Chapter One

Introduction and Literature Review

1.1 Introduction:

Material is a group made up of one type of elements or more, or is a group of the chemical compounds with each other, and the physical properties of the ability to Connecting to the power supply, and this is done by connecting the different materials, whether composed of one or more elements, or if they are made up of vehicles with electric source, wires, and thus we can see the potential for to connecting the power supply, where it was classified materials to the buffer conductive or semiconductor, thereby contributing to this classification on the order of the elements in the periodic table is divided into groups according to the ability of the material and efficiency in the delivery of electricity. And also connected to the heat we can see of this property in a lot of material, if we put a piece of iron and a piece of wood in the sun or the heat, such as heating source, we find that a piece of iron Stschen faster and by much more than a piece of wood, it is through this property we can differentiate between thermally insulating material or conductive. And with the advancement of the science discovered in the early twentieth century, a strange property of some materials and characterized these materials disappearance of electrical resistance below a certain temperature and was the class of less than 4 Kelvin was named this phenomenon conduction superior and Smitalmwad super-connectors and the meaning of the disappearance of electrical resistance in which that power is going where no any loss and non-stop [1].

1.2 Objective of Research:

Recognize the meaning of superconductivity and the effect of temperature on conductivity of conductors and superconductivity.

1.3 Literature Review:

Guanhua Chen, Jean-Marc Langlois, Yuejin Guo, and William A Goddard III: The equations for the magnon pairing theory of high temperature copper-oxide-based superconductors are solved and used to calculate several properties, leading to results for specific heat and critical magnetic fields consistent with experimental results. In addition, the theory suggests an explanation of why there are two sets of transition temperatures (T, - 90 K and T_c 55 K) for the YBa2Cu306+, class of superconductors. It also provides an explanation of why La2zSr.CuO4 is a superconductor for only a small range of x (and suggests an experiment to independently test the theory). These results provide support for the magnon pairing theory of high-temperature superconductors. On the basis of the theory, some suggestions are made for improving these material.

Tsuyoshi ARIYOSHI and T akanori SAWAI: In recent years, global warming has become a serious environmental issue. Development efforts are currently underway toward achieving practical application of high-temperature superconducting wires. A high-temperature superconductor has zero electrical resistance at the temperature of liquid nitrogen, so it can reduce the power losses in electrical equipment. The authors have developed a prototype electric vehicle equipped with a motor system that uses bismuth superconducting wire to verify the potential and problems of superconductors. It was verified that the prototype superconducting motor has a torque of 70 Nm, an output of 18 kW and a maximum speed of 70 km/h. The maximum torque can be achieved at low rotations, and therefore a smooth start and acceleration is possible. After six months of test driving, there has been no problem .

Dale R. Harshman, Anthony T. Fiory and John D. Dow: It is demonstrated that the transition temperature (T_c) of high-T_c superconductors is determined by their layered crystal structure, bond lengths, valency properties of the ions, and Coulomb coupling between electronic bands in adjacent, spatially separated layers. Analysis of 31 high-T_c materials (cuprates, ruthenates, rutheno-cuprates, iron pnictides, organics) yields the universal relationship for optimal compounds, $K_B T_{co} = \beta/\ell\xi$, where ℓ is related to the mean spacing between interacting charges in the layers, δ is the distance between interacting electronic layers, β is a universal constant and $T_{co}$is the optimal transition temperature (determined to within an uncertainty of $\pm$ 1.4 K by this relationship). Non-optimum compounds, in which sample degradation is evident, e.g. by broadened superconducting transitions and diminished Meissner fractions, typically exhibit reducedT_c <T_{co}. It is shown that T_{co}may be obtained from an average of Coulomb interaction forces between the two layers .

1.4 Research Problem:

Superconductors play an important rule in today technology The first large scale commercial application of superconductivity was in magnetic resonance imaging (MRI). The problem of this research is to study the effect of temperature increasing on superconducting material .

1.5 Research Method:

Theoretical back ground of superconducting material and practical.

1.6 Thesis Layout:

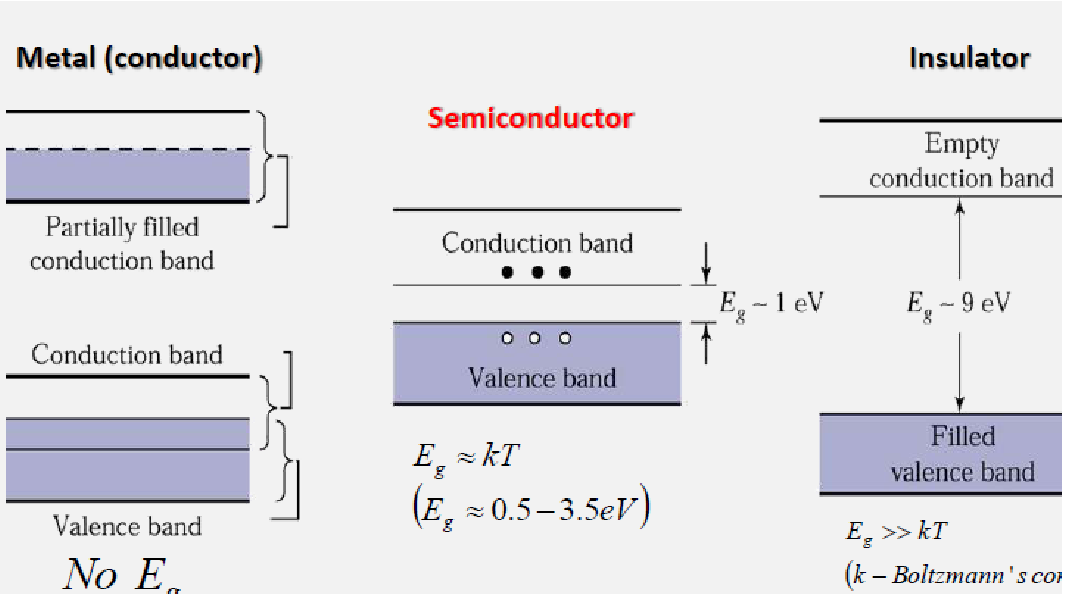
This research contains four chapters: Chapter One Introduction and literature review, Chapter two conductivity, Chapter three superconductivity and chapter Four about methodology and practical.

Chapter Two
Conductivity

2.1 Introduction:

Every solid has its own characteristic energy band structure. In order for a material to be conductive, both free electrons and empty states must be available. Metals have free electrons and partially filled valence bands, therefore they are highly conductive Figure (2.1.a) [5,6]. Semimetals have their highest band filled. This filled band, however, overlaps with the next higher band, therefore they are conductive but with slightly higher resistivity than normal metals Figure (2.1.b). Examples: arsenic, bismuth, and antimony.

Insulators have filled valence bands and empty conduction bands, separated by a large band gap E_g (typically>4eV), they have high resistivity Figure (2.1.c). Semiconductors have similar band structure as insulators but with a much smaller band gap. Some electrons can jump to the empty conduction band by thermal or optical excitation. Eg =1.1 eV for Si, 0.67 eV for Ge and 1.43 eV for GaAs [5,6].



(a) (b) (c)

Figure (2.1) Energy band diagram for (a) metals (b) Semiconductors and (c) insulator

2.2 Electrical conductor's basic information:

Electrical conductivity is the ability of a material to carry an electrical current. The term conductivity can also be used in other contexts (e.g., thermal conductivity). For simplicity, in this guide the term "conductivity" is always used in the sense of electrical conductivity [7,8]. The transport of electricity through matter always requires the presence of charged particles. Conductors can be classified into two main groups based on the nature of the charged particle. Conductors in the first group consist of a lattice of atoms with an outer shell of electrons. The electrons in this 'electron cloud' can dissociate freely from their atom and transport electricity through the lattice and therefore also through the material. Metals, graphite, and a few other chemical compounds belong to this group. The conductors in the second group are so-called ionic conductors. In contrast to the conductors of the first group the current flow is not caused by freely moving electrons but by ions. Thereby the charge transfer in electrolytes is always linked to the transport of matter. Conductors in the second group consist of electrically charged and moveable ions and are called electrolytes. Ionization occurs by dissolving in a polar solvent (such as water) or through melting [7, 8,9].

2.3 Definition of conductivity:

According to Ohm's law the voltage (V) set up across a solution is proportional to t he flowing current (I):

$$V = R \times I \qquad (2.1)$$

R≡Resistance (ohm, Ω).

V ≡ Voltage (volt, V).

I ≡ Current (ampere, A) .

The resistance (R) is a constant of proportionality and can be calculated with the measured current flow if a known voltage is applied:

$$R = \frac{V}{I} \qquad (2.2)$$

Conductance (G) is defined as the inverse of resistance:

$$G = \frac{1}{R} \qquad (2.3)$$

G ≡ conductance (Siemens, S) [10].

