Chapter One

1.1 Introduction:

Materials are probably more deep-seated in our culture than most of us realize.Transportation, housing, clothing, communication, recreation, and food productionvirtually every segment of our everyday lives is influenced to one degree or anotherby materials.

Sometimes it is useful to subdivide the discipline of materials science and engineeringinto*materials science* and *materials engineering* sub disciplines. Strictly speaking, "materials science" involves investigating the relationships that exist between the structures and properties of materials. In contrast, "materials engineering" is, on the basis of these structure–property correlations, designing or engineering the structure of a material to produce a predetermined set of properties. From a functional perspective, the role of a materials scientist is to develop or synthesize new materials, whereas a materials engineer is called upon to create new products or systems using existing materials, and/or to develop techniques for processing materials. Most graduates in materials programs are trained to be both materials scientists and materials engineers.

Virtually all important properties of solid materials may be grouped into six differentcategories: mechanical, electrical, thermal, magnetic, optical, and deteriorative. For each there is a characteristic type of stimulus capable of provoking different responses Mechanical properties relates deformation to an applied load or force; examples include elastic modulus and strength. For electrical properties, such as electrical conductivity and dielectric constant, the stimulus is an electric field. The thermal behavior of solids can be represented in terms of heat capacity and thermal conductivity. Magnetic properties demonstrate the response of a material to the application of a magnetic field. For optical properties, the stimulus is electromagnetic or light radiation; index of

refraction and reflectivity are representative optical properties. Finally, deteriorative characteristics relate to the chemical reactivity of materials [1].

1.2 Objective:

Create conductor it has highelectrical conductivity (superconductor)in normal temperature.

1.3 Problem:

Create some samples of alloy cast iron and copper and study the electrical conductivity for them.

1.4 Assumptions:

Imagine all samples of alloy cast iron and copper had high electrical conductivity.

1.5 Questions:

a. How can we create the samples of alloy cast iron and copper.

i. How can we calculate electrical conductivity of samples.

m. How much the electrical conductivity of the all samples.

1.6 previous studies:

This study was forwarding by *Hana Mohamed El-hassan Ahmed Abdalla (B.Sc in science (U of K, 2004) A thesis submitted to the U of K for the degree of M.Sc in physics* Study on thermal and electrical conductivity of copper and Aluminum.

For this study shed light upon the states of material and the appearance of its coexistence in nature, and how heat and electricity pass through it. To this end, the research completed examining both Thermal characterizations through Thermal Conductivity, and Electric characterizations through Electrical Conductivity.

The study drew attention the classical free electron theory and stated the aspects of its success and failure. Moreover, the study detected the

interrelationship between Thermal Conductivity and Electrical Conductivity; this comes within Wiedmann Franz Law.

The study figured out accurately the Thermal Conductivity and Electrical Conductivity for Copper and Aluminum; the results were found to be:

[4.37 (w /K_m), 5.63× $10^7 (\Omega. m)^{-1}$], [252 (w /K_m), 3.24× $10^7 (\Omega. m)^{-1}$] Respectively in good agreement with the data found in literature.

The aim of this study is to examine the thermal and the electrical characteristics of copper and aluminum, in addition, to know the extent of thermal and electrical conductivities by calculating them[3].

1.7 Thesis Layout:

Research consists of four chapters the first chapter an introduction, Chapter two theoretical part the third chapter talks about the result and calculation, Chapter four dissections and conclusion.

Chapter Two

Theoretical part

2.1 Introduction:

Solid materials have been conveniently grouped into three basic classifications: metals, ceramics, and polymers .This scheme is based primarily on chemical makeup and atomic structure, and most materials fall into one distinct grouping or another, although there are some intermediates. In addition, there are the composites, combinations of two or more of the above three basic material classes. A brief explanation of these material types and representative characteristics is offered next .Another classification is advanced materials; those used in high-technology application. Semiconductors, biomaterials, smart materials, and Nano-engineer materials[1].

2.2 Classification of Materials:

There are different ways of classifying materials. One way is to describe five groups[1].

2.2.1 Metals:

Materials in this group are composed of one or more metallic elements (such as iron, aluminum, copper, titanium, gold, and nickel), and often also nonmetallic elements (for example, carbon, nitrogen, and oxygen) in relatively small amounts Atoms in metals, and their alloys are arranged in a very orderly manner, and in comparison to the ceramics and polymers, are relatively dense. With regard to mechanical characteristics, these materials are relatively stiff, and strong, yet are ductile (capable of large amounts of deformation without fracture), and are resistant to fracture, which accounts for their widespread use in structural applications [1].

