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ABSTRACT

This project is all about superconductivity. Superconductivity is the phenomenon by which a substance conducts electicity at zero resitance state. In this project superconductivity is well defined and there is a detail information about superconductors and the effects related to superconductivity. There is the detail information about types of superconductors. There are two types of conductors namely Type-I and Type-II superconductors. There is a Meissner Effect related to superconductivity. Many theories are there like London theories and many other conventional theories are there which describe the superconductivity. Superconductivity has many properties like magnetic and electromagnetic properties which include critical field and vanishing of resistance. Superconductivity has wide range of applications. With so advantages superconductivity has many disadvantages which have discussed in the project in further details.

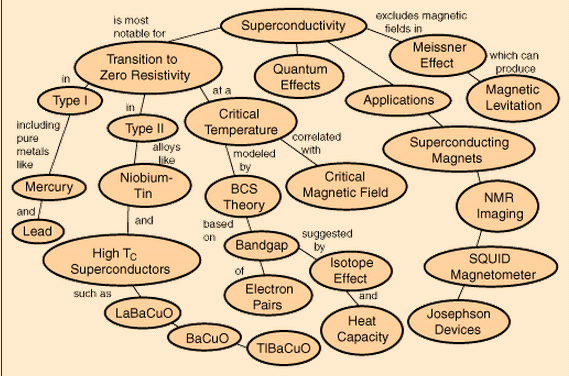
**INTRODUCTION: SUPERCONDUCTIVTIY**

Below a critical temperature, some materials expel magnetic fields (Meissner

effect) and have a zero electrical resistance. It is called superconductivity.

Superconductivity is a phenomenon of exactly zero electrical resistance and expulsion of magnetic fields occurring in certain materials when cooled below a characteristic critical temperature. It was discovered by Dutch physicist Heike Kamerlingh Onnes on April 8, 1911 in Leiden. Like ferromagnetism and atomic spectral lines, superconductivity is a quantum mechanical phenomenon. Electrical resistance in metals arises because electrons propagating through the solid are scattered due to deviations from perfect translational symmetry. These are produced either by impurities (giving rise to a temperature independent contribution to the resistance) or the phonons - lattice vibrations - in a solid.

In a superconductor below its transition temperature Tc, there is no resistance because these scattering mechanisms are unable to impede the motion of the current carriers. The current is carried in all known classes of superconductor by pairs of electrons known as Cooper pair.

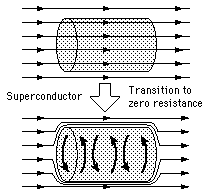


The electrical resistivity of a metallic conductor decreases gradually as temperature is lowered. In ordinary conductors, such as copper or silver, this decrease is limited by impurities and other defects. Even near absolute zero, a real sample of a normal conductor shows some resistance. In a superconductor, the resistance drops abruptly to zero when the material is cooled below its critical temperature. An electric current flowing through a loop of superconducting wire can persist indefinitely with no power source.

The best available model of high-temperature superconductivity is still somewhat crude. There are currently two main hypotheses – the resonating-valence-bond theory, and spin fluctuation which has the most support in the research community. The second hypothesis proposed that electron pairing in high-temperature superconductors is mediated by short-range spin waves known as paramagnons.

**SUPERCONDUCTOR**

The magnetic behavior of a superconductor is distinct from perfect diamagnetism. It will actively exclude any magnetic field present when it makes the phase change to the superconducting state.



**CLASSIFICATION OF SUPERCONDUCTORS**

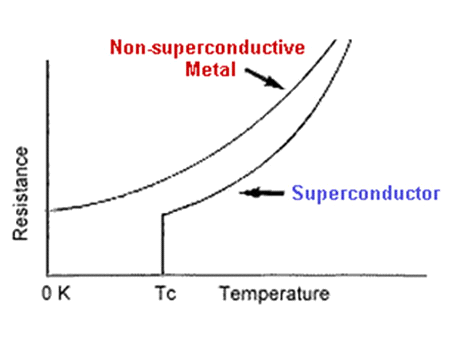
There is not just one criterion to classify superconductors. The most common are

* By their response to a magnetic field: they can be Type I, meaning they have a single critical field, above which all superconductivity is lost; or they can be Type II, meaning they have two critical fields, between which they allow partial penetration of the magnetic field.
* By the theory to explain them: they can be conventional (if they are explained by the BCS theory or its derivatives) or unconventional (if not).
* By their critical temperature: they can be high temperature (generally considered if they reach the superconducting state by just cooling them with liquid nitrogen, that is, if Tc > 77 K), or low temperature (generally if they need other techniques to be cooled under their critical temperature).
* By material: they can be chemical elements (as mercury or lead), alloys (as niobium-titanium or germanium-niobium or niobium nitride), ceramics (as YBCO or the magnesium diboride), or organic superconductors (as fullerenes or carbon nanotubes, though these examples technically might be included among the chemical elements as they are composed entirely of carbon).

