SUPERCONDUCTOR THEORY MATERIALS AND DEVICES

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ABSTRACT

Superconductivity is a phenomenon in the solid-state physics that occurs under a certain critical temperature (often referred to as Tc) in ceramic materials. A superconducting material is characterized by its infinitely high electrical conductivity and zero resistance and the absence of any magnetic field in the interior. From many areas of research, this so-called superconductivity has become indispensable. In present study possible explain for the zero resistance in all YBCO system and Bi-Sr-Ca-Cu-O system of high temperature Superconductors. Among other possibilities, the nuclear magnetic resonance, the magnetic levitation train, the transport processing of electrical energy (motors, generators, transformers and power lines) and superconducting magnetic energy storage (SMES) systems are already solutions contributing to the nowadays daily life, but more than that, are solutions that will contribute to improve the quality of life of many human beings in the near future.

Keywords: *Superconductivity, YBCO system, Bi-Sr-Ca-Cu-O system, High temperature, Cuprates, perovskite.*

INTRODUCTION

Superconductivity was find from liquefactions of helium in 1908 by Professor Heike Kamerlingh Onnes was a Dutch physicist and Nobel laureate .he was the first milestone in direction of superconductivity. Superconductivity is the process of zero electrical resistance show by a material at a particular temperature that temperature is called critical temperature T_c. At T_c electrical resistance drops by many order near about 10^{-9} ohm As the material cool down H.K.Onnes found the mercury become superconducting at a temp of 4.2 K after that a large no. and variety of chemical compound were found to super conduct at medium or under high pressure.

BACKGROUND

The liquefaction of helium was the key for discovering superconductivity in 1908 by H. K. Onnes. Later he studied the resistivity of metals at very low temperature using liquid helium as a coolant. In 1911, H. K. Onnes and his assistant Gilles Holst began to investigate the electrical properties of metal in extremely cold temperature as it was not known what limiting value of the resistance would approach at 0 K. Onnes passed a current through a very mercury wire and noticed that the resistance of mercury suddenly drops to zero at 4.2 K. H. K. Onnes initially thought that their apparatus had shorted out. Only later did he realize that the effect was real. Figure is the graphic representation of resistance versus temperature in mercury wire as measured by Onnes. According to Onnes, “Mercury has passed into a new state, which on account of its extraordinary electrical properties unlike any known before, and this new state was called the superconducting state”. The experiment left no doubt about the disappearance of the resistance of a mercury and H. K. Onnes called this newly discovered state, Superconductivity. Onnes received a noble prize in 1913 for his outstanding discovery of superconductivity.

