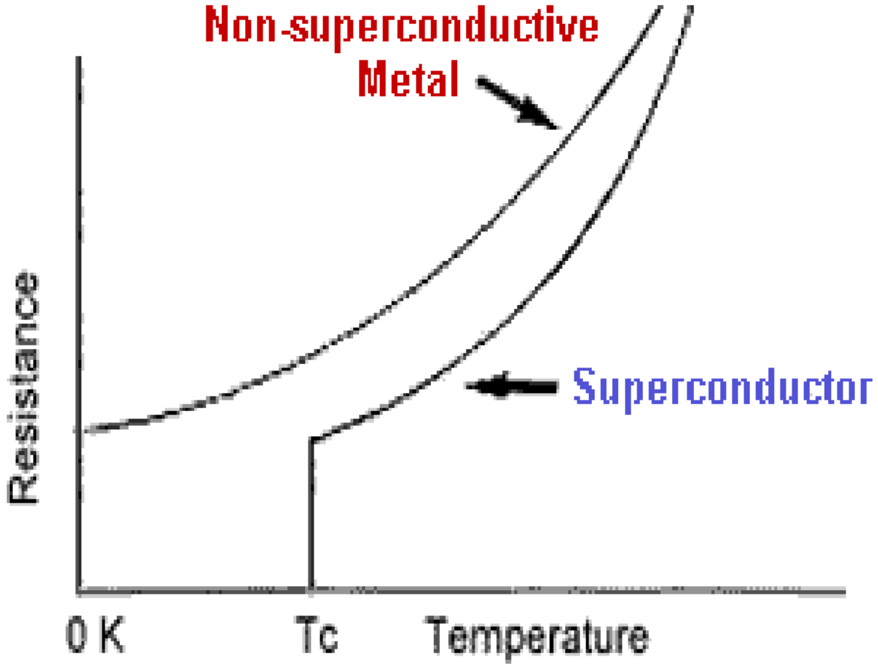
- **Superconductivity :** The electrical resistance disappears abruptly and completely at temperatures, a few degrees above absolute zero. Materials are said to be superconducting when they offer no resistance to the passage of electricity. The maximum temperature which a superconducting materials exhibits superconductivity, is called critical temperature(Tc). Materials in superconducting state becomes diamagnetic and are repelled by magnets.

Or

- Certain metals and alloys exhibits almost zero resistivity (i.e. infinite conductivity) when they are cooled to sufficiently low temperatures. This phenomenon is called Superconductivity. The material is called superconductor and is said to be in Superconducting



- Type I superconductors: Type I superconductors are those superconductors which lose their superconductivity very easily or abruptly when placed in the external magnetic field. Type I superconductors are also known as soft superconductors

- Type II superconductors: Type II superconductors are those superconductors which lose their superconductivity gradually but not easily or abruptly when placed in the external magnetic field. Type II superconductors are also known as hard superconductors

- Meissner effect: The property of expulsion of magnetic field is called Meissner effect

- Critical temperature (T_c):The temperature at which the material undergoes a transition from normal state to superconducting state is known as Critical temperature

- Critical magnetic field (H_c):The magnetic field at which a superconductor loses its superconductivity and becomes a normal conductor is known as Critical magnetic field

Concepts:

- The electrical Resistivity certain metals and alloys drops to zero(i.e, conductivity is infinity),when they cooled to sufficient low temperature. This phenomenon is called as Superconductivity

Based on the behaviour and properties of Superconductors, these are classified into two categories-

(1) Type – I Superconductors: Low Temperature Superconductors.

(2) Type – II Superconductors: High Temperature Superconductors.

CRITICAL TEMPERATURE

- The temperature at which a material electrical resistivity drops to zero is called the Critical Temperature or Transition Temperature.

- Below critical temperature, material is said to be in superconducting and above this it is said to in normal state.

Metal	Critical T_c (K)
Mercury	4.15 K
Aluminum	1.19K
Tin	3.7K
Niobium	9.3K
Niobium-Tin	17.9K

Critical current (I_c) The maximum current that a superconductor can carry without resistance .Important Factors to define a Superconducting State