**PROPERTIES OF SUPERCONDUCTIVITY**

Most of the physical properties of superconductors vary from material to material, such as the heat capacity and the critical temperature, critical field, and critical current density at which superconductivity is destroyed.

On the other hand, there is a class of properties that are independent of the underlying material. For instance, all superconductors have exactly zero resistivity to low applied currents when there is no magnetic field present or if the applied field does not exceed a critical value. The existence of these "universal" properties implies that superconductivity is a thermodynamic phase, and thus possesses certain distinguishing properties which are largely independent of microscopic details.



Critical Temperature for Superconductors

The critical temperature for superconductors is the temperature at which the electrical resistivity of a metal drops to zero. The transition is so sudden and complete that it appears to be a transition to a different phase of matter; this superconducting phase is described by the BCS theory. Several materials exhibit superconducting phase transitions at low temperatures. The highest critical temperature was about 23 K until the discovery in 1986 of some high temperature superconductors.

Materials with critical temperatures in the range 120 K have received a great deal of attention because they can be maintained in the superconducting state with liquid nitrogen (77 K).

**Types I and II Superconductors**

There are thirty pure metals which exhibit zero resistivity at low temperatures and have the property of excluding magnetic fields from the interior of the superconductor (Meissner effect). They are called Type I superconductors. The superconductivity exists only below their critical temperatures and below a critical magnetic field strength. Type I superconductors are well described by the BCS theory.

Starting in 1930 with lead-bismuth alloys, a number of alloys were found which exhibited superconductivity; they are called Type II superconductors. They were found to have much higher critical fields and therefore could carry much higher current densities while remaining in the superconducting state.

The variations on barium-copper-oxide ceramics which achieved the superconducting state at much higher temperatures are often just referred to as high temperature superconductors and form a class of their own.

**Type I Superconductors**

The 27 pure metals listed in the table below are called Type I superconductors. The identifying characteristics are zero electrical resistivity below a critical temperature, zero internal magnetic field (Meissner effect), and a critical magnetic field above which superconductivity ceases.

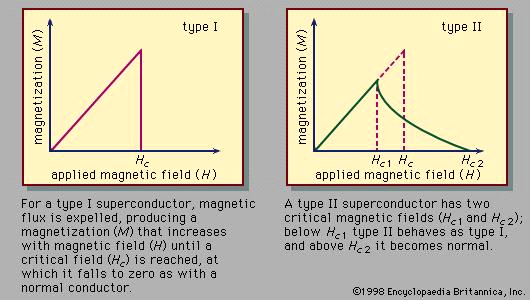
The superconductivity in Type I superconductors is modeled well by the BCS theory which relies upon electron pairs coupled by lattice vibration interactions. Remarkably, the best conductors at room temperature (gold, silver, and copper) do not become superconducting at all. They have the smallest lattice vibrations, so their behavior correlates well with the BCS Theory.

While instructive for understanding superconductivity, the Type I superconductors have been of limited practical usefulness because the critical magnetic fields are so small and the superconducting state disappears suddenly at that temperature. Type I superconductors are sometimes called "soft" superconductors while the Type II are "hard", maintaining the superconducting state to higher temperatures and magnetic fields.

**Type II Superconductors**

Superconductors made from alloys are called Type II superconductors. Besides being mechanically harder than Type I superconductors, they exhibit much higher critical magnetic fields. Type II superconductors such as niobium-titanium (NbTi) are used in the construction of high field superconducting magnets.

Type-II superconductors usually exist in a mixed state of normal and superconducting regions. This is sometimes called a vortex state, because vortices of superconducting currents surround filaments or cores of normal material.



**ELEMENTRY PROPERTIES OF SUPERCONDUCTIVITY**

**Zero electrical DC resistance**



Electric cables for accelerators at [CERN](http://en.wikipedia.org/wiki/CERN)

Both the massive and slim cables are rated for 12,500 [A](http://en.wikipedia.org/wiki/Amperes)

The simplest method to measure the [electrical resistance](http://en.wikipedia.org/wiki/Electrical_resistance) of a sample of some material is to place it in an [electrical circuit](http://en.wikipedia.org/wiki/Electrical_circuit) in series with a [current source](http://en.wikipedia.org/wiki/Current_source) *I* and measure the resulting [voltage](http://en.wikipedia.org/wiki/Voltage) *V* across the sample. The resistance of the sample is given by [Ohm's law](http://en.wikipedia.org/wiki/Ohm%27s_law) as *R = V / I*. If the voltage is zero, this means that the resistance is zero.

