



Behaviour of Super Conductivity at Various Temperatures

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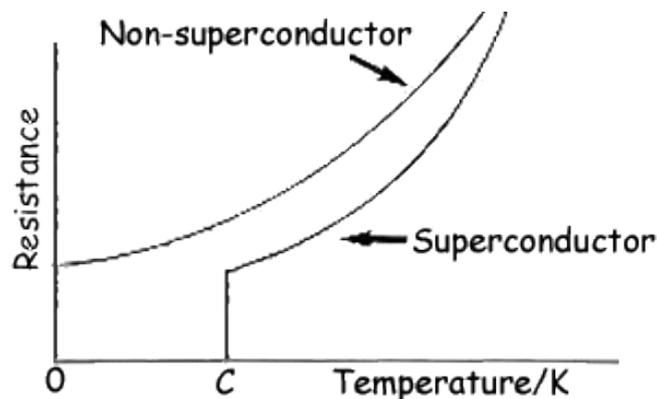
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Abstract: The high temperature superconductivity has a massive potential for technological use since its discovery. But the mechanism of high temperature superconductivity still remains hard to define; a lot of development has been made resulting in a major reduction in the number of proposed mechanisms under consideration. At present, electron phonon interaction or spin fluctuations are considered to be principal of the mechanism of high temperature superconductivity. While the transition temperature has not been improved over the last few years and we are unable to see room temperature superconductivity in near future, but many of the technological applications are still in use and being constantly improved. New materials with a better possibilities are also being discovered. This paper attempts to explain the progress made till know and shed light on the challenges of understanding the working of superconductors and achieving room temperature superconductivity.

Keywords: Superconductivity, HTSC (High Temperature Superconductivity), Critical Temperature (T_c), Cuprates.

I. INTRODUCTION

In 1908, Heike Kamerlingh Onnes in Holland found the way to liquefy helium and to reach temperatures as low as 4K. In 1911, he discovered that below a temperature of the order of 4.2K, Hg(mercury) loses the resistivity[1]. His discoveries lead him to realize that he was in the presence of a new state of solid matter. He could establish that when a particular magnetic field than rely on temperature, the critical field, H_c (T), was applied, the standard properties of the metal were recovered. Also a critical current, J_c (T), could have the same effect. He called that new phenomena, superconductivity.



C = critical temperature

Fig. 1. Superconductivity Characteristics

II. PREPROCESSING

The new phase has many new materials have been found which shows this phenomenon. Today over a thousand materials, including several pure chemical elements, are discovered to become superconductors at various temperatures ranging up to about 20 K, but not at room temperature.

Within the last several years a new family of ceramic compounds has been revealed which are insulators at room temperature and superconductors at temperatures of liquid nitrogen. Which shows that far from being an exceptional physical phenomenon, superconductivity is a fairly common property of most of the materials.

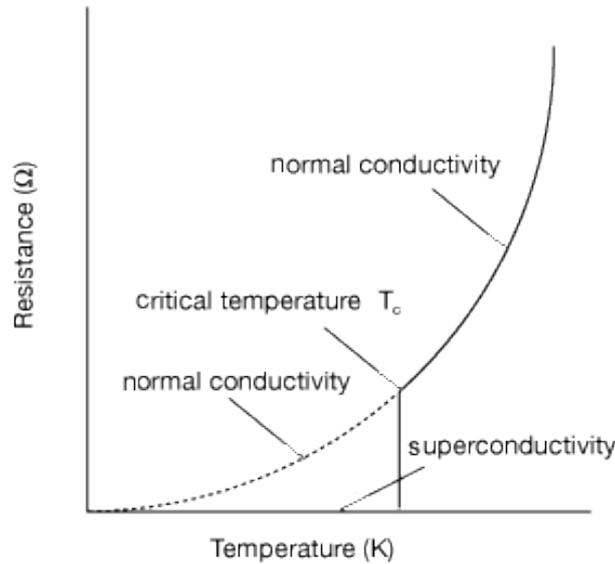


Fig. 2. Superconductivity Properties

Heike Kamerlingh Onnes description was successful when, in 1913, he concluded superconductivity in lead and tin (also at 4K). This excited Onnes very much because now he had established that other substances had the property to form the superconductors. Not only that, these substances were easily drawn into wires example Hg(mercury). The potential to produce superconducting devices was immediately apparent to Onnes. 'Tin and lead being easily workable materials, we can now anticipate all kinds of electrical experiments with apparatus without resistance.' Onnes, 1913 Onnes received the Nobel prize in 1913 for discovery of phenomena of super conductivity.