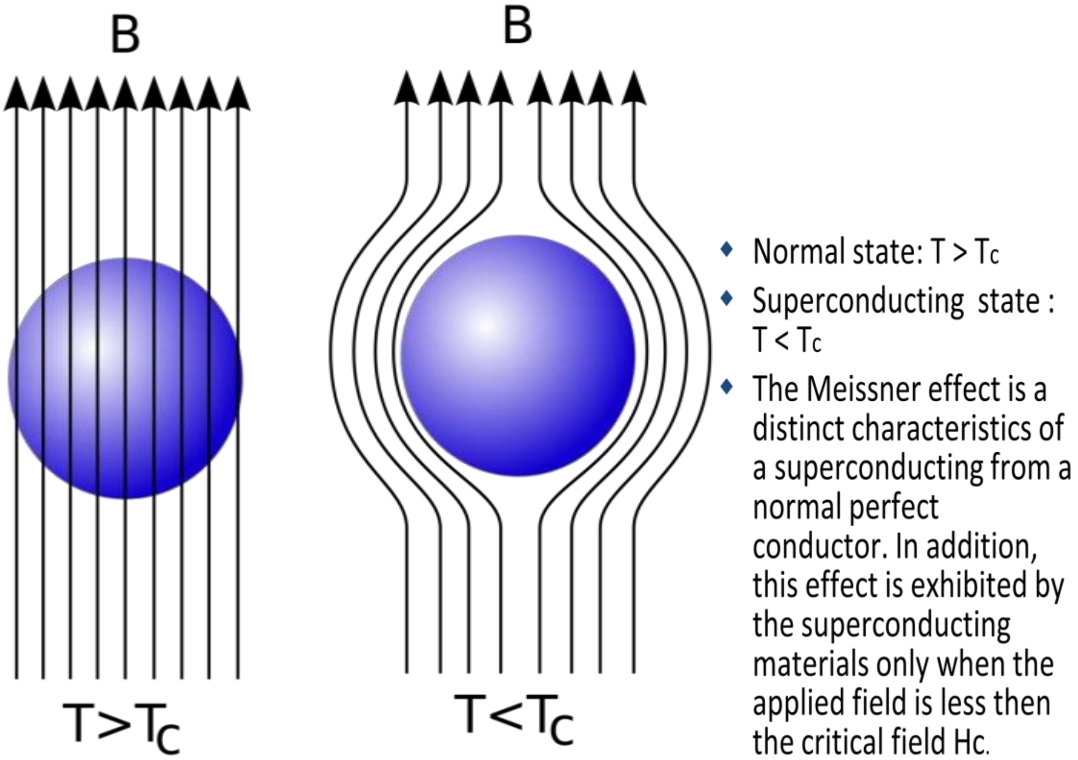
The superconducting state is defined by three very important factors:

1.Critical temperature (T_c)

2.Critical field (H_c)

3.Critical current (I_c).

Meissner Effect: (Effect of a weak magnetic field):When a weak magnetic field is applied to a superconductor as temperature below critical temperature (Tc), the magnetic flux lines are expelled (repelled).This effect is called "Meissner effect". The Specimen of Superconductor is act as a Diamagnate



TYPES OF SUPERCONDUCTORS

TYPE 1

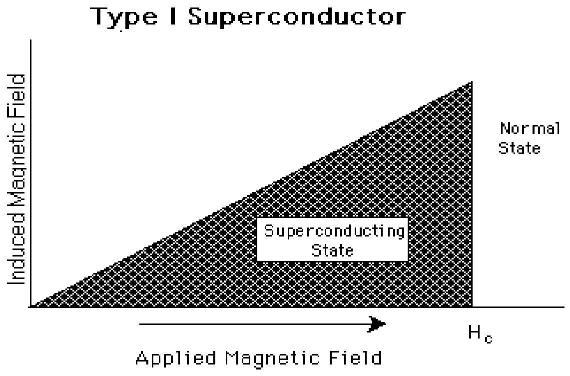


Fig. 10

TYPE 2

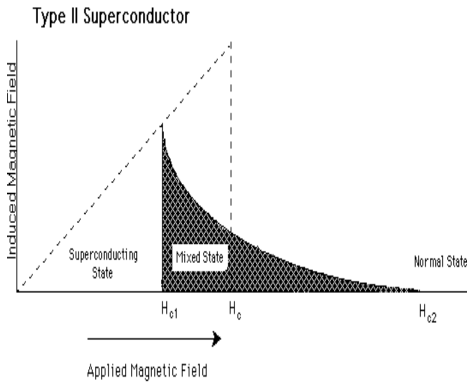


Fig. 11

Type – I and Type – II superconductors slightly different in their behaviour and properties are shown in the table below