2.4 Band theory of solids: metals, semiconductors and insulators:

2.4.1 Metals:

Energy bands a range of allowed electron energies. The energy band in a metal is only partially filled with electrons. Metals have overlapping valence and conduction bands [11].

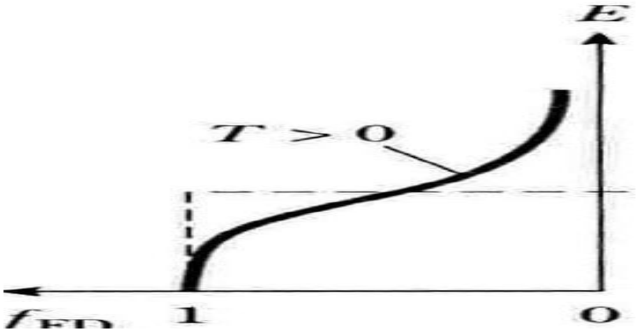


Figure (2.2) Energy gab for metals

At T = 0, all levels in conduction band below the Fermi energy E_F are filled with electrons, while all levels above E_F are empty. Electrons are free to move into “empty “states of conduction band with only a small electric field E, leading to high electrical conductivity. At T > 0, electrons have a probability to be thermally “excited “from below the Fermi energy to above it. [11]

2.4.2 Semi conductivity:

Energy levels and energy gap in pure semiconductors. The energy gap is < 2 eV. Eg Semiconductors have resistivity’s in between those of metals and insulators.

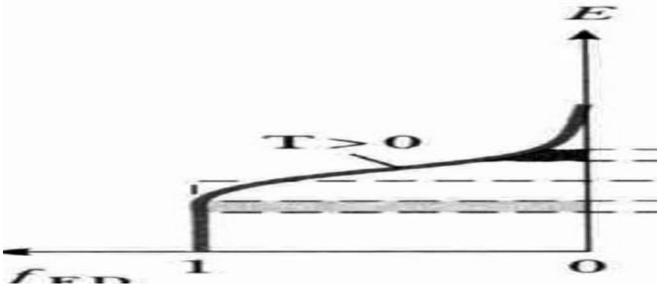


Figure (2.3) Energy gab for semiconductor

At T = 0, lower valence band is filled with electrons and upper conduction band is empty, leading to zero conductivity. Fermi energy E_f is at midpoint of small energy gap (<1eV) between conduction and valence bands. At T > 0, electrons thermally “excited “from valence to conduction band, leading to measurable conductivity.

2.4.3 Insulator:

The valence band and conduction band are separated by a large (>4eV) energy gap, which is a “forbidden “range of energies. Electrons must be promoted across the energy gap to conduct, but the energy gap is large. Energy gap E_g

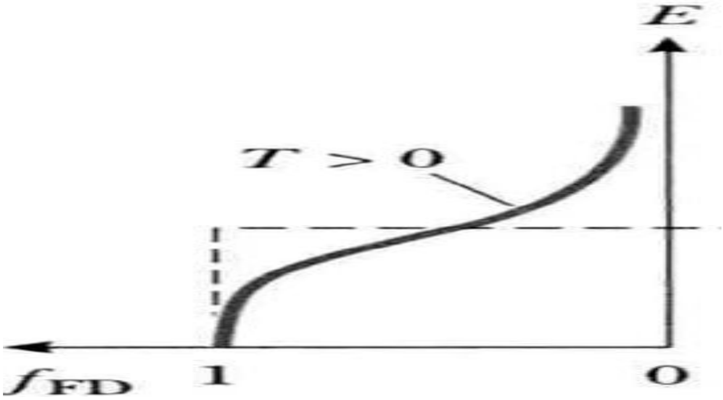


Figure (2.4) Energy gap for insulator

At T = 0, lower valence band is filled with electrons and upper conduction band is empty, leading to zero conductivity. Fermi energy E_g is at midpoint of large energy gap (2-10eV) between conduction and valence bands. At T > 0, electrons are usually NOT thermally “excited “from valence to conduction band, leading to zero conductivity [11].

2.5 Resistivity:

The resistivity ρ is defined by scattering events due to the Imperfections and thermal vibrations. Total resistivity ρ_{tot} can be described by the Matthiessen rule:

$$\rho_{tot} = \rho_{thermal} + \rho_{impurity} + \rho_{deformation} \qquad (2.4)$$

Where $\rho_{thermal}$: is a thermal vibrat.

$\rho_{impurity}$: is an impurity.

$\rho_{deformation}$: is deformation-induced defects [12].

2.6 Temperature Dependence:

There are three contributions top:

ρt due to phonons (thermal).

ρi due to impurities.

ρd due to deformation [11].

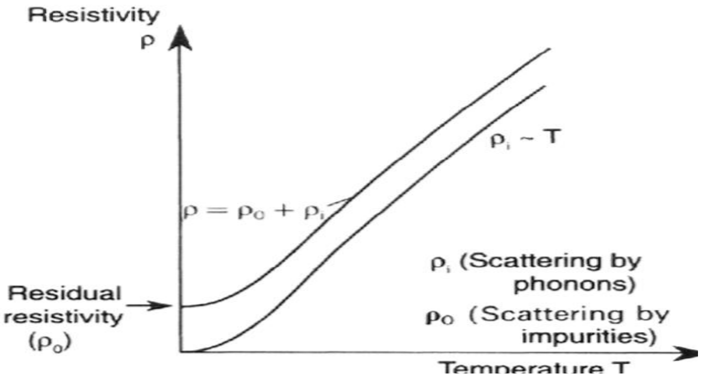


Figure (2.5) Resistivity as a function of temperature

2.7 The Fermi Function:

This equation represents the probability that an energy level E, is occupied by an electron and can have values between 0 and 1. At 0K, the f (E) is equal to 1 up to E_f and equal to 0 above E_f [12].

$$f(E) = \frac{1}{\left[\frac{e(E-E_f)}{KT}+1\right]} \qquad (2.5)$$

where: E ≡ Energy level.

E_F ≡ Fermi Energy level.

e ≡ charge of electron.

K ≡ Bolte man constant.

T ≡ temperature.

In metals, electrons near the Fermi energy see empty states a very small energy jump away, and can thus be promoted into conducting states above E_f very easily (temp or electric field).

- High conductivity.
- Atavistically: weak metallic bonding of electrons.
- In semiconductors, insulators, electrons have to jump across band gap into Conduction band to find conducting states above E_f: requires jump >> kT
- No. of electrons in CB decreases with higher band gap, lower T.
- Relatively low conductivity.
- An electron in the conduction band leaves a hole in the valence band, that can also conduct.
- Atomistically: strong covalent or ionic bonding of electrons[12].

2.8 Influence of temperature:

Resistivity rises linearly with temperature (increasing Thermal vibrations and density of vacancies).

$$\rho_T = \rho_0 + \alpha T \quad (2.6)$$

Temperature variation of conductivity Basic equation for conductivity:

$$\sigma = n|e|\mu_e + p|e|\mu_h \quad (2.7)$$

Therefore, the temperature dependence of thermal conductivity is defined by the temperature dependences of carrier concentration and mobility Carrier concentration vs T: Intrinsic semiconductors Extrinsic region: All P donor state electrons are excited Freeze-out region: Thermal energy is too low for exciting the electrons from P donor states to the conduction band Intrinsic region: Excitations across the band gap dominate[11].

2.9 Carrier mobility:

For dopant concentrations below $10^{24}m^{-3}$, mobility of both electrons and holes decreases with increasing temperature due to the enhanced thermal scattering [12].