Superconductors are also able to maintain a current with no applied voltage whatsoever, a property exploited in [superconducting electromagnets](http://en.wikipedia.org/wiki/Superconducting_magnet) such as those found in [MRI](http://en.wikipedia.org/wiki/Magnetic_resonance_imaging) machines. Experiments have demonstrated that currents in superconducting coils can persist for years without any measurable degradation. Experimental evidence points to a current lifetime of at least 100,000 years. Theoretical estimates for the lifetime of a persistent current can exceed the estimated lifetime of the [universe](http://en.wikipedia.org/wiki/Universe), depending on the wire geometry and the temperature.

In a normal conductor, an electric current may be visualized as a fluid of [electrons](http://en.wikipedia.org/wiki/Electron) moving across a heavy [ionic](http://en.wikipedia.org/wiki/Ion) lattice. The electrons are constantly colliding with the ions in the lattice, and during each collision some of the [energy](http://en.wikipedia.org/wiki/Energy) carried by the current is absorbed by the lattice and converted into[heat](http://en.wikipedia.org/wiki/Heat), which is essentially the vibrational [kinetic energy](http://en.wikipedia.org/wiki/Kinetic_energy) of the lattice ions. As a result, the energy carried by the current is constantly being dissipated. This is the phenomenon of electrical resistance.

The situation is different in a superconductor. In a conventional superconductor, the electronic fluid cannot be resolved into individual electrons. Instead, it consists of bound *pairs* of electrons known as [Cooper pairs](http://en.wikipedia.org/wiki/Cooper_pair). This pairing is caused by an attractive force between electrons from the exchange of[phonons](http://en.wikipedia.org/wiki/Phonon). Due to [quantum mechanics](http://en.wikipedia.org/wiki/Quantum_mechanics), the [energy spectrum](http://en.wikipedia.org/wiki/Energy_spectrum) of this Cooper pair fluid possesses an [*energy gap*](http://en.wikipedia.org/wiki/Energy_gap), meaning there is a minimum amount of energy Δ*E* that must be supplied in order to excite the fluid. Therefore, if Δ*E* is larger than the [thermal energy](http://en.wikipedia.org/wiki/Thermal_energy) of the lattice, given by *kT*, where *k* is [Boltzmann's constant](http://en.wikipedia.org/wiki/Boltzmann%27s_constant) and *T* is the[temperature](http://en.wikipedia.org/wiki/Temperature), the fluid will not be scattered by the lattice. The Cooper pair fluid is thus a superfluid, meaning it can flow without energy dissipation.

In a class of superconductors known as [type II superconductors](http://en.wikipedia.org/wiki/Type_II_superconductor), including all known [high-temperature superconductors](http://en.wikipedia.org/wiki/High-temperature_superconductor), an extremely small amount of resistivity appears at temperatures not too far below the nominal superconducting transition when an electric current is applied in conjunction with a strong magnetic field, which may be caused by the electric current. This is due to the motion of vortices in the electronic superfluid, which dissipates some of the energy carried by the current. If the current is sufficiently small, the vortices are stationary, and the resistivity vanishes. The resistance due to this effect is tiny compared with that of non-superconducting materials, but must be taken into account in sensitive experiments. However, as the temperature decreases far enough below the nominal superconducting transition, these vortices can become frozen into a disordered but stationary phase known as a "vortex glass". Below this vortex glass transition temperature, the resistance of the material becomes truly zero.

**SUPERCONDUCTING PHASE OF SUPERCONDUCTIVITY**

In superconducting materials, the characteristics of superconductivity appear when the temperature T is lowered below a critical temperature Tc. The value of this critical temperature varies from material to material. Conventional superconductors usually have critical temperatures ranging from around 20 K to less than 1 K. Solid mercury, for example, has a critical temperature of 4.2 K. The highest critical temperature found for a conventional superconductor is 39 K for magnesium diboride , although this material displays enough exotic properties that there is some doubt about classifying it as a "conventional" superconductor. Cuprate superconductors can have much higher critical temperatures: one of the first cuprate superconductors to be discovered, has a critical temperature of 92 K, and mercury-based cuprates have been found with critical temperatures in excess of 130 K. The explanation for these high critical temperatures remains unknown. Electron pairing due to phonon exchanges explains superconductivity in conventional superconductors, but it does not explain superconductivity in the newer superconductors that have a very high critical temperature.

At a fixed temperature below the critical temperature, superconducting materials stop to superconduct when an external magnetic field is applied which is greater than the critical magnetic field. This is because the Gibbs free energy of the superconducting phase increases four times with the magnetic field while the free energy of the normal phase is roughly independent of the magnetic field. If the material superconducts in the absence of a field, then the superconducting phase free energy is lower than that of the normal phase and so for some finite value of the magnetic field (proportional to the square root of the difference of the free energies at zero magnetic field) the two free energies will be equal and a phase transition to the normal phase will occur. A higher temperature and a stronger magnetic field lead to a smaller fraction of the electrons in the superconducting band and consequently a longer London penetration depth of external magnetic fields and currents. The penetration depth becomes infinite at the phase transition.