A. THE MEISSNER EFFECT

The Meissner effect, Walter Meissner and Robert Ochsenfeld in 1933 discovered a magnetic phenomenon that showed that superconductors are not just perfect conductors. The thought experiment that highlights this difference as Type I and Type II Superconductors. Imagine that both the ideal conductor under the ideal condition and superconductor are above their critical temperature, T_c. That is, they both are in a normal conducting state and have electrical resistance. A magnetic field, B_a, is then applied in order to observe this phenomena[2]. This results in the field penetrating both materials. Both samples are then cooled so that the ideal conductor now has zero resistance. It is noted that the superconductor expels the magnetic field from inside it, while the ideal conductor maintains its interior field.

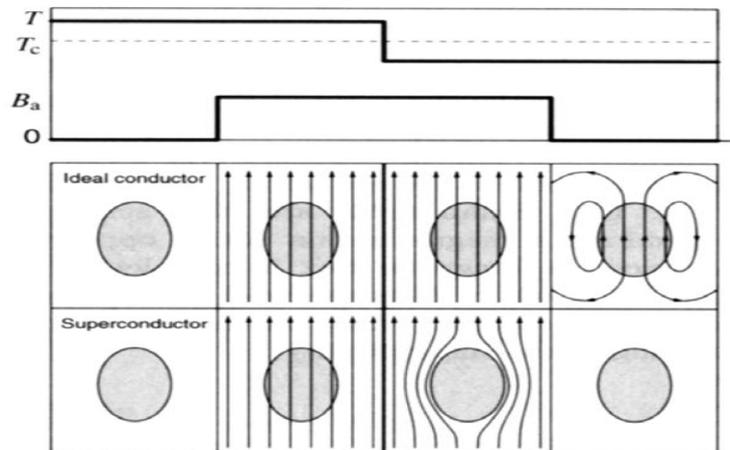


Fig. 3. The Meissner Effect

Note that energy is needed by the superconductor to debar the magnetic field. This energy comes from the exothermic superconducting transition. Switching off the field induces currents in the ideal conductor that prevent changes in the magnetic field inside it according to Lenz's law. However, the superconductor returns to its initial state, i.e. no magnetic field inside or outside it[4].



II. MECHANISM

The properties exhibited by conventional superconductors were very well explained by the BCS theory. This theory envisages an attractive interaction between electrons mediated by phonons resulting in the formation of the so called Cooper pairs. The electrons in these pair states are no longer required to obey the Fermi-Dirac statistics. The theory was very successful, making many predictions that were quickly conformed by experiment. For most of the conventional superconductors this theory satisfactorily explains the properties like Isotope Effect, Specific heat Jump, Penetration Depth, the Energy Gap, Coherence Length and others as summarized in[4].

The BCS theory was further validated by the flux quantization measurement and Josephson effect both of which suggested that super-currents involve pair of electrons. However, the theory also implied that the forces binding the Cooper pairs were very feeble, so they would be tear apart by thermal vibrations at anything other than extremely low temperatures and therefore superconductivity might not occur above 30K.

A. BCS THEORY AND COOPER PAIRS

Theories in modern physics that can explain experimental phenomena across 10 or more orders of magnitude in energy scales are very few. The Bardeen, Cooper, and Schrieffer (BCS) theory of superconductivity is such a theory that works over a massive range of systems, from a very small scale (nuclei) up to a very large scale (neutron stars), with all the systems between them[1]. The structure developed by John Bardeen, Leon Cooper, and J. Robert Schrieffer was, after all, intended to answer a apparently unimaginative question: Why is it that if we immerse a piece of common metal, such as Pb, Al, or Hg, in liquid He, we cannot measure any trace of resistance? The answer to this apparently benign question eluded Albert Einstein, Felix Bloch, Werner Heisenberg, and others of their calibre for more than four decades. The BCS landmark paper, which was published in 1957, sheds light on these previous unsuccessful attempts. The methods of modern many-body theory, necessary for a proper treatment of the interaction between electrons and the lattice, had not been developed until then.

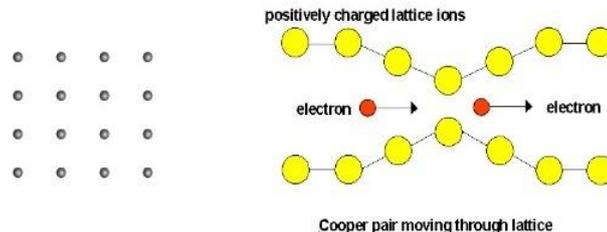


Fig. 3. The Meissner Effect

It turns out that this macroscopic coherence of microscopic quantum objects (the electrons) is possible only if the electrons are glued into pairs and if the pairs mutually overlap. The bottom figure illustrates the idea of electronic pairing by lattice vibrations. Ions in a metal are positively charged, and the mobile electrons have a negative charge; therefore, ions around an individual electron are attracted to it, creating a more concentrated positive charge around the electron[3].