Metallic materials have large numbers of nonlocal zed electrons; that is, these electrons are not bound to particular atoms. Manyproperties of metals are directly attributable to these electrons. For example, metals are extremely good conductors of electricity, and heat, and are not transparent to visible light; a polished metal surface has a lustrous appearance. In addition, some of the metals (Fe, Co, and Ni) have desirable magnetic properties [1].

2.2.2 Ceramics:

Ceramics are compounds between metallic and nonmetallic elements; they are most frequently oxides, nitrides, and carbides. For example, some of the common ceramic materials include aluminum oxide (or alumina, Al_2O_3), silicon dioxide (or *silica,* SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4), and, in addition, what some refer to as the *traditional ceramics*, those composed of clay minerals (i.e., porcelain), as well as cement, and glass. With regard to mechanical behavior, ceramic materials are relatively stiff and strong—stiffness's and strengths are comparable to those of the metals. In addition, ceramics are typically very hard. On the other hand, they are extremely brittle (lack ductility), and are highly susceptible to fracture. These materials are typically insulate to the passage of heat and electricity (i.e., have low electrical conductivities), and are more resistant to high temperatures and harsh environments than metals and polymers. With regard to optical characteristics, ceramics may be transparent, translucent, or opaque, and some of the oxide ceramics exhibit magnetic behavior[1].

2.2.3 Polymers:

Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements (O,N, and Si). Furthermore, they have very large molecular structures, often chain-like in natures that have a backbone of carbon atoms. Some of the common and familiar polymers are polyethylene (PE), nylon, poly

(vinyl chloride) (PVC), polycarbonate (PC), polystyrene (PS), and silicone rubber. These materials typically have low densities, whereas their mechanical characteristics are generally dissimilar to the metallic and ceramic materials they are not as stiff nor as str0ong as these other material types. However, on the basis of their low densities, many times their stiffness's and strengths on a per mass basis are comparable to the metals and ceramics. In addition, many of the polymersare extremely ductile and pliable (i.e., plastic), which means they are easily formed into complex shapes. In general, they are relatively inert chemically and unreactive in a large number of environments. One major drawback to the polymers is their tendency to soften and/or decompose at modest temperatures, which, in some instances, limits their use. Furthermore, they have low electrical conductivities and are nonmagnetic[1].

2.2.4 Composites:

A composite is composed of two (or more) individual materials, which come from the categories discussed above, metals, ceramics, and polymers. The design goalof a composite is to achieve a combination of properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials. A large number of composite types exist that are represented by different combinations of metals, ceramics, and polymers. Furthermore, some naturally-occurring materials are also considered to be composites—for example, wood and bone. However, most of those we consider in our discussions are synthetic (or man-made) composites[1].

Glass fibers are embedded within a polymeric material (normally an epoxy or polyester). The glass fibers are relatively strong and stiff (but also brittle), whereas the polymer is ductile (but also weak and flexible). Thus, the resulting fiberglass is relatively stiff, strong, flexible, and ductile. In addition, it has a low density [1].

Another of these technologically important materials is the "carbon fiberrein forced polymer" (or "CFRP") composite carbon fibers that are embedded within a polymer. These materials are stiffer and stronger than the glass fiber-reinforced materials yet they are more expensive. The CFRP composites are used in some aircraft and aerospace applications, as well as high-tech sporting equipment (bicycles, golf clubs, tennis rackets, and skis/snowboards [1].

2.3 Structure of Materials:

Materials scientists and engineers have developed a set of instruments in order to characterize the structure of materials at various length scales. We can examine and describe the structure of materials at five different levels:

2.3.1 Atomic structure:

To examine atomic structure (the nucleus consisting of protons and neutrons and the electrons surrounding the nucleus) in order to lay a foundation for understanding how atomic structure affects the properties, behavior, and resulting applications of engineering materials. We will see that the structure of atoms affects the types of bonds that hold materials together. These different types of bonds directly affect the suitability of materials for real-world engineering applications. The diameter of atoms typically is measured using the angstrom unit (Å or 10^{-10} m) [1].