The onset of superconductivity is accompanied by abrupt changes in various physical properties, which is the hallmark of a phase transition. For example, the electronic heat capacity is proportional to the temperature in the normal (non-superconducting) regime. At the superconducting transition, it suffers a discontinuous jump and thereafter ceases to be linear. At low temperatures, it varies instead as e−α/T for some constant, α. This exponential behavior is one of the pieces of evidence for the existence of the energy gap.

The order of the superconducting phase transition was long a matter of debate. Experiments indicate that the transition is second-order, meaning there is no latent heat. However in the presence of an external magnetic field there is latent heat, because the superconducting phase has a lower entropy below the critical temperature than the normal phase. It has been experimentally demonstrated that, as a consequence, when the magnetic field is increased beyond the critical field, the resulting phase transition leads to a decrease in the temperature of the superconducting material.

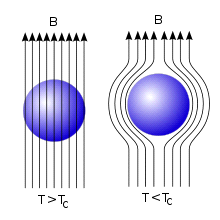
**THE MEISSNER EFFECT**

When a material makes the transition from the normal to superconducting state, it actively excludes magnetic fields from its interior; this is called the Meissner effect.

This constraint to zero magnetic field inside a superconductor is distinct from the perfect diamagnetism which would arise from its zero electrical resistance. Zero resistance would imply that if you tried to magnetize a superconductor, current loops would be generated to exactly cancel the imposed field (Lenz's law). But if the material already had a steady magnetic field through it when it was cooled trough the superconducting transition, the magnetic field would be expected to remain. If there were no change in the applied magnetic field, there would be no generated voltage (Faraday's law) to drive currents, even in a perfect conductor. Hence the active exclusion of magnetic field must be considered to be an effect distinct from just zero resistance. A mixed state Meissner effect occurs with Type II materials.

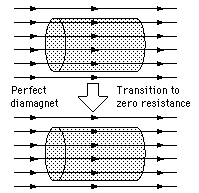
In a weak applied field, a superconductor expels nearly all magnetic flux. It does this by setting up electric currents near its surface. The magnetic field of these surface currents cancels the applied magnetic field within the bulk of the superconductor. As the field expulsion, or cancellation, does not change with time, the currents producing this effect do not decay with time. Therefore the conductivity can be thought of as infinite: a superconductor. Near the surface, within a distance called the London penetration depth, the magnetic field is not completely cancelled. Each superconducting material has its own characteristic penetration depth.

Any perfect conductor will prevent any change to magnetic flux passing through its surface due to ordinary electromagnetic induction at zero resistance. The Meissner effect is distinct from this: when an ordinary conductor is cooled so that it makes the transition to a superconducting state in the presence of a constant applied magnetic field, the magnetic flux is expelled during the transition. This effect cannot be explained by infinite conductivity alone. Its explanation is more complex and was first given in the London equations by the brothers Fritz and Heinz London. It should thus be noted that the placement and subsequent levitation of a magnet above an already superconducting material does not demonstrate the Meissner effect, while an initially stationary magnet later being repelled by a superconductor as it is cooled through its critical temperature does.



**PERFECT DIAMAGNETIC**

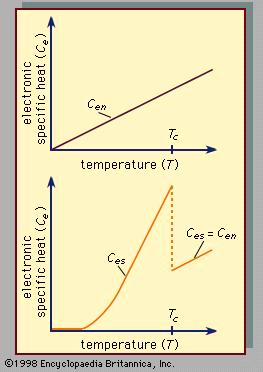
If a conductor already had a steady magnetic field through it and was then cooled through the transition to a zero resistance state, becoming a [perfect diamagnet](http://hyperphysics.phy-astr.gsu.edu/hbase/solids/meis.html), the magnetic field would be expected to stay the same.



Superconductors in the Meissner state exhibit perfect diamagnetism, or superdiamagnetism, meaning that the total magnetic field is very close to zero deep inside them (many penetration depths from the surface). This means that their [magnetic susceptibility](http://en.wikipedia.org/wiki/Magnetic_susceptibility),  = −1. Diamagnetics are defined by the generation of a spontaneous magnetization of a material which directly opposes the direction of an applied field. However, the fundamental origins of diamagnetism in superconductors and normal materials are very different. In normal materials diamagnetism arises as a direct result of the orbital spin of electrons about the nuclei of an atom induced electromagnetically by the application of an applied field. In superconductors the illusion of perfect diamagnetism arises from persistent screening currents which flow to oppose the applied field (the Meissner effect); not solely the orbital spin.