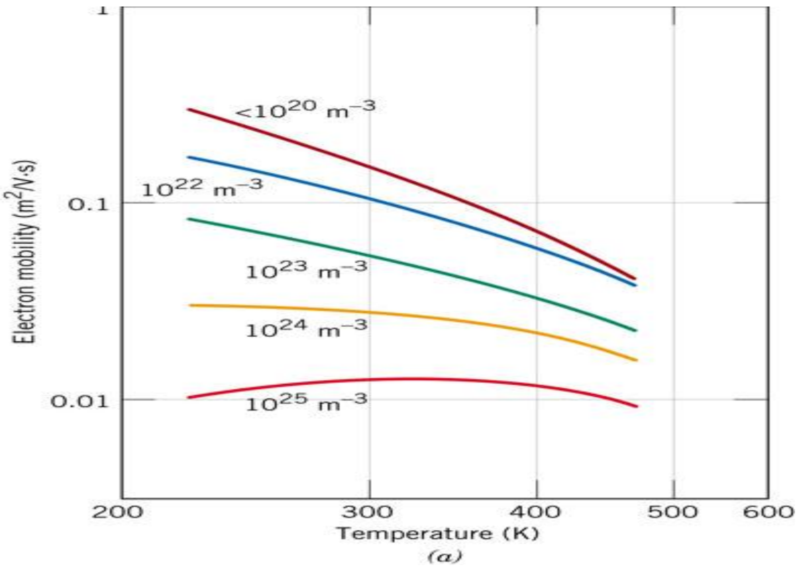
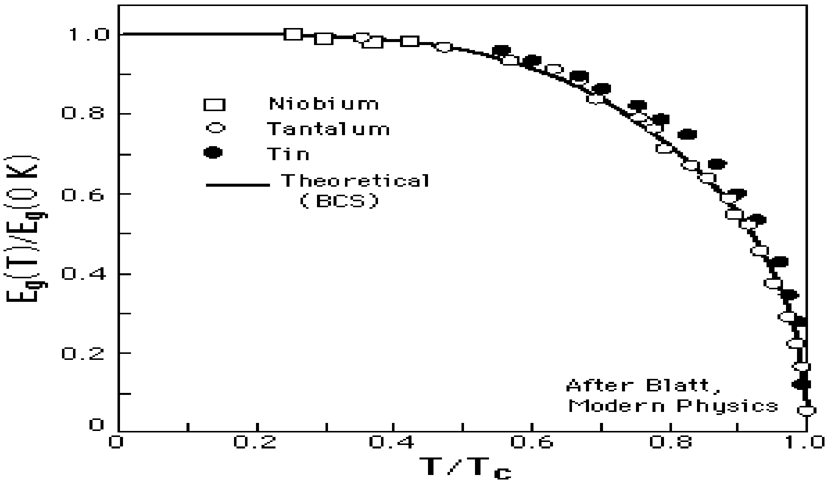


Figure (2.6) The relation between mobility and temperature

2.10 Energy Gap in Superconductors as a Function of Temperature:

The effective energy gap in superconductors can be measured in microwave absorption experiments. The data at left offer general confirmation of the BCS theory of superconductivity. The data is attributed to Townsend and Sutton.[13,14]The reduction of the energy gap as you approach the critical temperature can be taken as an indication that the charge carriers have some sort of collective nature. That is, the charge carriers must consist of at least two things which are bound together, and the binding energy is weakening as you approach the critical temperature. Above the critical temperature, such collections do not exist, and normal resistivity prevails. This kind of evidence, along with the isotope effect which showed that the crystal lattice was involved, helped to suggest the picture of paired electrons bound together by phonon interactions with the lattice [13,15].



Figure(2.7) Energy Gap in Superconductors as a Function of Temperature

2.11 Temperature dependence of the superconductor energy gap:

Magnitude of the temperature dependent energy gap, the gap between the energy of the Fermi level and the next available electronic energy level in the system, for a superconductor depends strongly upon the superconductor's internal magnetic field. Because of this it is necessary to specify the internal magnetic field of a superconductor to make coherent superconductor to be able to receive an external magnetic field, there must be a vacant energy state in the superconductor to receive the energy associated with the field [16]. For a small range of energies near that of the critical magnetic field, H_C, these energy states lie within the superconductor temperature dependent energy gap. Thermodynamic analysis of the energy balance in the loss of dissipative electron scattering and the change in entropy of the conducting phase that occur in the phase transition between the normal metal and the superconducting state to suggest that changes in electron Gibbs free energy at T, from these sources are the basis for the temperature dependent energy gap. The critical magnetic field for a superconductor at temperature, T, H_C(T) occurs when the energy of the magnetic field is equal to the magnitude of the superconductor energy gap at T [14]. Under these conditions, the internal magnetic field of the superconductor corresponds to $\mathrm{H_C}$. When the superconductor energy gap is occupied with the energy of the external magnetic field, the normal metal conducting bands that became inaccessible at the superconductor , normal conductor phase transition are once again available for conduction, and the superconductor quenches. Origins of the superconductor energy gap arising from loss of dissipative electron scattering and development of coherent electron lattice order at the superconductor phase transition lie in the laws of thermodynamics, which cannot be casually neglected. The ratio of the superconductor energy gap to the superconductor critical temperature depends upon the chemical structure of superconductor. We anticipate that the superconducting energy gaps for mercury, and lead will show small maxima near 0.21, and 0.11 K, respectively. Anticipated maxima for type I superconductors are due to the two sources of entropy differences between the normal phase and the superconducting phase:

1) dissipative electron scattering in the normal phase.

2) coherent order in the superconducting phase.

The dissipative scattering component of the free energy depends upon the existence of a current, which is often neglected in the study of circuits. In this case the current in the superconducting state is essential to operation of the Meissner Ochsenfeld effect. In some of the elemental superconductors for which high quality Hc data is available, hypothetical curve maxima are anticipated at sub-zero temperatures. The fact basis supporting these details was presented in the late 1950’s, and the original authors were careful to point out the significant differences in properties for individual elements [16].

Chapter Three

Superconductivity

1.3 Superconductivity:

Superconductivity in physics is the phenomenon that occurs in certain materials when cooled to very low temperatures close to absolute zero (Zero Kelvin), where superconductors allow the passage of electricity through without almost any electrical resistance [17,18].

2.3 Phenomenology of Superconductivity:

Superconductivity was discovered in 1911 in the Leiden laboratory of Kimberling Ones when a so-called “blue boy” (local high school student recruited for the tedious job of monitoring experiments) noticed that the resistivity of Hg metal vanished abruptly at about 4K [19]. Although phenomenological models with predictive power were developed in the 30’s and 40’s, the microscopic mechanism underlying superconductivity was not discovered until 1957 by Bardeen Cooper and Schrieffer. Superconductors have been studied intensively for their fundamental interest and for the promise of technological applications which would be possible if a material which super conducts at room temperature were discovered. Until1986, critical temperatures (T_c’s) at which resistance disappears were always less than about 23K. In 1986, Bednorz and Mueller published a paper, subsequently recognized with the 1987 Nobel prize, for the discovery of a new class of materials which currently include members with T_c’s of about 135K [20].

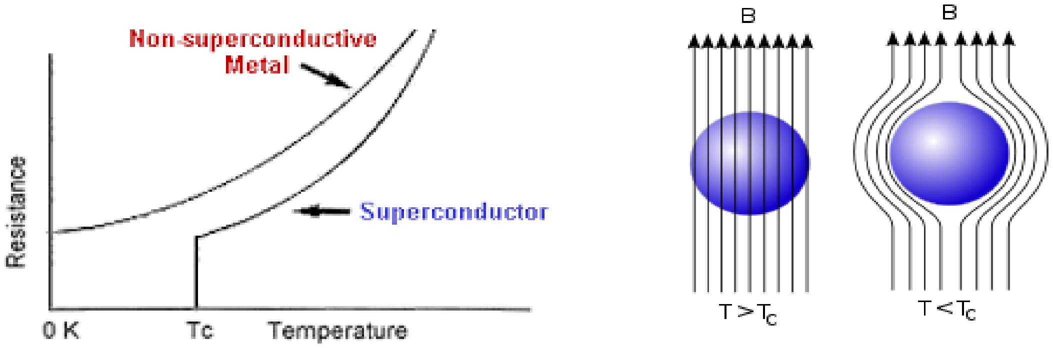


Figure (1.3) Properties of superconductors

3.3 Basic properties of the superconducting state:

Superconducting materials exhibit the following unusual behaviors:

3.3.1 Zero resistance:

Below a material's T_c, the DC electrical resistivity is really zero, not just very small. This leads to the possibility of a related effect [20].

3.3.2 Persistent currents:

If a current is set up in a superconductor with multiply connected topology, e.g. a torus. it will flow forever without any driving voltage. (In practice experiments have been performed in which persistent currents flow for several years without signs of degrading)[19].

3.3.3 Perfect diamagnetism:

A superconductor expels a weak magnetic field nearly completely from its interior (screening currents flow to compensate the field within a surface layer of a few 100 or 1000 A, and the field at the sample surface drops to zero over this layer)[19].

3.3.4 The Meissner effect:

In 1933, Walter Meissner and Robert Ochsenfeld discovered a conductor's magnetic phenomenon that showed that superconductors are not just perfect. Illustrates a thought experiment that highlights this difference. Imagine that both the ideal conductor 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, Ba, is then applied. This results in the field penetrating both materials. Both samples are then cooled so that the ideal conductor now has zero resistance. It is found that the magnetic field from inside it, while the ideal conductor maintains its interior field. Note that energy is needed by the superconductor to expel 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 – by Lenz's law . However, the superconductor returns to its initial state, i.e. no magnetic field inside or outside it [20].

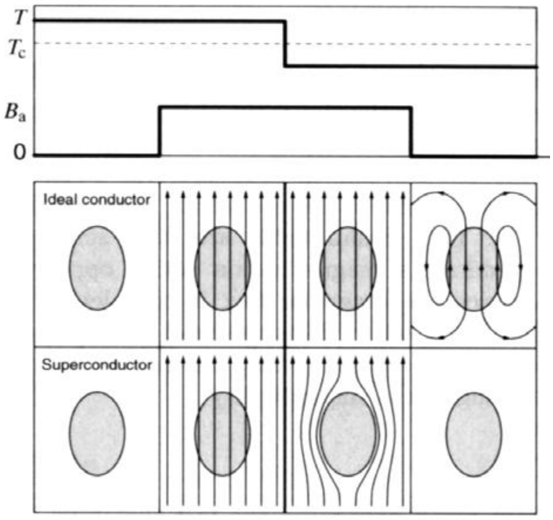


Figure (3.2). The Meissner effect.