S.No.	Type – I super conductors	Type – II super conductors.
1	These are called soft super conductors	These are called Hard super conductors
2	They exhibit complete Meissner effect I.e they are completely diamagnetic	They do not exhibit complete Meissner effect
3	There is only one critical magnetic field (HC)	There are two critical magnetic field (HC)
3	There is only one critical magnetic field (HC)	There are two critical magnetic field (HC)
4	No mixed state exists.	Mixed state is present
5	The material loses its magnetization suddenly The material loses its Ex: lead, tin, Hg etc.,	The material loses its magnetisation gradually Ex; Nb-Sn, Nb-zr, Nb-Ti etc.,
6	Low critical temperature (typically in the range of 0K to 10K)	High critical temperature (typically greater than 10K)
7	Low Critical magnetic field (Typically in the range of 0.0000049 T to 1T)	High Critical magnetic field (Typically greater than 1T)
8	Perfectly obey the Meissner effect: Magnetic field cannot penetrate inside the material.	Partly obey the Meissner effect but not completely: Magnetic field can penetrate inside the material.
9	Exhibits single critical magnetic field.	Exhibits two critical magnetic field
10	Easily lose the superconducting state by low-intensity magnetic field. Therefore, type-I superconductors are also known as soft superconductors.	Does not easily lose the superconducting state by external magnetic field. Therefore, type-II superconductors are also known as hard superconductors.

General Properties of Superconductors:

1) Superconductivity is a low temperature phenomenon

2)Electrical resistance: Virtually zero electrical resistance. so, it can conduct the current even in the absence of an applied voltage.

3)Isotope effect: The critical or transition temperature Tc value of a superconductors is found to vary with its isotopic mass. i.e. "the transition temperature is inversely proportional to the square root of isotopic mass of single superconductors."

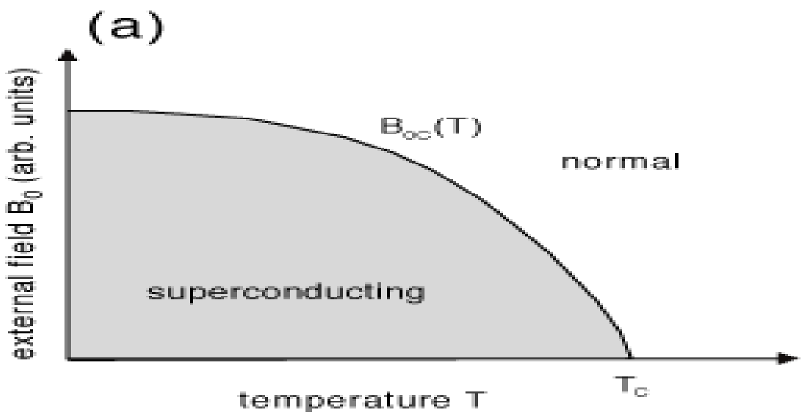
4)Effect of impurities: Superconducting property of a superconducting substance is not disappearing even by adding impurities.

5)Magnetic field effect: If Strong magnetic field applied to superconductors below its TC, the superconductors undergoes a transition from superconducting state to normal state.

6)Transition metals having odd number of valence electrons are favourable to exhibit superconductivity, while metals having even number of valence electrons are in favourable.

7)Effects of pressures and stress: certain materials exhibits superconductivity on increasing the pressure in superconductors, the increase in stress results in increase of the Tc value.

Critical magnetic field (Hc).This minimum magnetic fields required to destroy the superconducting state is called the critical magnetic field Hc .



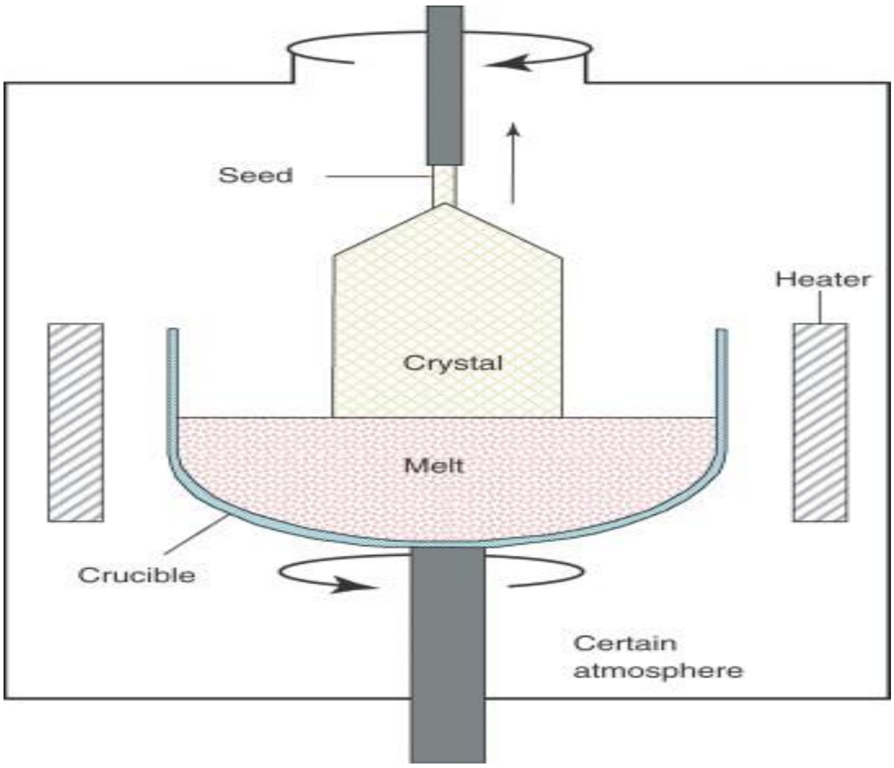
❖ Some important applications of superconductors are:

- Superconductors are used for producing very strong magnetic field of about 20 – 30 T which is much larger than the field obtained from an electromagnet and such high magnetic fields are required in power generators.
- Efforts are being made at present to develop electrical machines and transformers utilizing superconductivity. Calculations show that if we could use superconductors as conducting material, in addition to superconducting magnets, which are already being produced, it is possible to manufacture electrical generators and transformers in exceptionally small size, having an efficiency as high as 99.99%.
- Magnetic energy can be stored in large superconductors and drawn as required to counter the voltage fluctuations during peak loading.
- The superconductors can be used to perform logic and storage functions in computers
- A superconductor material can be suspended in air against repulsive force from permanent magnet. The levitation can be used in transportation.
- As there is no heat loss in superconductors (i.e. I2R loss is zero), so power can be transmitted through the superconducting cables.

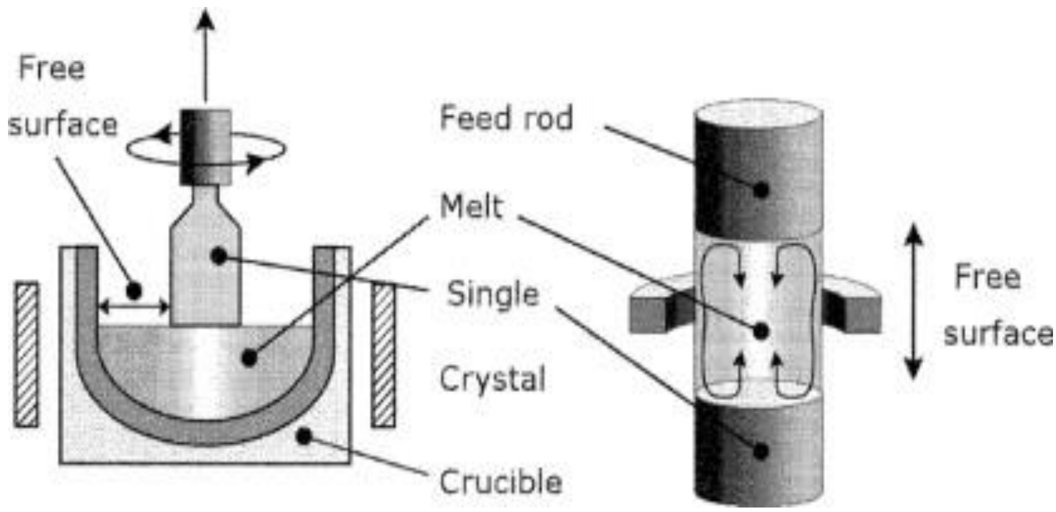
- Superconducting materials if used for power cables enable transmission of power over very long distances using a diameter of a few centimeters without any significant power loss or drop in voltage. Superconducting solenoids which do not produce any heat during operations have been produced.
- However, it must be noted that superconductivity can be destroyed if the magnetic field exceeds a critical value. It has been possible to design electromagnets using superconductivity for use in laboratories and for low temperature devices like the maser.

Czochralski technique

The Czochralski (Cz) method is the most important method for the production of bulk single crystals of a wide range of electronic and optical materials (Figure 2). At the beginning of the process, the feed material is put into a cylindrically shaped crucible and melted by resistance or radio-frequency heaters. After the feed material is completely molten, a seed crystal with a diameter of typically a few millimeters is dipped from the top into the free melt surface and a melt meniscus is formed. Then, after re-melting of a small portion of the dipped seed, the seed is slowly withdrawn from the melt (often under rotation) and the melt crystallizes at the interface of the seed by forming a new crystal portion. During the further growth process, the shape of the crystal, especially the diameter, is controlled by carefully adjusting the heating power, the pulling rate, and the rotation rate of the crystal. Therefore, an automatic diameter control is generally applied. This diameter control is based, either on the control of the meniscus shape (e.g., for silicon) or on the weighing of the crystal (e.g., for GaAs, InP) or of the melt (for oxides).



Czochralski technique


Free
surface
Feed rod
Melt
Single
Crystal
Crucible
Free
surface