CHAPTER I

Introduction

Superconductivity was discovered in 1911 by Onnes (1). He measured the electrical resistivity of mercury and found that it dropped abruptly to zero below critical temperature T_c = 4.2 K. Onnes surmised correctly that he was dealing with a new state of matter below the critical temperature , and coined the term superconducting state. Onnes further discovered that the superconducting state could be destroyed by placing the superconductor in a large enough magnetic field, and he also note that sending a large enough current through the superconductor would destroy the superconducting state. Silsbee (2) later suggested that these two phenomena were relate. The disruption of the superconducting state by the current is caused by the magnetic field created by the current at the surface of the wire. In general , the critical magnetic field (that destroys superconductivity) and the critical temperature (at which the material becomes superconducting) are functionally related. The highest superconducting transition temperature occurs when there is no external magnetic field.

Furthermore , many years passed after Onnes' discovery before other really fundamental discoveries were made about the superconducting state. In 1932, Keesom and Kok (3) found a jump in the electronic specific heat at the superconducting transition temperature. Such a jump is consistent with the later idea of the existence of an energy gap in the density states of the electrons in a superconductor. In 1933 , Meissner and Ochsenfeld (4) made a discovery of fundamental importance. They found that superconductors expelled magnetic flux when they were cooled below the critical temperature. This is called Meissner effect. This behaviour has been called perfect diamagnetism. In 1934 , Gorter and Casimir (5) introduced the two - fluid model of superconductivity. This model is the conduction electrons in a superconducting substance fall into two classes , superelectrons and normal electrons. In 1935, F. and H. London (6) and have proposed that superconductivity is a quantum phenomenon on a macroscopic scale and developed semi-empirical theory of the electrodynamic properties for impure alloys superconductors. This theory can be explained the Meissner effect. The Londons' analysis showed that the field decays exponentially into the sample over a characteristic "penetration depth". In 1953, Pippard (7) introduced the coherence length while proposing a nonlocal generalization London's theory , for pure superconductors.

In 1950 , Fröhlich (8) suggested that the interaction between electrons and lattice vibrations , or phonons might be responsible for the formation of the superconducting state. At about the same time, Maxwell (9) and Reynolds , Serin , Wright and Nesbitt (10) found that the superconducting transition temperature depended on the isotopic mass of the superconductor. This experimental result gave strong support to the ideal that the interaction between electrons and phonons was involved in the superconducting transition temperature. Bardeen, Cooper and Schrieffer (11) or BCS theory, in 1957, finally developed a formalism which apparently contained the correct explanation of the superconducting state. Their ideas had some similarity to Frohlich's ideas , but the BCS theory used a much better mathematical approch. In fact , the crucial idea in the BCS theory was supplied by Cooper in 1956 (12). Cooper analyzed the electron - phonon interaction in a different way than Frohlich. Frohlich had discussed the effect of the lattice vibrations on the self - energy of the electrons. Cooper analyzed the effect of the lattice vibrations on the effective interaction between electrons. Cooper's calculation showed that an attractive interaction between etectrons , even a very weak attractive interaction at low enough temperatures would cause pairs of electrons , or the Cooper pairs to form bound states near the Fermi energy. As we will see, the pairing interaction couses a gap in the density of single electron states.

The field of superconductivity has opened many new areas for both experimental and theoretical research. So far we have mentioned only a few of the most basic experiments and theoretical ideas. Many more experiments have been done which tend to confirm the BCS theory.

The Theory of the strong - coupling superconductors was developed by Eliashberg in 1960 (13) , McMillan in 1968 (14) , derived a formula for the superconducting transition temperature for metals and alloys from strong - coupling theory.

As far as conventional superconductors are concerned , the BCS theory can explain all these phenomena and more, but considerable insight was obtained in advance of that by Ginzburg and Landau (15) who , in 1950, analysed the energetics of the superconducting phase changes. Landau had previously produced a general theory of second - order phase transitions (in which the entire system changes state essentially simultaneously without the involvement of latent heat). The essential concept of Landau's theory is the order parameter having its maximum magnitude when the system is most ordered , as might occur at absolute zero. As temperature increases , the order parameter decreases , becoming zero (maximum disorder) at and above the critical temperature. To explain phenomena in the neighbourhood of the transition , Landau formalized the free energy density of the system in terms of the order parameter and determined the value of the parameter associated with the minimum free energy at a given temperature.