In a superconductor, the magnetic field is expelled independently of the cooling procedure, either first cooling and then applying B or first applying B and then cooling. The superconducting state is a new state of matter. Inside the superconductor, the magnetic induction B disappears:

$$B = H + 4\pi M = 0 \qquad (3.1)$$

Where H is the external magnetic field [21].

The phenomenon is most important impact of the Master are displayed comment in a vacuum (Ievitation effect) If we put magnets small on the surface of high-transmission dimensions Okbermn magnet dimensions and in the critical temperature and then reduced the degree of temperature below the critical temperature will pop magnet above the super carrier where the generated electric current flowing through the surface of the material. This trend in turn will generate a field magnet will eliminate completely the original magnetic field which is trying to influence into the ultra carrier [22].

3.3.5 The Josephson effects:

Is a currents take place during the tunneling phenomenon for couples -kopr through thin insulating layer (with a thickness of several nanometers when latency Thiaz zero (which is called the influence of Josephson dc) in addition to the presence of current tunneling resulting from individual electrons[23]. The effect Josephson of the alternating current is a current shaky pairs -kopr that take place when the teams applied in a fixed latency through the checkpoint tunneling. and it raised the idea of the weak links (weak links), such as a link super carrier-insulator-high transmission (SIS), with important practical applications, and as shown in Figure (3.3)[24].

Figure(3.3) Qualitatively weak links (a) of the type (SIS). (B) of the type (SNS) where N: is an extraordinary film.

3.3.6 Energy gap in the excitation spectrum :

Most thermodynamic properties of a superconductor are found to vary as e−_/(kBT), indicating the existence of a gap, or energy interval with no allowed eigenenergies, in the energy spectrum. Idea: when there is a gap, only an exponentially small number of particles have enough thermal energy to be promoted to the available unoccupied states above the gap. In addition, this gap is visible in electromagnetic absorption: send in a photon at low temperatures (strictly speaking, T = 0), and no absorption is possible until the photon energy reaches, i.e. until the energy required to break a pair is available[25].

3.3.7 Proximity effect:

The impact of the neighborhood and it happens in the contact area between the high transmission and natural metal incite where high conductivity within the normal metal, and in only a thin surface layer of the contact area and shall be of the rank of the length of the thread about (10^4Å). And thus pairs of ultra-Cooper carrier moves to the normal metal and have the effect of neighboring strongest when temperatures T «T_c. Any approaching absolute zero, knowing that all the high carrier showing the effect of the neighborhood[26].

3.3.8 Isotope effect :

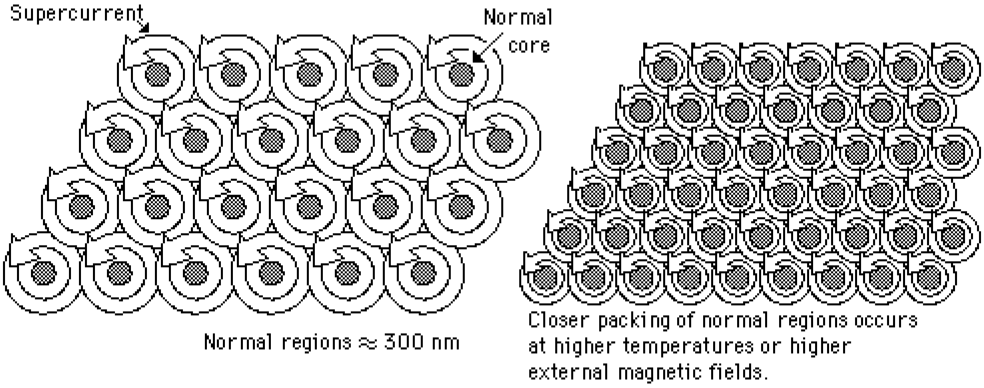
Different isotopes has high conductivity of metals possess marginal temperatures according to the equation :

$$T_c M\alpha = \text{CONSTANT} \qquad (3.2)$$

Where (M) is an isotope mass and approaching the value of α from the classical value of 0.5 for the most high-vectors. But he is not a general phenomenon, where he loses in the vector of non-conventional and mostly in similar areas perfectly and even in traditional high-vectors can be non-existent[26].

3.3.9 Vortex State for Superconductors :

Type II superconductors usually exist in a vortex state with normal cores surrounded by superconducting regions. This allows magnetic field penetration. As their critical temperatures are approached, the normal cores are more closely .packed and eventually overlap as the superconducting state is lost[25].



Figure(3.4) Vortex State for Superconductors

At the lower of the two critical magnetic fields in a Type II superconductor, magnetic fields begin to penetrate through cores of normal material surrounded by superconducting current vortices. As long as these vortices are stationary (pinned), the magnetic fields can penetrate while still maintaining zero electric resistivity paths through the material. While the Meissner effect is modified to allow magnetic fields through the normal cores, magnetic fields are still excluded from the superconducting regions. As the temperature or the external magnetic field is increased, the normal regions are packed closer together. The vortices feel a force when current flows, and if they move, the superconducting state is lost [24].

3.4 Characteristics of the superconducting state:

3.4.1 Critical temperature:

The phase transition from normal into the superconducting state is a secondorder transition, occurring at a temperature called the critical temperature T_c [21].

3.4.2 Order parameter:

In general, pairing is possible for some pair the mechanism if single particle energies corresponding to the states kσ and k`σ` are degenerate, since in this case the pairing interaction is most attractive. In the BCS case, a guarantee of this degeneracy for k ↑ and −k ↓ in zero field is provided by Kramer's theorem, which says these states must be degenerate because they are connected by time reversal symmetry.they are connected by time reversal symmetry. However, there are other symmetries: in a system with inversion symmetry, parity will provide another type of degeneracy, so k ↑, k ↓, −k ↑ and −k ↓ are all degenerate and may be paired with one another if allowed by the pair interaction[24].

3.4.3 Penetration depth:

Is a very thin layer through which high-current (supercurrent) on the surface of a material with high conductivity and by which high-conductivity material may cancel the magnetic field inside through the consolidation of this constant current[17,18].

3.4.4 Coherence length and the Cooper-pair size:

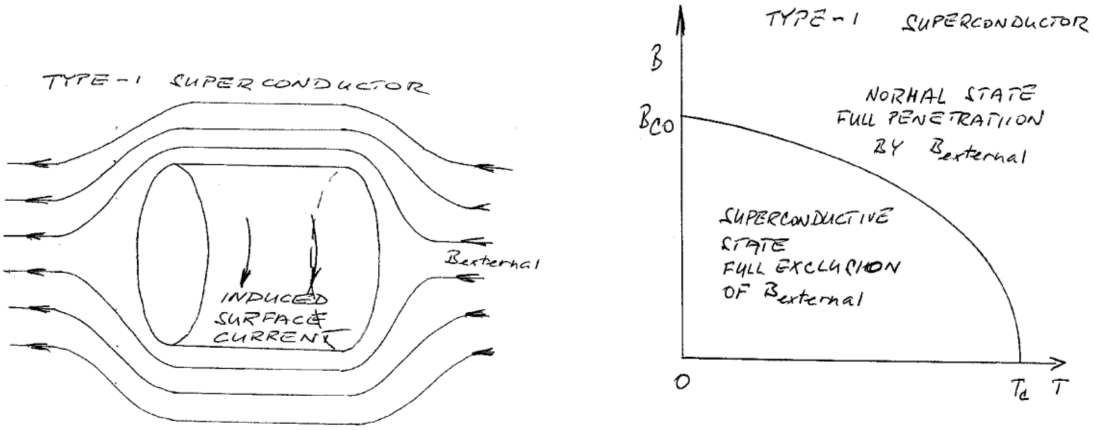
In many of the scientific literature they consider that the distance between the two electrons in a Cooper pair (size of the Cooper pair) is exactly the same so-called correlation length. But there is a difference between the two concepts. As the size of a pair Cooper be linked aftershock waveform pair Cooper (the waveform is a physicist, a term found in quantum mechanics, where a particle is described by that of the waveform, and gives the following relationship (-$r_2 r_1$ψ where the difference between $r_1$and $r_2$represent relative coordinates, as the case of high conductivity is a quantum state occur on the macroscopic level.) and is independent of temperature[27].

