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Study Of Superconductivity

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Introduction: Superconductivity was discovered in 1911 by Dutch physicist Heike Kammerlingh Onnes by studying the resistivity of solid mercury at cryogenic temperatures using the recently discovered liquid helium as a refrigerant. After this discovery of superconductivity many metals and alloys had shown superconductivity when these specimen are cooled to sufficiently low temperature. Superconducting materials are very important in scientific and technological prospective. Some technological innovations benefiting from the discovery of superconductivity are

- ✓ Magnetic resonance imaging
- ✓ Sensitive magnetometer based on SQUIDS.
- ✓ Beam-steering magnets in particle accelerator.
- ✓ Microwave filters.
- ✓ Electronic power transmission cables.
- ✓ Magnetic levitation devices.

Historical Background:

In the history of superconductivity few important milestones are:

- ✓ In 1911 Dutch physicist Heike Kammerlingh Onnes by studying the resistivity of solid mercury at cryogenic temperatures using the liquid helium as a refrigerant discovered superconductivity.
- ✓ In1933 the basic physics for the understanding of superconductivity was developed by Meissner and Ochsenfeld, called Meissner effect.
- ✓ In 1950, Ginzburg-Landau develop a theory known as Ginzburg-Landau theory to explain the microscopic properties of superconductors.
- ✓ In the same year, Maxwell and Reynolds et.al. found the critical temperature dependence relation with the isotopic mass of the constituent element.

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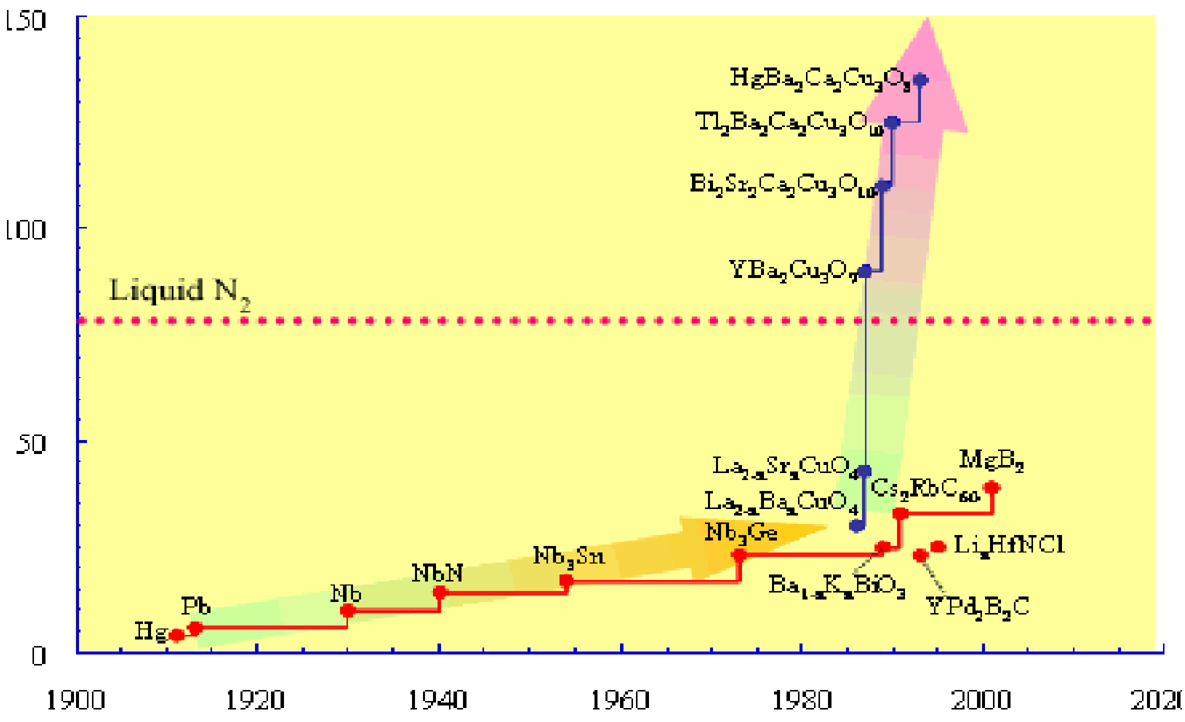
- ✓ The complete microscopic theory of superconductivity was finally proposed in 1957 by Barden, Cooper and Schrieffer by their theory known as BCS theory.
- ✓ A new era in the study of superconductivity began in 1986 with the discovery of high critical temperature superconductors and introduced the outstanding challenges of theoretical condensed matter physics.