2.3.2 Short and longrange atomic arrangements:

It also is important to understand how atomic structure and bonding lead to different atomic or ionic arrangements in materials. A close examination of atomic arrangements allows us to distinguish between materials that are amorphous (those that lack a long-range ordering of atoms or ions) or crystalline (those that exhibit periodic geometrical arrangements of atoms or ions.) Amorphous materials have only short-range atomic arrangements, while crystalline materials have short- and long-range atomic arrangements. In short-

range atomic arrangements, the atoms or ions show a particular order only over relatively short distances (1 to 10 Å). For crystalline materials, the long-range atomic order is in the form of atoms or ions arranged in a three-dimensional pattern that repeats over much larger distances (from _10 nm to cm.) [1].

2.3.3 Nanostructure:

Materials science and engineering is at the forefront of Nano-science and Nano-technology. Nano-science is the study of materials at the nanometer length scale, and nanotechnology is the manipulation and development of devices at the nanometer length scale. The nanostructure is the structure of a material at a length scale of 1 to 100 nm. Controlling nanostructure is becoming increasingly important for advanced materials engineering applications[1].

2.3.4 Microstructure:

The microstructure is the structure of materials at a length scale of 100 to 100,000 nm or 0.1 to 100 micrometers (often written as _m and pronounced as "microns"). The microstructure typically refers to features such as the grain size of a crystalline material and others related to defects in materials. (A *grain* is a single crystal in a material composed of many crystals)[1].

2.3.5 Macrostructure:

Macrostructure is the structures of a material at a macroscopic level where the length scale is _100 _m. Features that constitute macrostructure include porosity, surface coatings, and internal and external micro-cracks [1].

2.4 Atomic Bonding:

There are four important mechanisms by which atoms are bonded in engineered materials. These are:

2.4.1 Metallic bonds:

The metallic elements have electropositive atoms that donate their valence electrons to form a "sea" of electrons surrounding the atoms. Aluminum, for example, gives up its three valence electrons, leaving behind a core consisting of

the nucleus and inner electrons. Since three negatively charged electrons are missing from this core, it has a positive charge of three. The valence electrons move freely within the electron sea and become associated with several atom cores. The positively charged ion cores are held together by mutual attraction to the electrons, thus producing a strong metallic bond. Because their valence electrons are not fixed in any one position, most pure metals are good electrical conductors of electricity at relatively low temperatures ($\sim T < 300$ K). Under the influence of an applied voltage, the valence electrons move, causing a current to flow if the circuit is complete [2].

Metals show good ductility since the metallic bonds are non-directional. There are other important reasons related to microstructure that can explain why metals actually exhibit *lower strengths* and *higher ductility* than what we may anticipate from their bonding. Ductility refers to the ability of materials to be stretched or bent permanently without breaking. We will discuss these concepts in greater detail in Chapter 6. In general, the melting points of metals are relatively high. From an optical properties viewpoint, metals make good reflectors of visible radiation. Owing to their electropositive character, many metals such as iron tend to undergo corrosion or oxidation. Many pure metals are good conductors of heat and are effectively used in many heat transfer applications. We emphasize that metallic bonding is *one of the factors* in our efforts to rationalize the trends observed with respect to the properties of metallic materials. As we will see in some of the following chapters, there are other factors related to microstructure that also play a crucial role in determining the properties of metallic materials[2].

2.4.2 Covalent bonds:

Materials with covalent bonding are characterized by bonds that are formed by sharing of valence electrons among two or more atoms. For example, a silicon atom, which has a valence of four, obtains eight electrons in its outer energy shell by sharing its valence electrons with four surrounding silicon atoms.

Each instance of sharing represents one covalent bond; thus, each silicon atom is bonded to four neighboring atoms by four covalent bonds. In order for the covalent bonds to be formed, the silicon atoms must be arranged so the bonds have a fixed directional relationship with one another. A directional relationship is formed when the bonds between atoms in a covalently bonded material form specific angles, depending on the material. In the case of silicon, this arrangement produces a tetrahedron, with angles of 109.5° between the covalent bonds. Covalent bonds are very strong. As a result, covalently bonded materials are very strong and hard. For example, diamond (C), silicon carbide (SiC), silicon nitride (Si3N4), and boron nitride (BN) all have covalent bonds. These materials also exhibit very high melting points, which mean they could be useful for high-temperature applications. On the other hand, the high temperature needed for processing presents a challenge. The materials bonded in this manner typically have limited ductility because the bonds tend to be directional. The electrical conductivity of many covalently bonded materials (silicon, diamond, and many ceramics) is not high since the valence electrons are locked in bonds between atoms and are not readily available for conduction. With some of these materials such as Si, we can get useful and controlled levels of electrical conductivity by deliberately introducing small levels of other elements known as dopants. Conductive polymers are also a good example of covalently bonded materials that can be turned into semiconducting materials. The development of conducting polymers that are lightweight has captured the attention of many scientists and engineers for developing flexible electronic components. We

cannot simply predict whether or not a material will be high or low strength, ductile or brittle, simply based on the nature of bonding! We need additional information on the atomic, microstructure, and macros structure of the material; however, the nature of bonding does point to a trend for materials with certain types of bonding and chemical compositions [2].