The length of the correlation parameter defines the change in rank (order parameter) of condensate super-conductivity. Where the parameter defines Rank: that the waveform of the output of the intensification of high-conductivity, in other words, you can magnetic fields influence into the ultra-carrier and the form of filaments microscopic microscopic filaments called vortices vortices) (at regular three-network and each of these vortices is made up of ordinary nuclei and form that inside the magnetic field is large and surrounded by high conductivity zone, and an approximation of a long cylinder with a parallel axis of the magnetic field outside as inside the roller be parameter rank non-existent, and thus the radius of the drum represents the so-called rank along bonding. and the length of interdependence be continued on the temperature [26].

3.4.5 Type-I and type-II superconductors:

3.4.5.1 Type I Superconductors:

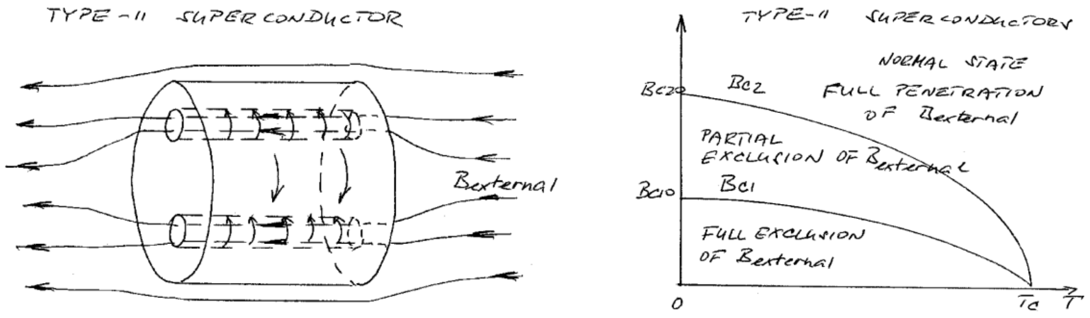
In Type I superconductors transition from normal state to superconducting state occurs instantly i.e. at exactly it's critical/transition temperature T_c also this type of superconductors "repel" magnetic field lines fully, i.e. no magnetic field line could penetrate through in this type of superconductors As you can see no magnetic field line penetrates though this type of superconductor in Figure(3.1)[25].



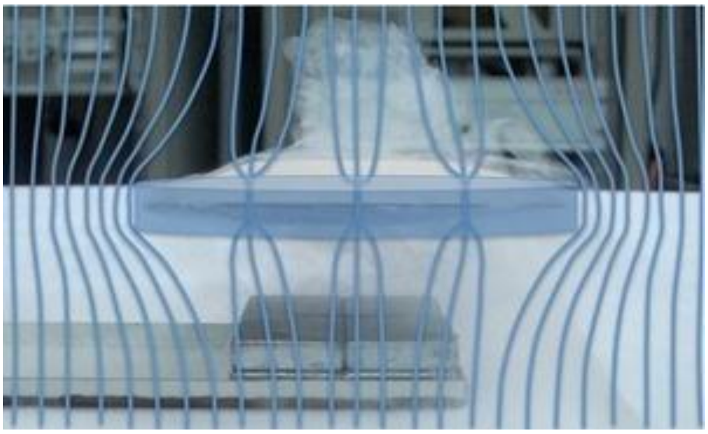
Figure(3.5) Type I superconductor

3.4.5.2 Type II Superconductors:

In Type II superconductors transition from a normal state to a superconducting state occurs "slowly" i.e. as you decrease temperature from it's critical temperature superconducting properties increase[27]:



Figure(3.6) Type II superconductor



Figure(3.7) Magnetic field lines in Type II Superconductors

As you can see on image, there is small curve which approaches zero resistance after critical temperature T_c .The conclugen So there are few differences between Type I and Type II superconductors, first of them it transition of superconducting state, second is magnetic field lines. Also there are few more differences between them, for example Type I superconductors always have lower critical temperature than the most of Type II superconductors, also There is theory (BCS Theory) which explains only type

I superconductors but can't explain type II superconductors (i.e. High temperature superconductivity)[23].

3.4.6 Critical magnetic fields:

If the external magnetic field is too strong, then the superconducting state is destroyed. The dependence of the critical magnetic field Hc on Temperature is given by

$$H_c\,(T) = H_{c0}\,[1 - [\frac{T}{T_C}]\,^2] \qquad (3.3)$$

Where H_{c0} is the value of the critical magnetic field at zero temperature [24].

3.4.7 Critical current:

Superconductive state is destroyed by magnetic field. Consider a straight wire. Since electric current in the:

$$H = \frac{\mu_{0I}}{2\pi r} \qquad (3.4)$$

The wire can carry maximum superconductive Current,I_c, corresponding to the critical magnetic field H_c at the surface of the wire, r = R

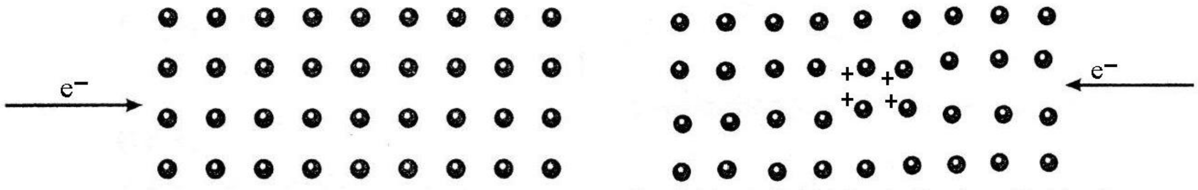
$$I_c = \frac{2\pi R H_c}{\mu_0} \qquad (3.5)$$

μ_0= 4π 10^{-7}Tm/A is the magnetic permeability of free space.

3.5 BCS Theory:

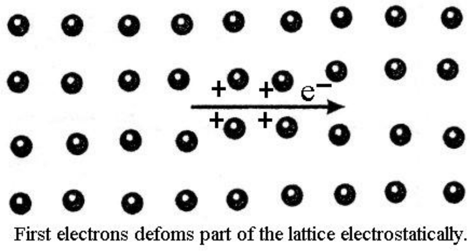
In 1957 scientists began to unlock the mysteries of superconductors. Three Cooper, and Robert Schrieffer, developed a model that has since stood as a good mental picture of why superconductors behave as they do. The model is expressed in terms of advanced ideas of the science of quantum mechanics, but the main idea of the model |suggests that electrons in a superconductor condense into a quantum ground state and travel together collectively and coherently. In 1972, Bardeen, Cooper, and Schrieffer received the Nobel Prize in Physics for their theory of superconductivity, which is now known as the BCS theory, after the initials of their last names [23].In 1986, Georg Bednorz and Alex Müller, working at IBM in Zurich Switzerland, were experimenting with a particular class of metal oxide ceramics called perovskites. Bednorz and Müller surveyed hundreds of different oxide compounds. Working with ceramics of lanthanum, barium, copper, and oxygen they found indications of superconductivity at 35 K, a startling 12 K above the old record for a superconductor. Soon researchers from_ around the world would be working with the new types of superconductors. In February of 1987, a perovskite ceramic material was found to superconduct at 90 K. This discovery was very significant because now it became possible to use liquid nitrogen as a coolant. Because these materials superconduct at significantly higher temperatures they are referred to as High Temperature Superconductors. Since then scientists have experimented with many different forms of perovskites producing compounds that superconduct at temperatures over 130 K. Currently, many governments, corporations and universities are investing large sums of money for research in High Temperature Superconductors. The ease of cooling new superconductors has greatly influenced vast efforts in the development of new materials, material fabrication, and changing theory of the behavior of superconductors at relatively high temperatures. In addition, electrical wer applications for the high temperature superconductors are expected to now be practical, thanks to the increased machine reliability and decreased cost associated with the cooling of such devices at now beginning[28].

3.6 Cooper pair:



First electron approach a section of the crystal lattice

Second electron is attracted to the net positive charge of the deformation



First electrons defoms part of the lattice electrostatically.

Figure(3.8). Classical description of the coupling of a Cooper pair.