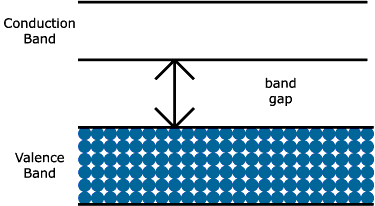
**THERMAL PROPERTIES OF SUPERCONDUCTORS**

Superconductivity is a startling departure from the properties of normal conductors of electricity. In materials that are electric conductors, some of the electrons are not bound to individual atoms but are free to move through the material; their motion constitutes an electric current. In normal conductors these so-called conduction electrons are scattered by impurities, dislocations, grain boundaries, and lattice vibrations. In a superconductor, there is an ordering among the conduction electrons that prevents this scattering. Consequently, electric current can flow with no resistance at all. The ordering of the electrons, called Cooper pairing, involves the momenta of the electrons rather than their positions. The energy per electron that is associated with this ordering is extremely small, typically about one thousandth of the amount by which the energy per electron changes when a chemical reaction takes place. One reason that superconductivity remained unexplained for so long is the smallness of the energy changes that accompany the transition between normal and superconducting states.



**ENERGY GAP**

As stated above, the thermal properties of superconductors indicate that there is a gap in the distribution of energy levels available to the electrons, and so a finite amount of energy, designated as delta (Δ), must be supplied to an electron to excite it. This energy is maximum (designated Δ0) at absolute zero and changes little with increase of temperature until the transition temperature is approached, where Δ decreases to zero, its value in the normal state. The BCS theory predicts an energy gap with just this type of temperature dependence



**MAGNETIC AND ELECTROMAGNETIC PROPERTIES OF SUPERCONDUCTORS**

**Critical field**

The weakest magnetic field that will cause this transition is called the [critical field](http://www.britannica.com/EBchecked/topic/143378/critical-field) (*Hc*) if the sample is in the form of a long, thin cylinder or ellipsoid and the field is oriented parallel to the long axis of the sample. The critical field increases with decreasing temperature. For the superconducting elements, its values (*H*0) at absolute zero range from 1.1 oersted for tungsten to 830 oersteds for tantalum.

These remarks about the critical field apply to ordinary ( type I) superconductors. In the following section the behaviour of other (type II) superconductors is examined.

**The Vanishing of the Electrical Resistance**

The initial observation of the superconductivity of mercury raised a fundamental question about the magnitude of the decrease in resistance on entering the superconducting state. During the first investigations of superconductivity, a standard method for measuring electrical resistance was used. The electrical voltage across a sample carrying an electric current was measured. Here one could only determine that the resistance dropped by more than a factor of a thousand when the superconducting

state was entered. One could only talk about the vanishing of the resistance in that the resistance fell below the sensitivity limit of the equipment and, hence, could no longer be detected. Here we must realize that in principle it is impossible to prove experimentally that the resistance has exactly zero value. Instead, experimentally, we

can only find an upper limit of the resistance of a superconductor. Of course, to understand such a phenomenon it is highly important to test with the most sensitive methods, to see if a finite residual resistance can also be found in

the superconducting state. So we are dealing with the problem of measuring extremely small values of the resistance. Already in 1914 Kamerlingh-Onnes used by far the best technique for this purpose. He detected the decay of an electric current flowing in a closed superconducting ring. If an electrical resistance exists, the stored energy of such a current is transformed gradually into Joule heat. Hence, we need only monitor such a current. If it decays as a function of time, we can be certain that a resistance still exists. If such a decay is observed, one can deduce an upper limit of the resistance from the temporal change and from the geometry of the superconducting circuit. This method is more sensitive by many orders of magnitude than the usual current-voltage measurement. It is shown schematically in Fig. 1.1. A ring made from a superconducting material, say, from lead, is held in the normal state above the transition temperature Tc. A magnetic rod serves for applying a magnetic field penetrating the ring opening. Now we cool the ring below the transition temperature Tc at which it becomes superconducting. The magnetic field1) penetrating the opening practically remains unchanged. Subsequently we remove the magnet.

This induces an electric current in the superconducting ring, since each change of the magnetic flux Fthrough the ring causes an electrical voltage along the ring. This induced voltage then generates the current.

If the resistance had exactly zero value, this current would flow without any change as a “permanent current” as long as the lead ring remained superconducting. However, if there exists a finite resistance R, the current would decrease

with time, following an exponential decay law.

**LONDON THEORY**

The first phenomenological theory of superconductivity was [London theory](http://en.wikipedia.org/wiki/London_equations). It was put forward by the brothers Fritz and Heinz London in 1935, shortly after the discovery that magnetic fields are expelled from superconductors. A major triumph of the equations of this theory is their ability to explain the [Meissner effect](http://en.wikipedia.org/wiki/Meissner_effect), wherein a material exponentially expels all internal magnetic fields as it crosses the superconducting threshold. By using the London equation, one can obtain the dependence of the magnetic field inside the superconductor on the distance to the surface.