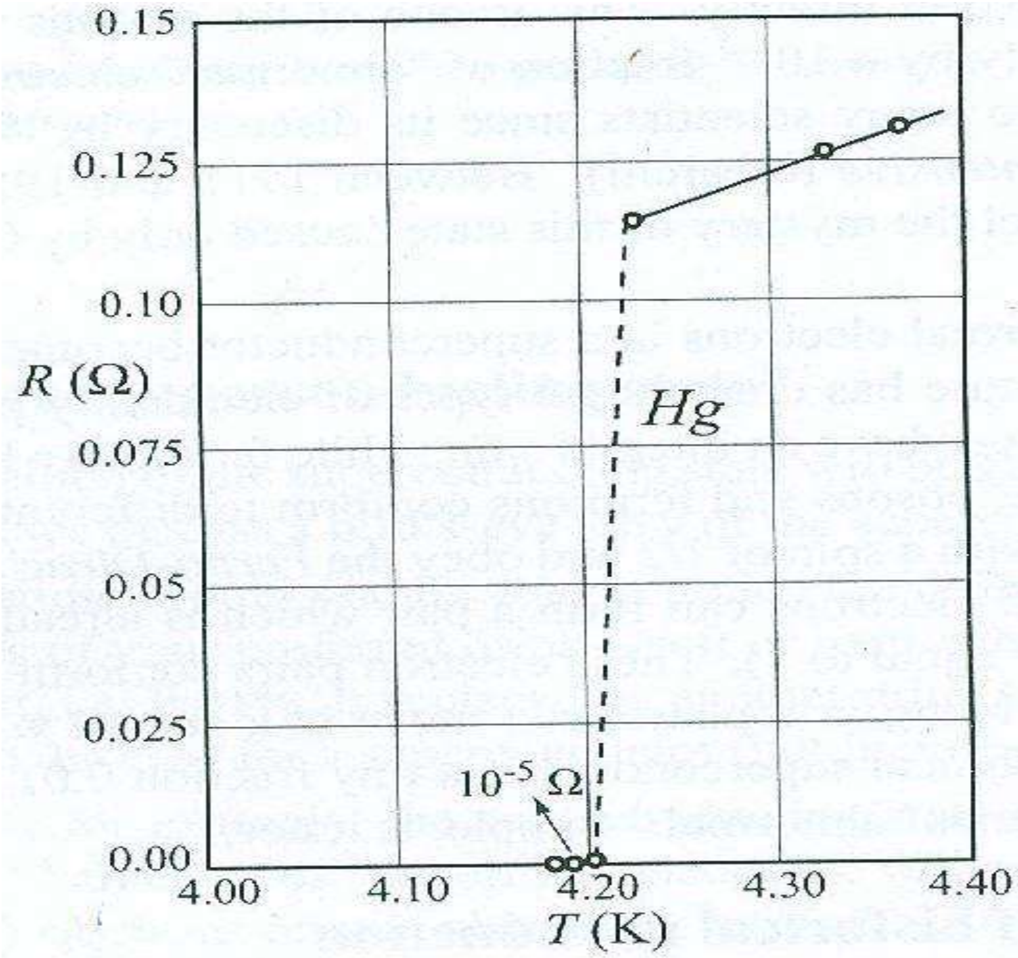


Figure: Drop down of resistance with temperature for mercury [Hg]

Soon after this discovery, many other elemental metals were found to exhibit zero resistance when their temperatures were lowered below a certain characteristic temperature of the material, called the critical temperature, Tc. In 1913, lead appeared as a superconductor at 7 K and in 1941 niobium nitrate was found to superconductor at 16 K. A lot of work has been carried out to understand this phenomenon. The transition temperature rose to 23.2 K in Nb3Ge during period 1911 to 1986. In 1957 scientists began to discover the mysteries of superconductivity.

BCS THEORY

The properties of Type I superconductors were modelled successfully by the efforts of John Bardeen, Leon Cooper, and Robert Schrieffer in what is commonly called the BCS theory. A key conceptual element in this theory is the pairing of electrons close to the Fermi level into Cooper pairs through interaction with the crystal lattice. This pairing result from a slight attraction between the electrons related to lattice vibrations; the coupling to the lattice is called a phonon interaction.

Pairs of electrons can behave very differently from single electrons which are fermions and must obey the Pauli Exclusion Principle. The pairs of electrons act more like bosons which can condense into the same energy level. The electron pairs have a slightly lower energy and leave an energy gap above them on the order of .001 EV which inhibits the kind of collision interactions which lead to ordinary resistivity. For temperatures such that the thermal energy is less than the band gap, the material exhibits zero resistivity.

Bardeen, Cooper, and Schrieffer received the Nobel Prize in 1972 for the development of the theory of superconductivity.

MEISSNER EFFECT

If a superconductor is placed in a constant magnetic field (H < Hc) and is then cooled through the transition temperature, then at Tc, the lines of magnetic induction are pushed out as shown in Figure 1.3. This phenomenon is called as Meissner effect2. A bulk superconductor in its superconducting state, when kept in an applied magnetic field (Ba), shows a total absence of magnetic field inside the specimen, i.e. there is a complete expulsion of magnetic flux from the specimen. It satisfies the following equation.

$B = B_a + \mu_o M = 0$

$\therefore \ | M / B | = -1 / \mu_o$

Meissner effect suggests that a superconductor is a perfect diamagnetic material and hence it possesses negative susceptibility.