According to classical physics, part of the resistance of a metal is due to collisions between free electrons and the crystal lattice’s vibrations, known as phonons[20].An electron passes through the lattice and the positive ions are attracted to it, causing a distortion in their nominal positions. The second electron (the Cooper pair partner) comes along and is attracted by the displaced ions. Note that this second electron can only be attracted to the lattice distortion if it comes close enough before the ions have had a chance to return to their equilibrium positions. The net effect is a weak delayed attractive force between the two electrons[28]. This short lived distortion of the lattice is sometimes called a virtual phonon because its lifetime is too short to propagate through the lattice like a wave as a normal phonon would. From the BCS theory, the total linear momentum of a Cooper pair must be zero. This means that they travel in opposite directions as shown in Figure 8. In addition, the nominal separation between the Cooper pair (called the coherence length) ranges from hundreds to thousands of ions separating them! This is quite a large distance and has been represented incorrectly in many textbooks on this subject. If electrons in a Cooper pair were too close, such as a couple of atomic spacings apart; the electrostatic (coulomb) repulsion will be much larger than the attraction from the lattice deformation and so they will repel each other. Thus there will be no superconductivity [20]. A current flowing in the superconductor just shifts the total moment slightly from zero so that, on average, one electron in a cooper pair has a slightly directions. The interaction between a Cooper pair is transient. Each electron in the pair goes on to form a Cooper pair with other electrons, and this process continues with the newly formed Cooper pair so that each electron goes on to form a Cooper pair with other electrons. The end result is that each electron in the solid is attracted to every other electron forming a large network of interactions. Causing just one of these electrons to collide and scatter from atoms in the lattice means the whole network of electrons must be made to collide into the lattice, which is energetically too costly. The collective behaviour of all the electrons in the solid prevents any further collisions with the lattice. Nature prefers situations that spend a minimum of energy. In this case, the minimum energy situation is to have no collisions with the lattice. A small amount of energy is needed to destroy the superconducting state and make it normal. This energy is called the energy gap [29].Although a classical description of Cooper pairs has been given here, the formal treatment from the BCS theory is quantum mechanical. The electrons have wave-like behaviour and are described by a wave function that extends throughout the solid and overlaps with other electron wave functions. As a result, the whole network of electrons behaves line one wave function so that their collective motion is coherent. In addition to having a linear momentum, each electron behaves as if it is spinning. This property, surprisingly, is called spin. This does not mean that the electron is actually spinning, but behaves as though it is spinning. The requirement from the BCS theory is that spins of a Cooper pair be in opposite directions [20].

3.7 Applications of superconductors:

1-Magnetic resonance imaging:

The first large scale commercial application of superconductivity was in magnetic resonance imaging (MRI). This is a non-intrusive medical imaging technique that creates a two-dimensional picture of say tumors and other abnormalities within the body or brain. This requires a person to be placed inside a large and uniform electromagnet with a high magnetic field. Although normal electromagnets can be used for this purpose, because of resistance they would dissipate a great deal of heat and have large power requirements[20,18].

2-Device SQUID:

Superconductors can also be used to make a device known as a superconducting quantum interference device (SQUID). This is incredibly sensitive to small magnetic fields so that it can detect the magnetic fields from the heart (10^{-10}Tesla) and even the brain (10^{-13}Tesla). For comparison, the Earth’s magnetic field is about 10^{-4}Tesla. As a result, SQUIDs are used in non-intrusive medical diagnostics on the brain [20].

3-Scientific research:

The traditional use of superconductors has been in scientific research where high magnetic field electromagnets are required. The cost of keeping the superconductor cool are much smaller than the cost of operating normal electromagnets, which dissipate heat and have high power requirements. One such application of powerful electromagnets is in high energy physics where beams of protons and other particles are accelerated to almost light speeds and collided with each other so that more particles are produced. It is expected that this research will answer fundamental questions such as those about the origin of the mass of particles that make up the Universe.

4-Energy source:

A use of large and powerful superconducting electromagnets is in a possible future energy source known as nuclear fusion. When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion. This results in the release of large amounts of energy without any harmful waste. Two isotopes of in ordinary water and tritium can be made during the nuclear fusion reactions from another abundantly available element – lithium. For this reason it is called clean nuclear energy. For this reaction to occur, the deuterium and tritium gases must be heated to millions of degrees so that they become fully ionized. As a result, they must be confined in space so that they do not escape while being heated. Powerful and large electromagnets made from superconductors are capable of confining these energetic ions. An international fusion energy project, known as the International Thermonuclear Experimental Reactor (ITER) is currently being built in the south of France that will use large superconducting magnets and is due for completion in 2017. It is expected that this will demonstrate energy production using nuclear fusion[20].

5-Magnetic trains Alastervaa:

Levitating trains have been built that use powerful electromagnets made from superconductors. The superconducting electromagnets are mounted on the train. Normal electromagnets, on a guideway beneath the train, repel (or attract) the superconducting electromagnets to levitate the train while pulling it forwards[20].

Chapter Four

Methodology and Practical

4.1 Introduction:

The resistance-change factor per degree Celsius of temperature change is called the temperature coefficient of resistance. This factor is represented by the Greek lower-case letter “alpha” (α). The resistance of all substances varies with temperature. This temperature resistance dependence has a bearing on electronic circuits in many ways. In most cases the resistance increases with temperature, but in some it falls. As a result it is often necessary to have an understanding of the resistance temperature dependence.

4.2 The Purpose:

Calculating the thermal coefficient of resistance and the Specific resistivity of copper wire.

4.3 Equipment and Materials:

Standard Resistance of ($S = 1\Omega$) , Galvanometer (G) , DC power supply , 2 holders, thermometer, calorimeter, heater, Welding wire, Wheatstone bridge(1m), copper coil , micrometer.

4.3.1Copper:

4.3.1.1 Copper is a Metallic Element:

Elements are the building blocks of our planet and copper is one of 94 naturally occurring elements. It is a metallic material with a distinct red-orange colour and metallic luster. Its Atomic Number is 29, Atomic Mass is 63.546 and its symbol is Cu. Copper is a relatively abundant element. It is estimated copper atoms comprise 22 parts per million [ppm] of the Earth’s crust making it the 8th most abundant metal. This translates to 68 ppm by weight. However, sometimes geological processes concentrate copper into ore deposits where it may be present in sulphide minerals or secondary minerals that result in copper yields of up to 1% of the host rock minerals[30].

4.3.1.2 Properties of copper:

Copper is essential to the functioning of society and has played several important roles in society for thousands of years. It is present in almost every modern household item that uses electricity. Copper is a soft, malleable and ductile metal. This means it can be beaten into thin sheets, can be drawn out into thin wires and made into pipes. Copper readily form compounds and while it does oxidize or tarnish it does not do so as readily as other metals.Copper is a good conductor of heat and electricity. It is a better conductor than most metals. Silver is a better electrical conductor but copper has better corrosion resistance and is a more abundant and hence cheaper material to use. Over half the global copper production goes into electrical wiring of some kind. Copper’s heat conduction and corrosion resistance properties also make it the metal of choice for most vehicle radiators and heat transfer units in refrigerators and air conditioners.Copper can also be joined to itself very easily. This property, along with its corrosion resistance, strength and abundance has made copper the number one material used in modern household water piping and associated plumbing [30].

4.3.1.3 Physical properties of copper:

These copper properties can enhance with variations in composition and manufacturing methods. These copper properties can enhance with variations in composition and manufacturing methods.

- **Electrical conductivity**: copper has the highest conductivity of the engineering metals .You can add elements such as silver or other to increase strength, softening resistance or other properties without a significant loss of conductivity.

- **Thermal conductivity:** this property is similar to electrical conductivity. It can be used as alloys of copper for this property, which offset the good resistance to corrosion and serious resistance to loss of conductivity with increased alloying.
- **Color and Appearance**: many copper alloys have a distinctive color, which may vary with the circumstances of the body. For most alloys, it is easy to prepare and keep the surface level, even in adverse corrosion conditions .It uses many of the alloys in decorative applications, both in its original form or after metal plating. Alloys have specific colors, ranging from copper salmon pink m yellow, gold, bronze or Alokhaddrvi the circumstances. Exposure to the atmosphere can produce a green or bronze surface, and alloy pre-slitter is available in some picture production.
- **Corrosion resistance**: all copper alloys resist corrosion by fresh water and steam.
- **It can be restored by annealing flexibility**: it can be done either by a specific annealing process or by incidental annealing through welding procedures [30].

4.3.2 Welding wire:

4.3.2.1 Welding wire components:

Tin is the means available to connect electronic components together due to his conductivity to an electrical outlet and the softness and ease of configuration and the possibility mixed with other ores has been used in ancient times to whiten copper as it is with the copper alloy bronze very solid that cannot be easily removed and to be used in the manufacture of electrons added to several other ores typically uses welding wire consists of tin and lead by 60% tin and 40% lead where tin alloy welding work of the lead is to increase the hardness of the alloy so as not to facilitate the decoding of welding by hand because of the softer tin free. And be the melting point of the 188m wire. When this wire is used in the private mail welding professionals have added substance Filx FLUX is either organic or an equivalent chemical compound is used to get rid of the existing oxides on the edge of the element to be welded and prevents oxidation of the welding point after that. And insert material Filx (zinc chloride or potassium florins with or similar boric acid salts), equivalent to 2% of the weight of the wire in the middle to become the lead 38% is used for soldering electronic pieces such as an initial resistors and transistors regular Almtalat[31].

4.3.2.2 Thickness of the solder wire:

There is a direct correlation between the welding point size and thickness of the solder wire is a girth weld one wire mm suitable for most technical welds as this size small when welding thick parties such as the parties to the lighting adapter and need welding wire in size 1.2 mm but technician can control it easily. And it is also considered significant when welding close to the parties to complete the legs and we need to thickness of 0.8 mm and also a technician can control if investigated the accuracy of the work. And the rest of the business did easily with a size of 1 mm, so this is an appropriate size for the technical maintenance of radio and television [31].