There are two London equations:



The first equation follows from [Newton's second law](http://en.wikipedia.org/wiki/Newton%27s_second_law) for superconducting electrons.

Here  is the superconducting current density, **E** and **B** are respectively the electric and magnetic fields within the superconductor,  is the charge of an electron & proton,  is electron mass, and  is a phenomenological constant loosely associated with a number density of superconducting carriers. Throughout this article [Gaussian (cgs) units](http://en.wikipedia.org/wiki/Gaussian_units) are employed.

On the other hand, if one is willing to abstract away slightly, both the expressions above can more neatly be written in terms of a single "London Equation" in terms of the [vector potential](http://en.wikipedia.org/wiki/Vector_potential) **A**:



The last equation suffers from only the disadvantage that it is not [gauge invariant](http://en.wikipedia.org/wiki/Gauge_invariant), but is true only in the Coulomb Gauge, where the divergence of **A** is zero.

**CONVENTIONAL THEORIES**

During the 1950s, theoretical [condensed matter](http://en.wikipedia.org/wiki/Condensed_matter_physics) physicists arrived at a solid understanding of "conventional" superconductivity, through a pair of remarkable and important theories: the phenomenological Ginzburg-Landau theory (1950) and the microscopic [BCS theory](http://en.wikipedia.org/wiki/BCS_theory) (1957).

In 1950, the [phenomenological](http://en.wikipedia.org/wiki/Phenomenology_(science)) Ginzburg-Landau theory of superconductivity was devised by [Landau](http://en.wikipedia.org/wiki/Lev_Davidovich_Landau) and Ginzburg. This theory, which combined Landau's theory of second-order [phase transitions](http://en.wikipedia.org/wiki/Phase_transition) with a [Schrödinger](http://en.wikipedia.org/wiki/Schr%C3%B6dinger_equation)-like wave equation, had great success in explaining the macroscopic properties of superconductors. In particular, Abrikosov showed that Ginzburg-Landau theory predicts the division of superconductors into the two categories now referred to as Type I and Type II.Also in 1950, Maxwell and Reynolds *et al.* found that the critical temperature of a superconductor depends on the [isotopic mass](http://en.wikipedia.org/wiki/Isotope) of the constituent [element](http://en.wikipedia.org/wiki/Chemical_element)s. This important discovery pointed to the [electron](http://en.wikipedia.org/wiki/Electron)-[phonon](http://en.wikipedia.org/wiki/Phonon) interaction as the microscopic mechanism responsible for superconductivity.

The complete microscopic theory of superconductivity was finally proposed in 1957 by [Bardeen](http://en.wikipedia.org/wiki/John_Bardeen), [Cooper](http://en.wikipedia.org/wiki/Leon_Neil_Cooper) and [Schrieffer](http://en.wikipedia.org/wiki/John_Robert_Schrieffer). this BCS theory explained the superconducting current as a [superHYPERLINK "http://en.wikipedia.org/wiki/Superfluid" HYPERLINK "http://en.wikipedia.org/wiki/Superfluid"fluid](http://en.wikipedia.org/wiki/Superfluid) of [Cooper pairs](http://en.wikipedia.org/wiki/Cooper_pair), pairs of electrons interacting through the exchange of phonons. For this work, the authors were awarded the Nobel Prize in 1972.

The BCS theory was set on a firmer footing in 1958, when [N. N. Bogolyubov](http://en.wikipedia.org/wiki/N._N._Bogolyubov) showed that the BCS wavefunction, which had originally been derived from a variational argument, could be obtained using a canonical transformation of the electronic [Hamiltonian](http://en.wikipedia.org/wiki/Hamiltonian_(quantum_mechanics)). In 1959, [Lev Gor'kov](http://en.wikipedia.org/wiki/Lev_Gor%27kov) showed that the BCS theory reduced to the Ginzburg-Landau theory close to the critical temperature.

Generalizations of BCS theory for conventional superconductors form the basis for understanding of the phenomenon of superfluidity, because they fall into the [Lambda transition](http://en.wikipedia.org/wiki/Lambda_transition) universality class. The extent to which such generalizations can be applied to [unconventional superconductors](http://en.wikipedia.org/wiki/Unconventional_superconductor) is still controversial.

**HIGH-TEMPERATURE SUPERCONDUCTIVITY**

Physicists had believed that BCS theory forbade superconductivity at temperatures above about 30 K. In that year, Bednorz and Müller discovered superconductivity in a lanthanum-based cuprate perovskite material, which had a transition temperature of 35 K. It was soon found that replacing the lanthanum with yttrium raised the critical temperature to 92 K.