$\chi_m = | M / H | = -1$

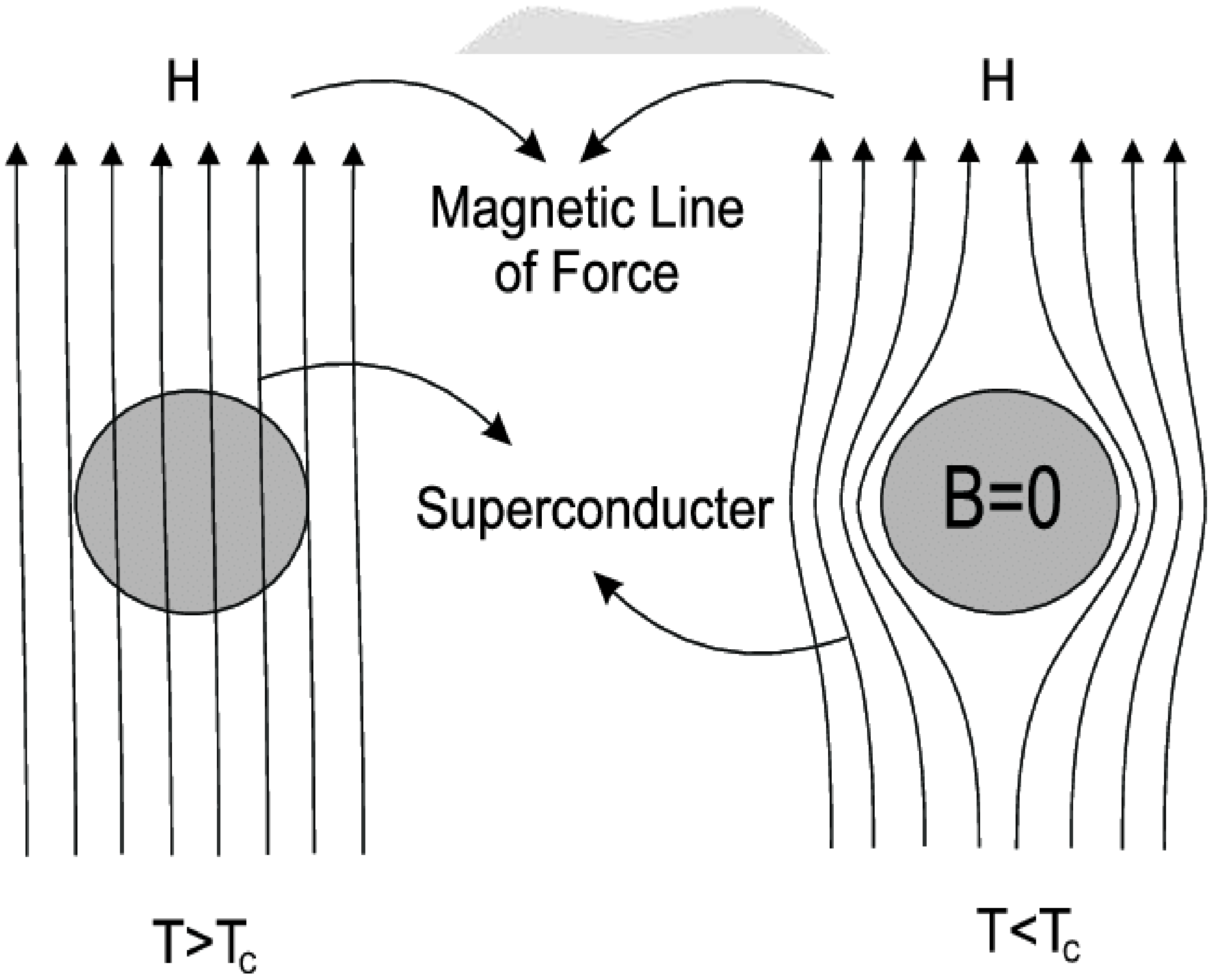
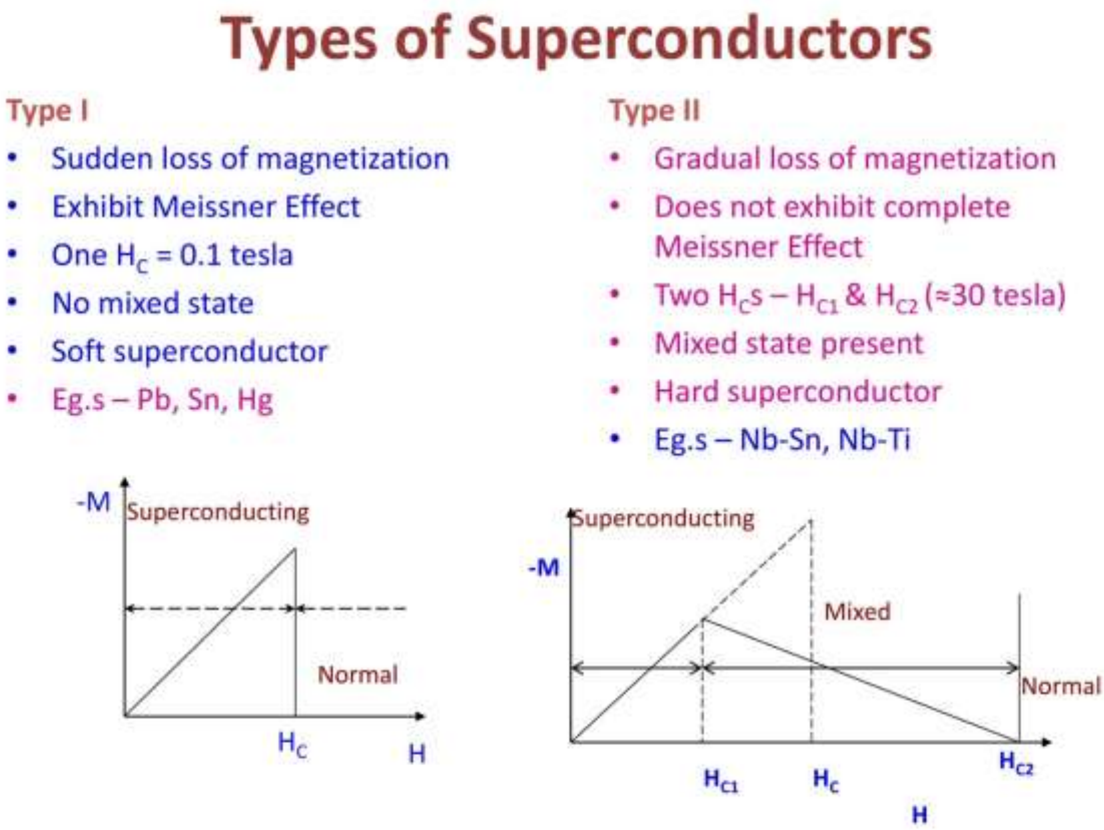