4.3.2.3 Quality of the welding wire:

When looking at the welding wire components observes that the more tin and say bullets needed less heat and increased softness wire and therefore simply touching the wire by hand can figure out the wire quality depending on the Aonth where leniency evidence of increased tin content and this does not require a lot of experience, where you can compare the wire content with questionable wire as well as the clear difference when conducting welding operations where good corps be manageable at work and does not require a lot of heating any point that the work of welding wire good takes less time than using wire is good. Shows more evident when removing welding using either Ahaaft or using veiled welding wire, we find that was good malleable wire plain jaw while containing a high concentration of lead will damage the printed panel to the intensity of his need for heat[31].

4.3.3 Wheatstone bridge:

Wheatstone bridge is one of the important constituencies, and the primary purpose of the use is to measure resistances ranging values from 1 ohm to 1 mega - ohm, and to measure the change in temperature through thermal resistance [32].

4.4 Theory:

$$\mathrm{R_t = R_0(1 + \alpha t)} \tag{4.1}$$

where α can bee defined as

$$\alpha = \frac{\mathrm{R_t - R_0}}{\mathrm{R_0 t}} \tag{4.2}$$

$$\rho = \frac{A}{L} R \tag{4.3}$$

$$\rho = \frac{\pi r^2}{L} R \tag{4.4}$$

Were:

$\mathrm{R_t}$ ≡The metal resistance at a temperature t/°C.

$\mathrm{R_0}$ ≡ The metal resistance at a temperature 0/°C.

α ≡ Thermal coefficient.

t ≡ Temperature.

ρ ≡ Resistivity.

L ≡ Length of the wire.

A ≡ Cross Sectional area.

r ≡ The radius of the wire.

4.5 The Procedure:

The circuit was connected as shown in figure (4.1) then heater has been switched on to 100 degree Celsius. using wheatstone bridge the current was set at zero balance .Then as the temperature increases the (G) starts to lead .L_1 represents the legth between the wire at wheatstone bridge and the Known resistance (1Ω) and L_2 represents the length between the wheatstone bridge wire and the unknown resistant of the these wires. The unknown resistance. Calculated for different temperature in cooling manner the result has been tabulated as in table (4.1) the previous steps were repeated by taking 15cm of coated Cu wire by welding as in table (4.2) and then 50cm has been coated by the same way in table (4.3) .the resistivity has been calculated for all samples. The relation between obtained resistances R (T) and temperature T is plotted as in figures (4.2), (4.3) and (4.4).

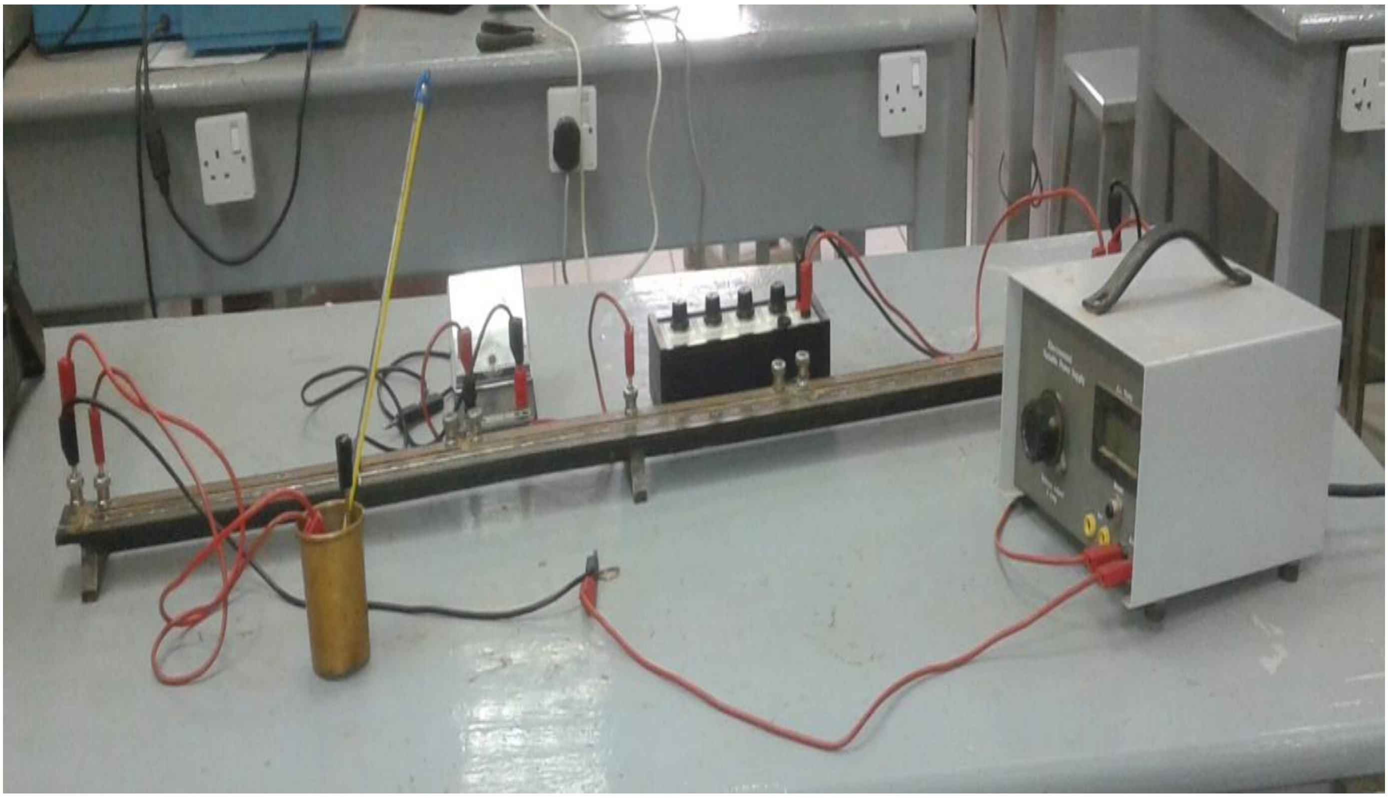


Figure (4.1) The circuit diagram

4.6 Results:

Table (4.1) shows the relationship between the net resistance of copper with the temperature :

T/°C	Length (L_1)/cm	Length (L_2)/cm	$R = S\frac{L_1}{L_2}/\Omega$
90	10.3	89.7	0.115
80	9.9	90.1	0.109
70	9.5	90.5	0.105
60	9.1	90.9	0.100
50	8.9	91.1	0.098
40	8.6	91.4	0.094
30	8.0	92.0	0.087

Table (4.2) shows the relationship between the resistance of the coated wire length of 15 cm with temperature:

T/°C	L_1/cm	L_2/cm	$R = S\frac{L_1}{L_2}/\Omega$
90	10.1	89.7	0.112
80	9.2	90.8	0.101
70	9.0	91.0	0.099
60	9.3	90.7	0.103
50	9.0	91.0	0.099
40	8.5	91.5	0.093
30	8.7	91.3	0.095

Table (4.3) shows the relationship between the resistance of the coated wire length of 50 cm with temperature:

T/°C	L_1/cm	L_2/cm	$R = S\frac{L_1}{L_2}/\Omega$
90	8.8	91.2	0.096
80	7.6	92.4	0.082
70	7.5	92.5	0.081
60	7.4	92.6	0.080
50	7.1	92.9	0.076
40	7.1	92.9	0.076
30	7.3	92.7	0.079

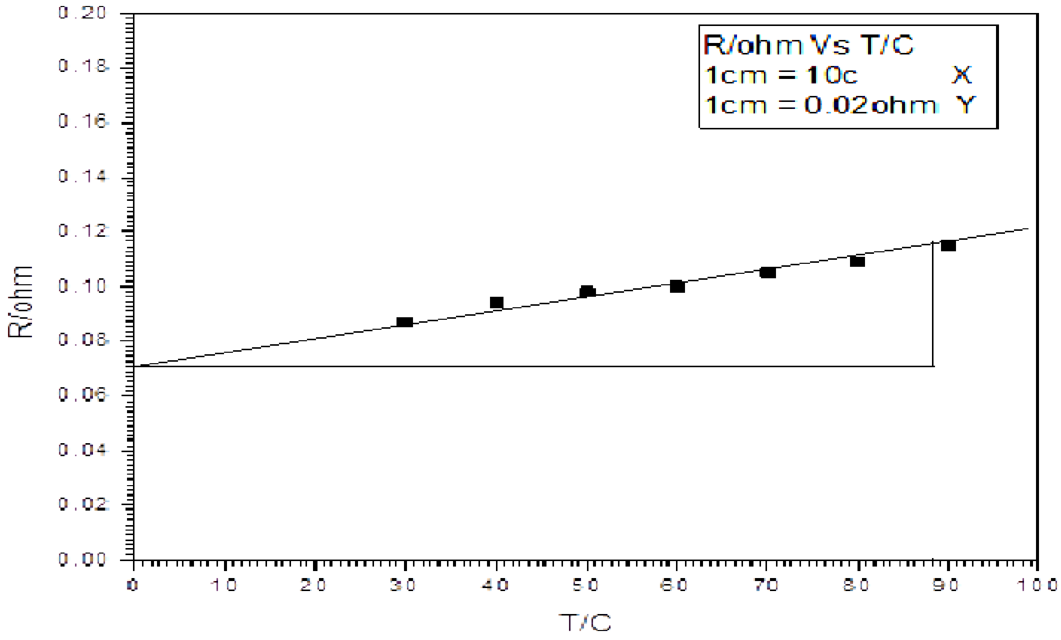


Figure (4.2) showing the relationship between the net resistance of copper with the temperature