This temperature jump is particularly significant, since it allows liquid nitrogen as a refrigerant, replacing liquid helium. This can be important commercially because liquid nitrogen can be produced relatively cheaply, even on-site, avoiding some of the problems (such as so-called "solid air" plugs) which arise when liquid helium is used in piping. Many other cuprate superconductors have since been discovered, and the theory of superconductivity in these materials is one of the major outstanding challenges of theoretical condensed matter physics.

Since about 1993, the highest temperature superconductor was a ceramic material consisting of thallium, mercury, copper, barium, calcium and oxygen with Tc = 133–138 K. The latter experiment (138 K) still awaits experimental confirmation, however. In February 2008, an iron-based family of high-temperature superconductors was discovered. Hideo Hosono, of the Tokyo Institute of Technology, and colleagues found lanthanum oxygen fluorine iron arsenide, an oxypnictide that superconducts below 26 K.

The high temperature superconductors represent a new class of materials which bear extraordinary superconducting and magnetic properties and great potential for wide-ranging technological applications. The importance of understanding the transport and magnetic behaviors of these novel materials is two-fold. First, it could lead to a better understanding of the basic phenomena of superconductivity in these materials. Second, it could provide ways to improve the magnetic quality of the presently known materials by enhancing flux pinning in a controllable manner.

When a current is applied to a type II superconductor (blue rectangular box) in the mixed state, the magnetic vortices feel a force (Lorentz force) that pushes the vortices at right angles to the current flow. The magnetic vortices that penetrate the material should form a uniform triangular lattice with a lattice spacing determined by the strength of H. If H is increased, the vortices become more closely spaced and their cores start to overlap.The weak pinning of the flux lines of high-temperature superconductors gives rise to energy dissipation in these materials at finite currents, which limits the maximum value of the critical current (the current required to destroy superconductivity) and, hence, a variety of applications of the high-temperature superconductors. Knowing how the vortices move and arrange themselves under various temperature and magnetic-field conditions, as well as how these phenomena are influenced by the physical properties of the material, will be critical in controlling the flux motion and maintaining the supercurrent flow in these materials.

Our research is conducted on several systems of copper-oxide superconductors, some of which exhibit superconductivity at temperatures as high as about 130 K, well above the boiling point of liquid nitrogen (77 K). Measurements such as magnetic susceptibility, magnetoresistance, Hall effect, and current-voltage characteristics over a wide range of temperatures, applied magnetic fields, and/or applied pressures are used to probe the physics of these materials. These experiments are carried out on two major pieces of equipment:

(1) a low temperature platform suitable for transport measurements which consists of a 4He cryostat with pumping station and temperature controller for measurements from room temperature to 1.8 K, a 9 tesla magnet, and the required computer-interfaced electronics;

(2) a SQUID (superconducting quantum interference device) magnetometer which incorporates all the hardware and software needed for precise magnetic measurements from room temperature to 1.8 K and magnetic fields up to 5 tesla.

Superconductors can radically change energy management as we know it, but most are commercially unusable because they only work close to absolute zero. A research group at EPFL has now published an innovative approach that may help us understand and use superconductivity at more realistic temperatures.  
High-temperature superconductors are materials that have a superconducting transition temperature (Tc) above 30 K, which was thought to be the highest theoretically allowed Tc. Technological applications benefit from both the higher critical temperature being above the boiling point of liquid nitrogen and also the higher critical magnetic field (and critical current density) at which superconductivity is destroyed. In magnet applications the high critical magnetic field may be more valuable than the high Tc itself. Some cuprates have an upper critical field around 100 tesla. However, cuprate materials are brittle ceramics which are expensive to manufacture and not easily turned into wires or other useful shapes.

**APPLICATIONS OF SUPERCONDUCTIVITY**

Applications of superconductivity are:

* Superconducting magnets are some of the most powerful electromagnets known. They are used in MRI/NMR machines, mass spectrometers, and the beam-steering magnets used in particle accelerators.
* the production of sensitive magnetometers based on SQUIDs
* fast digital circuits (including those based on Josephson junctions and rapid single flux quantum technology),
* powerful superconducting electromagnets used in maglev trains, Magnetic Resonance Imaging (MRI) and Nuclear magnetic resonance (NMR) machines, magnetic confinement fusion reactors (e.g. tokamaks), and the beam-steering and focusing magnets used in particle accelerators
* low-loss power cables
* RF and microwave filters (e.g., for mobile phone base stations, as well as military ultra-sensitive/selective receivers)
* fast fault current limiters
* high sensitivity particle detectors, including the transition edge sensor, the superconducting bolometer, the superconducting tunnel junction detector, the kinetic inductance detector, and the superconducting nanowire single-photon detector
* railgun and coilgun magnets
* electric motors and generators.
* low thermal loss current leads for LTS devices (low thermal conductivity),
* RF and microwave filters (low resistance to RF), and
* increasingly in specialist scientific magnets, particularly where size and electricity consumption are critical (while HTS wire is much more expensive than LTS in these applications, this can be offset by the relative cost and convenience of cooling); the ability to ramp field is desired (the higher and wider range of HTS's operating temperature means faster changes in field can be managed); or cryogen free operation is desired (LTS generally requires liquid helium that is becoming more scarce and expensive).