Ginzburg and Landau applied this theory to superconductors. The condition for a minimum of free energy , it turns out , closely resembles a Schrodinger equation , thus allowing the identification of the order parameter with the macroscopic wave function mentioned above. The solutions reveal several features of superconductors , they reproduce the London and Pippard equations. They yield a characteristic minimum length over which the wave function can significantly change the coherence length, and internal magnetic field dacays exponentially into the superconductor over a characteristic penetration depth. Perhaps the most significant insight provided by the Ginzburg - Landau theory concerns the difference between type I and type II superconductors as exhibited in their contrasting responses to external magnetic fields. The expulsion of mangnetic flux by a sample costs energy and there will clearly be an applied field strength at which it becomes energetically easier to assume the normal conducting stste. Ginzburg and Landau showed that in type II material , the penetration depth exceeds the coherence length , the increase in energy of the bluk from the formation of restricted region of normal conducting material is more than offset by the decrease in magnetic energy as the flux enters those - regions . Thus normal cores are formed lying parallel to applied , sheathed by vortices of supercurrent and threaded by magnetic flux .

It turns out that a triangular lattice of cores is the preferred geometry in this mixed state . At the lower critical field the normal cores are spaced a penetration depth apart. As the field increases , more cores are formed and the seperation decreases until , at the upper critical field , the cores are separate only by a coherence length or so. In 1959 , Gor'kov (16) showed that the Ginzburg - Landau equations can be derived from microscopicall and is valid for temperatures close to , and below the superconduction transition temperature .

Since Onnes's discovery , superconductivity of material had been found that the highest value of critical temperature was only 23 K for the compoud Nb_3Ge (17). It was thus understood that superconductivity was a physical state at a low temperature phenomenon. But great famous and furore surrounds was discovered high - T_c supercondutivity in ceramic oxides compounds by Bednorz and Müller (18) in 1986 , reseach on high - T_c ceramic oxide superconductors , had been developing with surprisingly high speed and have extended very rapidly to the high - T_c superconductivity of T_c of 125 K (19). High - T_c superconductivity has now been observed in five families of ceramic oxide compounds

1. The $La_2AE_2CuO_4$ phases (18) where AE , is a alkaline earth atom Ba , Sr or Ca , with a maximum T_c of 40 K .

2. The $YBa_2Cu_3O_7$ (1 2 3) phases (20) , where Y can be replaced by other rare earths , with a maximum T_c of 93 K.

3. The $Bi_2Ca_1Sr_2Cu_2O_8$ (2 1 2 2) phases (21) , where Bi can be replaced by Tl and Sr by Ba , with a maximum T_c around 90 K

4. The $Tl_2Ca_2Ba_2Cu_3O_{10}$ (2 2 2 3) phases (19) with a maximum T_c of 125 K .

5. THE $Ba_{1-x} K_x Bi O_3$ phase (22) with a maximum T_c around 30 K.

Most of the recent theoretical explanations of high T_c - superconductivity start from regular structures and use the coventional BCS Theory (23 , 24) resonating valence bond (25 , 26), plasmon - type coupling (27) , bipolaron mechanism (28) , negative U - effects (29) or modify the idea of the resonating valence bond (30 , 31 , 32) to explain the phenomenon.

The purpose of this thesis was to study the properties of high T_c supesconductivity , rooted in the theoretical frameworks of Ginzburg - Landau theory and Ginzburg's - Theory (33). which had been proprosed in 1987.

The plan of the thesis is as follows. In chapter II we will review fundamental properties and theory of superconductivity. In chapter III we will review the Ginzburg - Landau theory , both the phenomenological and the microscopic theory. In chapter IV we will present the Ginzburg - Landau equations from the Ginzburg - theory for high - T_c superconductivity. We derive an expression for a penetration depth , coherence length , specific heat, Thermodynamic field , lower and upper critical field , surface nucleation field , critical current of thin wire or films and parallel critical field of thin flims of the high - T_c superconductors. The final chapter (V) is discussion and conclusion.