Because an electron moves so much faster than an ion, by the time the slow ions complete their travel toward the electron, the electron has already left this area, leaving behind the cloud of displaced ions with their net positive charge. Of course, when the ions realize that they were being attracted to an object that is no longer there, they start moving back to their original locations. However, this takes time. Within this time, another electron can be attracted to this cloud of positive charge[5].

If the time scales are properly tuned, the second electron can trace the path of the first one, following it around the crystal. In such a situation, we say that the electrons have formed a “Cooper pair.”

III. LITERATURE SURVEY

A. SUPERCONDUCTIVITY ABOVE 130 K IN THE Hg-Ba-Ca-Gu-O SYSTEM SCHILLING, M. GANTONI, J. D. GUO & H. R. OTT

The author demonstrated about superconductivity below a transition temperature of 94 K in HgBa₂CuO_a*6 has enlarged the repertoire of high-T_c superconductors consisting copper oxide planes merged in suitably layered materials.



Previous experience with identical compounds containing bismuth and thallium instead of mercury recommended that even higher transition temperatures might be accomplished in mercury-based compounds with more than one CuO₂ layer per unit cell. Thus we conclude that at present we cannot relate the different superconducting stage to crystallographic phases. There is no uncertainty proof that the occurrence of superconductivity in our samples stems from the HgBa₂Ca_{1-x}Cu₂O_{8-y} phases.

B. HIGH TEMPERATURE SUPERCONDUCTIVITY: MATERIALS, MECHANISM AND APPLICATIONS- M.A. MALIK, B.A. MALIK

The author states that superconductivity is a phenomenon contest by certain materials by virtue of which they drop all their electric resistance beneath certain sufficiently low temperature attend by a total expulsion of magnetic field from within. Thus we conclude that the technological uses of high temperature superconductivity are immense, a main benefit is that because of their ability to reduce size and weight and in the method save energy, high temperature superconductivity promises to show the global environmental issues as well.

IV. PROPOSED METHOD

A. HIGH TEMPERATURE SUPERCONDUCTIVITY - M. BRIAN MAPLE

The author demonstrated about the discovery of superconductivity at ~30 K in the La-Ba-Cu-O system ignited an explosion of interest in high temperature superconductivity. These initial developments rapidly evolved into an intense worldwide research effort that still persists after more than a decade, fueled by the fact that high temperature superconductivity constitutes an extremely important and challenging intellectual problem and has enormous potential for technological applications. Thus we conclude that during the past decade, remarkable progress in the areas of basic research and technological applications has been made on the high T_c cuprate superconductors. The availability of high quality poly-crystalline and single crystal bulk and thin film materials has made it possible to make reliable measurements of the physical properties of these materials and to optimize superconducting properties (e.g., J_c) that are important for technological applications.

B. A BREAKTHROUGH OF THE CENTURY

Later on, four individuals of the Tanaka group, who were later called the “Gang of Four”—Shoji Tanaka, Koichi Kitazawa, Shinichi Uchida, and Hidenori Takagi, depending up on previous diagram scientists worked twenty four hours on intense research that resulted first of all in the confirmation of Meissner effect, and identification of the chemical composition and crystal structures that ready the platform for the phenomenon of superconductivity to appear. In early December that year.

Kitazawa presented these findings at the MRS Meeting in Boston, effectively sparking a firestorm of interest worldwide[3].

This was a “breakthrough of the century” that prompted the fast-track launch, in FY1987, of another project in Specific Research, on the “Sankabutsu koon chodendotai no kenkyu” (written report on high-temperature superconducting oxides), following in the footsteps of the earlier Specific Research project on “Shin chodendo busshitsu” (new superconducting materials)

The “Pack of Four” responsible for tend the fever of curiosity in copper-oxide superconductivity. : Kitazawa, Tanaka, Uchida, and Takagi. (1986) with the breakthrough of novel copper-oxide compounds, the critical temperature at which superconductivity sets in bush initially from 23 Kelvin to 30 Kelvin, and then, in the spring of 1987, leaped all the way to 100 Kelvin. Because this was more than the -196 C boiling point of liquid nitrogen, the prospects for commercial applications of superconductivity attracted broad public interest and spurred a widening global race to find materials with even higher critical temp. The high- temperature superconductivity “fever” had taken hold[2].

V. APPLICATIONS

The practical applications of conventional superconductors are limited due to the very low operating temperature. The discovery of higher T_c materials extends the feasible applications of superconductors. These applications include high-speed trains, magnetic energy storage, magnetic resonance imaging (MRI) for medical applications, Josephson devices, Superconducting Quantum Interference Devices (SQUID), Magneto encephalography, microwave devices and resonators to high energy physics experiments. SQUIDS deserve a special mention because of their versatility finding applications in magnetic materials characterization , medicine , NMR , MRI , geophysics, quantum computing etc. SQUID magnetometers may be the most sensitive measurement device known.