**ADVANTAGES OF SUPERCONDUCTIVITY**

Advantages of superconductivity are:

* Because the resistance of superconductive material is so low, there is no current wastage when they are used to conduct electricity.
* When used in the process of magnetic levitation, no kinetic energy is wasted due to friction from contact with the ground.
* Advantage on Superconductivity of Heavily Boron-Doped (111) Diamond Films

The superconductivity transition temperatures Tc(onset) of 11.4 K and Tc(offset) of 7.4 K, which are the highest in diamond at present, are realized on homo epitaxially grown (111) diamond films with a high boron doping concentration of 8.4E21 cm-3 (4.7 atomic percent). Tc values of (111) diamond films are more than twice as high as those of (100) films at the equivalent boron concentration. The Tc of boron-doped (111) diamond increases as the boron content increases up to the maximum incorporated concentration and is agrees with the value estimated using McMillan's equation. The advantageous Tc for (111) diamond films is due to the higher carrier concentration which exceeds its boron concentration.

* Relatively narrow superconducting wires can be used to carry huge currents.
* Can carry large quanities of energy without heat loss and are able to generate strong magnetic fields. Superconductors beneficial applications in medical imaging techniques. New superconductive films may result in miniturisation and increased speed in computer chips.
* Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature.
* A typical SMES system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely.
* The stored energy can be released back to the network by discharging the coil. The power conditioning system uses an inverter/rectifier to transform alternating current (AC) power to direct current or convert DC back to AC power. The inverter/rectifier accounts for about 2–3% energy loss in each direction. SMES loses the least amount of electricity in the energy storage process compared to other methods of storing energy. SMES systems are highly efficient; the round-trip efficiency is greater than 95%.
* Due to the energy requirements of refrigeration and the high cost of superconducting wire, SMES is currently used for short duration energy storage. Therefore, SMES is most commonly devoted to improving power quality. If SMES were to be used for utilities it would be a diurnal storage device, charged from baseload power at night and meeting peak loads during the day.

**DISADVANTAGES OF SUPERCONDUCTIVITY**

* To show their properties, and be of any use, they must be at critical temperature, which can be costly.
* They emit strong magnetic fields which can affect humans by causing blindness, sterility, brain cancer and other things.
* There is a maximum current that superconducting materials can carry.
* Environmental benefits from less pollution and more efficent power production.
* Cost is prohibitive for immediate replacement of existing technologies.
* Less fuel required to generate electricity which will lead to a reduction in costs.
* Developing countries will not be able to afford the technology.
* Superconducting cables will be smaller and can fit into existing conduits for expansion of the power supply.
* Above a critical current density, superconductivity breaks down limiting current.
* Most materials people use are insulators, like plastic, or conductors, like an aluminum pot or a copper cable. Insulators show very high resistance to electricity. Conductors like copper show some resistance. Another class of materials show no resistance at all when cooled to very low temperatures, cooler than the coolest deep freezer. Called superconductors, they were discovered in 1911. Today, they are revolutionizing the electric grid, cell phone technology and medical diagnosis. Scientists are working to make them perform at room temperature.
* To show their properties and be of any use they must be at transition temperature which can be costly.
* They emit strong magnetic fields which can effect humans by causing sterility, blindness and brain cancer.
* The highest transition temperature is 138K which is still a long way to go before superconductors are available to average user at room temperatures.
* They are impractical for handheld, consumer devices to have liquid nitrogen running through them.

**CONCLUSION**

As after doing this project I have come to know about the superconductors and superconductivity. Below a critical temperature, some materials expel magnetic fields (Meissner effect) and have a zero electrical resistance. Superconductivity is the phenomena in which exactly zero electrical resistance and expulsion of magnetic fields occurring in certain materials when cooled below a characteristic critical temperature.

In this advance world of technology there is a great need of technology where high techniques are needed to cope up with the world. So superconductors can be one of those techniques.

Superconductors are substances which conduct electricity at zero resistance. They conduct electricity at very low temperature that is the critical temperature. There are two types of superconductors Type-I and Type-II superconductors. There is Miessner Effect related to superconductivity.

Superconductivity will remain a viable technology because of its density and

high efficiency.In the future, the applications of superconductivity science will increase, not decrease. The applications of superconductivity do and will benefit both the civil and defence domains thereby, it increases the opportunities to improve the application of this technology.

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**REFRENCES**