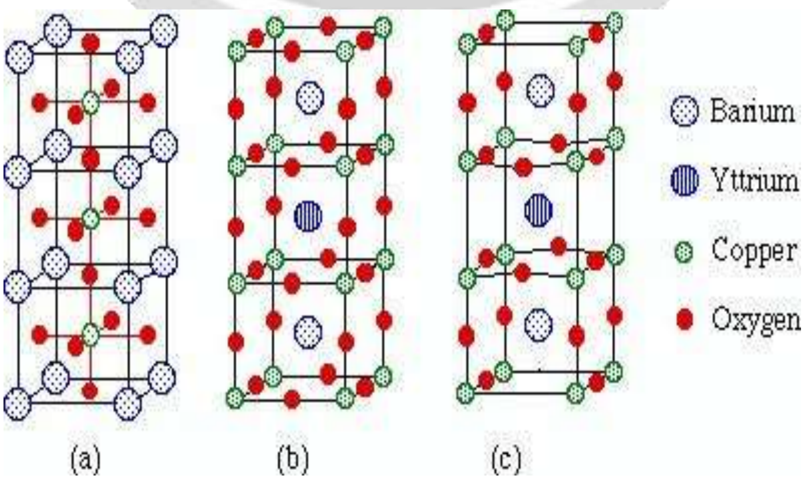
Fig. shows Meissner effect in a superconducting sphere cooled below its superconducting transition temperature Tc in a constant magnetic field H < Hc.

CLASSIFICATIONS OF SUPERCONDUCTER



STRUCTURES OF SUPERCONDUCTER

Cuprates are layered materials, consisting of superconducting layers of copper oxide, separated by spacer layers. Cuprates generally have a structure close to that of a two-dimensional material. Their superconducting properties are determined by electrons moving within weakly coupled copper-oxide (CuO_2) layers. All high temp superconductors are characterised by large unit cell volume & pronounce layer anisotropy. Superconducting property of these oxides SC are seemed to be caused by the availability of plane layer of Cu & O ions in their unit cell. Most of ceramic oxide high temp Tc superconductor are having perovskite [ABO_3] type structure. In YBCO system plane the chain of alternating copper and oxygen ion are clearly distinguished. In majority of other oxide the plane layer of Cu & O are formed to perpendicular chain alternating Cu & O ions.



SUPERCONDUCTING FLUCTUATION

It has been reported that thermodynamic SC fluctuation result in copper pair formation with some finite probability for $T > T_c$. the variation of resistivity with temp could be thought of as essentially metallic in nature and expressed as

$$\rho_{(T)} = a + bT$$

Anderson and Zao, however developed relation based upon RVB theory, which takes care the metallic conductivity in copper oxide plane and semiconducting behaviour for conduction process between the plane and across the grain boundary expressed as:

$$\rho_{(T)} = AT + B / T$$

Where linear term takes care of the ab-plane resistivity and B/T term for C axis variation. Aslamzov and Larkin (AL) predicted that for the BCS superconductivity.

APPICATION OF SUPERCONDUCTIVITY

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. I^2R 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.

FUTURE PROSPECTS

It must be realized that the above applications require conductors to be maintained at temperatures very close to 0 K. This may often mean that the whole equipment associated with the conductor has to be kept at near 0 K. This is a great challenge facing the scientists today. We can also use the superconducting material in nano-size for increasing the conductivity at high temperature near about room temperature.

CONCLUSION

Superconductivity occurs only at extremely low temperatures. To use the materials, therefore, extensive cooling systems are necessary. All the more astonished were scientists when they came across high-temperature superconductors a few years ago: with these substances, the effect already occurs at higher temperatures. Even if cooling is still necessary, it may be lower than with conventional superconductors. If physicists should someday come up with the secret, could possibly produce tailor-made materials in which superconductivity occurs even at normal ambient temperatures the consequences for the technology would be so profound but they are not yet in sight.

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