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The threshold for SQUID is of the order of 1fT, making it capable of measuring extremely feeble magnetic fields. In comparison, magnetic field of heart is around 50,000 fT and that of brain is a few fT. Because of their extreme sensitivity, SQUIDs have established themselves as very accurate devices for both Magneto cardiography and Magneto encephalography. SQUIDs are being considered for a search for the Dark Matter. The idea is that when axions of a given mass/energy enter a microwave cavity sited from a liquid helium-cooled superconducting solenoid, they will interact with the field and decay into photons. These photons can then be amplified and detected using extremely sensitive SQUIDs. Such experiments are underway in the university of Washington.

The other prospective application of superconductivity is lossless Power Transmission. In India, 22% of electric power is lost in transmission alone. A superconducting wire can transmit a dc current without losses or an ac current with an extremely small loss. In the west, people are contemplating to utilize the benefit of superconductivity in transporting energy on a scale of many gigawatts to terawatts from remote generation facilities (the Sahara desert), which otherwise would be futile owing to huge transmission losses[3]. The fact that HTSC are extreme type II, characterized by very high upper critical field values, opens up the possibility of superconducting Maglev Trains.

Superconducting Motors and generators could be made with a weight of about one tenth that of conventional devices for the same output. The basic elements of the world's first "quantum" computer are superconducting quantum bits. In the Fermilab, superconducting magnets were successfully used to increase the ultimate particle energy and the operating cost was greatly reduced. Recently, experts from the CERN Superconductors team obtained a world record current of 20 kA at 24 K in an electrical transmission line consisting of two 20-metre long cables made of MgB₂ superconductor. This result makes the technology a viable solution for long-distance power transportation.

VI. CONCLUSION

Since the discovery of superconductivity in the cuprate family La-Ba-Cu-O (T_c up to 35 K), hundreds of cuprate oxide superconductors have been synthesized with varying advantages. An exhaustive description of almost all High T_c superconducting cuprate families. We shall here mention only some of these cuprate families in order of increasing transition temperatures. Soon after the breakthrough of Bednorz and Muller, Wu et al discovered super conductivity in Y-Ba-Cu-O system with transition temperature well above the liquid nitrogen temperature ($T_c = 93$ K in YBa₂Cu₃O_{7-x}, $x = 0.07$). Later, super conductivity was discovered in the Bi-Sr-Ca-Cu-O system at a transition temperature of above 105 K. In the same year, Thallium based cuprates were found to show superconductivity at 120 K. Further, it followed that T_c could be enhanced by increasing the number of conducting CuO₂ layers. Another class of the Carbon based families-the oxy carbonates could show superconductivity up to a T_c of 117K. The critical temperature reached a value of 133K in Mercury based cuprates[4]. The transition temperature could further be increased by applying high pressure. At present the record high transition temperature is 164 K in Mercury based cuprates under high pressure which is within a factor of two of room temperature.

A team of researchers at MIT have reported the existence of charge density waves that would explain the phenomenon of high T_c superconductivity and hence lead to room temperature superconductivity. Kawashima suggest that room temperature superconductor may be obtained by bringing alkanes into contact with a graphite surface. Room temperature superconductivity in substitutionally doped graphene via a combined mechanism involving phononic and electronic processes has been reported by Sinha and Jindal. However, as of now, there is no conformation of a reproducible room temperature superconductivity and the only materials with T_c above the liquid Nitrogen temperature are still the copper oxide superconductors.

ACKNOWLEDGMENT

We would like to acknowledge the following research papers and related topics regarding Superconductivity as mentioned in the following references which are given below:

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- [5] High Temperature Superconductivity: Materials, Mechanism and Applications- M.A. Malik, B.A. Malik
- [6] High Temperature Superconductivity - M. Brian Maple
- [7] Superconductivity above 130 K in the Hg-Ba-Ca-Gu-O system A. Schilling, M. Gantoni, J. D. Guo & H. R. Ott

BIOGRAPHIES



I am **Aditya Sharma**, student of Bachelor's of Engineering in Electronics and Communication department. Current I am in the final year of my course assessment from LNCTS (RIT) Indore. I prefer Superconductivity because this has a huge technological potential in modern era.



I am **Deepesh Saxena**, student of Bachelor's of Engineering in Electronics and Communication department. Current I am in the final year of my course assessment from LNCTS (RIT) Indore. I decided to write a research paper to get better opportunities in higher studies.