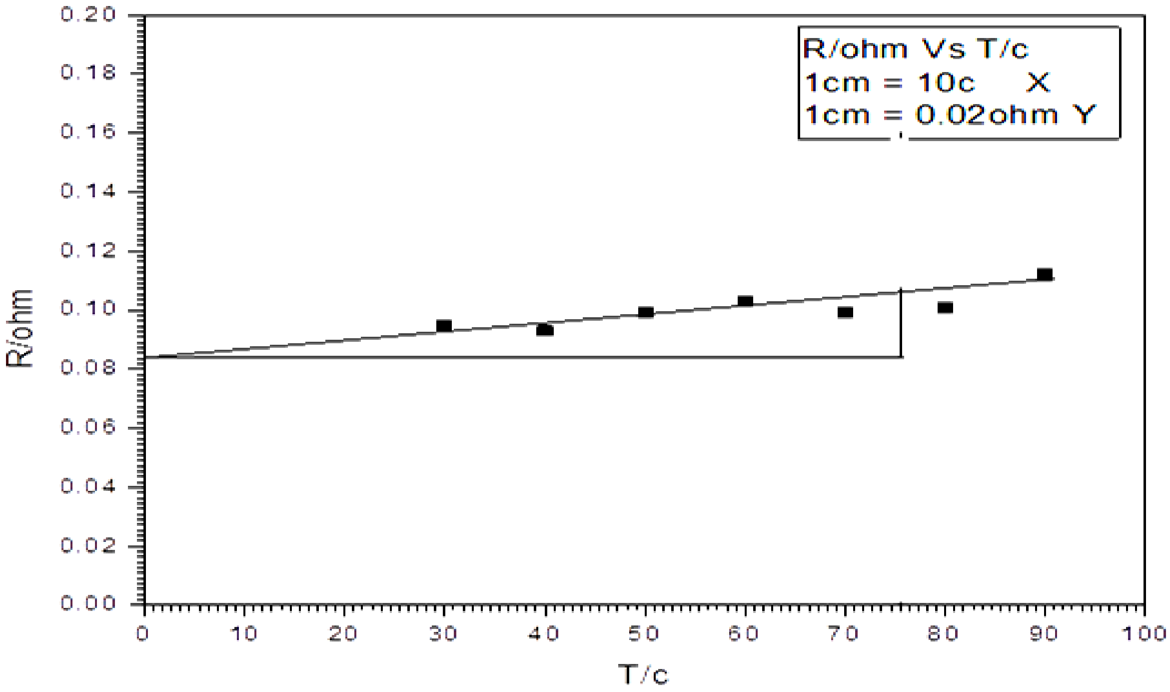


Figure (4.3) shows the relationship between the resistance of the coated wire length of 15 cm with temperature:

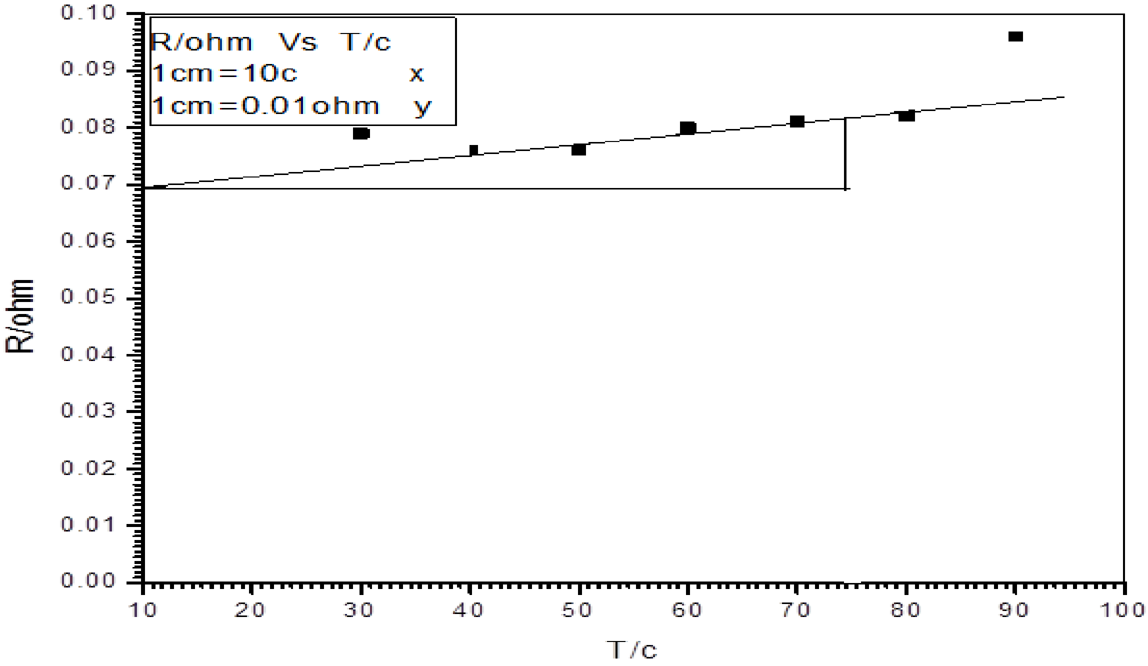


Figure (4.4) shows the relationship between the resistance of the coated wire length of 50 cm with temperature::

7.4 Calculations:

a) from equation (4.2) and graph(4.2) one can obtain:

$$\alpha = \frac{0.038}{(0.072)(88)} = 5.99 \times 10^{-3} \backslash ^{\circ}\mathrm{C}$$

And from equation (4.4)

$$\rho = \frac{\pi(0.039)^2}{50}\ (0.101) = 9.65 \times 10^{-6}\ \Omega cm$$

$$\rho = 9.65 \times 10^{-8} \Omega m$$

b) from equation (4.2) and graph(4.3) one can obtain:

$$\alpha = \frac{0.02}{(0.084)(76)} = 3.13 \times 10^{-3} \backslash ^{\circ}\mathrm{C}$$

And from equation (4.4)

$$\rho = \frac{\pi(0.0405)^2}{50}\ (0.100) = 1.03 \times 10^{-5} \Omega cm$$

$$\rho = 1.03 \times 10^{-7} \Omega m$$

c) from equation (4.2) and graph(4.4) one can obtain:

$$\alpha = \frac{0.013}{(0.069)(75)} = 2.51 \times 10^{-3} \backslash ^{\circ}\mathrm{C}$$

And from equation (4.4)

$$\rho = \frac{\pi(0.0443)^2}{50}\ (0.081) = 1.003 \times 10^{-5} \Omega cm$$

$$\rho = 1.003 \times 10^{-7} \Omega m$$

4.8 Discussion:

We note that from the results which obtained in table (4.1),(4.2)and(4.3) there is a relation between temperature and resistance . when temperature increases The resistance increases too as in figure (4.2) , (4.3) and (4.4) .

The intercept of the curves with y-axis gives the value of resistance at room temperature for each type copper wire,15cm coated with Block Soldering wire and50cm coated with Block Soldering wire respectively . The room temperature resistance is explained in table:

$R_0\backslash\Omega$	Figures
0.072	Figure (4.2)
0.084	Figure (4.3)
0.069	Figure (4.4)

From the table it is clear that the least resistance fo the 50cm coated wire while the largest value for 15cm coated.

The thermal coefficient for different wires it is slightly varied due to the weld operation has not effect in thermal conductivity of the wire. And the resistivity of wire calculated was a slight difference, due to variation in the diameter of wire. So that conductivity decreases with increasing resistivity difference.

In previous study it shows that the thermal conductivity coefficient α of the graph is calculated to be $\alpha = 0.0039/℃$ while in our study it was calculated to be $\alpha = 5.99 \times 10^{-3}$ / ℃ due to purity.

4.9 Conclusions:

From the results obtained we note that the thermal conductivity is very sensitive for temperature and the resistivity of Tree copper wires increased with increasing of temperature.

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