HIGH TEMPERATURE (Tc) SUPERCONDUCTORS

The history of high Tc superconductors was begins in 1986 with the discovery of superconductors on the system Ba-La-Cu-O having the critical temperature 36K by Karl Muller and Johannes Bednorz in IBM research laboratory. This opened a new branch of high Tc superconductivity namely "High Tc superconductivity "as they broke the barrier of 30K imposed by BCS theory. Soon after this many other oxide based superconductors were discovered having the critical temperature greater than 90K and they are shown below with the discovery year and their respective Tc



They have their structure derived from ideal Perovskite structure (therefore termed as defect perovskite structure), either through an intergrowth phenomenon or by an ordered removal of oxygen atoms. They have layered crystal structure consisting of one or more

Transition temperature: Tc (K)

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CuO_2 layers. Copper is present in the mixed state involving a partial oxidation of Cu^{2+} to Cu^{3+}. There is a charge transfer to and from the CuO_2 layers which is induced by doping near the metal insulator phase existing in all oxide high T_c superconductors.

LBCO: LBCO (Lanthanum Barium Copper Oxide) is the first oxide based HTSC material developed in 1986 having T_c of 35K. It is the only insulating material in the HTSC family. This discovery shows the path for the additional research in high T_c superconductivity on cuprate materials with structure similar to LBCO.

YBCO: YBCO (Yttrium Barium Copper Oxide) is the first material to break the liquid nitrogen temperature (77 K). It was discovered in the year 1987 by Paul Chu in the University of Houston. It shows the highest T_c of 93 K. YBCO is highly studied as it is the cleanest and most ordered crystals and shows strong electron-electron interaction.

BSCCO: BSCCO (Bismuth Strontium Calcium Copper Oxide) was the first high temperature superconductor which did not contain a rare earth element. It is a cuprate superconductor which shares a two dimensional layered Perovskite structure with the superconducting copper oxide plane. It has general formula $Bi_2Sr_2Ca_{n-1}Cu_n O_{2n+4+x}$ with specific transition temperature ranging from T_c = 20 K (n=1, 2201 phase), 85 K (n=2, 2212 phase), 110 K (n=3,2223 phase) and 104 K (n=4, 2224 phase).

TBCCO: It is the next higher member of HTSC family. It was discovered in the same year as BSCCO. General formula of TBCCO (Thallium Barium Calcium Copper Oxide) is $Ti_2Ba_2Ca_{n-1}Cu_nO_{2n+4+x}$ with transition temperature ranging from T_c = 85 K (n=1, 2201 phase), 110 K (n=2, 2212 phase) and 127 K (n=3, 2223 phase). The CuO_2 layers are thicker and closer together in comparison to BSCCO system.

HBCCO: HBCCO (Mercury Barium Calcium Copper Oxide) is the highest member of HTSC family till today. It was discovered in 2009. General formula of HBCCO system is $Hg_1Ba_2Ca_{n-1}Cu_nO_{2n+2+x}$ with specific transition temperature ranging from T_c= 94 K (n=1, 1201 phase), 128 K (n=2, 1212 phase) and 134 K (n=3, 1223 phase). The T_c of the Hg compound containing one CuO_2 layer is much larger as compared to the one CuO_2 layer compounds of TBCCO.

Recently the iron based superconductors have been discovered that shows the T_c above 56 K. The first iron based superconductor was developed by Ramihar et.al on 23rd February on LaFeAsO system. These are the first non-cuprate material where the two dimensional electronic structure was shown and their T_c is also controlled by a systematic aliovalent ion doping into the insulating block layers.

APPLICATION OF HIGH T_c SUPERCONDUCTORS

• As HTS thin film shows excellent superconducting properties (i.e. T_c >90, J_c (at 77K, 0T) > 10^6A/Cm^2, so they are useful for superconductive electronics. They are used in commercial and military microwave filter systems.

• For better rejection of interference noise in aircraft radar system, HTS filters are used in aircraft electronics.

• In rural areas rf coverage can be achieved by small number of base station, by use of HTS filters the rf power of the handsets in urban areas can be reduced.

• HTS Josephson junctions are available which can be used for the construction of highly sensitive magnetic field sensors (SQUIDS) and only HTS SQUIDS are able to observe magnetic signals in the presence of disturbing background fields without the burden of magnetic shielding. Also the SQUIDS fabricated by the HTS are applicable in medical diagnostics, sea communication, sub marine detection and geographical prospecting.

• As the HTS on superconducting magnet reduce the heat load to the cold magnetic system, so they are used in many application where classical superconducting coils cannot be used.

• A magnetically levitated train is developed in China by using HTS. The mechanism behind this is the magnet induced currents in the rails, causing a repulsion which suspends the train above the track.

• High gradient separation or HTS magnetic separators can be designed with HTS wires and cooled with two stage G-M cryocooler.

• High voltage generator can be developed by using HTS inductor and electronic RCL series resonant circuit.

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