2.4.3 Ionic bonds:

When more than one type of atom is present in a material, one atom may donate its valence electrons to a different atom, filling the outer energy shell of the second atom. Both atoms now have filled (or emptied) outer energy levels, but both have acquired an electrical charge and behave as ions. The atom that contributes the electrons is left with a net positive charge and is called a cation, while the atom that accepts the electrons acquires a net negative charge and is called an anion. The oppositely charged ions are then attracted to one another and produce the ionic bond. For example, the attraction between sodium and chloride ions produces sodium chloride (NaCl), or table salt [2].

2.4.4 Van der Waals bonds:

The origin of van der Waals forces between atoms and molecules is quantum mechanical in nature and a meaningful discussion is beyond the scope of this book. We present here a simplified picture. If two electrical charges $+q$ and $-q$ are separated by a distance d, the dipole moment is defined as $q \times d$.

Atoms are electrically neutral. Also, the centers of the positive charge (nucleus) and negative charge (electron cloud) coincide. Therefore, a neutral atom has no dipole moment.When a neutral atom is exposed to an internal or external electric field, the atom may become polarized (the centers of positive and negative charges separate). This creates or induces a dipole moment. In some molecules, the dipole moment does not have to be inducedit exists by virtue of the direction of bonds and the nature of atoms. These molecules are

known as polarized molecules. An example of such a molecule that has a permanently built-in dipole moment is water [2].

Molecules or atoms in which there is either an induced or permanent dipole moment attract each other. The resulting force is known as the van der Waals force. Van der Waals forces between atoms and molecules have their origin in interactions between dipoles that are induced or in some cases interactions between permanent dipoles that are present in certain polar molecules. What is unique about these forces is they are present in every material.

There are three types of van der Waals interactions, namely London forces, Keesom forces, and Debye forces. If the interactions are between two dipoles that are induced in atoms or molecules, we refer to them as London forces (carbon tetrachloride). When an induced dipole (that is, a dipole that is induced in what is otherwise a non-polar atom or molecule) interacts with a molecule that has a permanent dipole moment, we refer to this interaction as a Debye interaction. An example of Debye interaction would be forces between water molecules and those of carbon tetrachloride [2].

If the interactions are between molecules that are permanently polarized (water molecules attracting other water molecules or other polar molecules), we refer to these as Keesom interactions. The attraction between the positively charged regions of onewater molecule and the negatively charged regions of a second water molecule provides an attractive bond between the two water molecules[2].

The bonding between molecules that have a permanent dipole moment, known as the Keesom force, is often referred to as a hydrogen bond, where hydrogen atoms represent one of the polarized regions. Thus, hydrogen bonding is essentially a Keesom force and is a type of van der Waals force. The relatively strong Keesom force between water molecules is the reason why surface tension

(72 mJ/m^2 or dyne/cm at room temperature) and the boiling point of water (100°C) are much higher than those of many organic liquids of comparable molecular weight (surface tension~20 to 25 dyne/cm, boiling points up to 80°C) [2].

Note that van der Waals bonds are secondary bonds, but the atoms within the molecule or group of atoms are joined by strong covalent or ionic bonds. Heating water to the boiling point breaks the van der Waals bonds and changes water to steam, but much higher temperatures are required to break the covalent bonds joining oxygen and hydrogen atoms [2].

Although termed "secondary," based on the bond energies, van der Waals forces play a very important role in many areas of engineering. Van der Waals forces between atoms and molecules play a vital role in determining the surface tension and boiling pointsof liquids. In materials science and engineering, the surface tension of liquids and the surfaceenergy of solids come into play in different situations. For example, when we want to process ceramic or metal powders into dense solid parts, the powders often have to be dispersed in water or organic liquids. Whether we can achieve this dispersion effectively depends upon the surface tension of the liquid and the surface energy of the solid material. Surface tension of liquids also assumes importance when we are dealing with processingof molten metals and alloys (casting) and glasses [2].

Van der Waals bonds can dramatically change the properties of certain materials. Forexample; graphite and diamond have very different mechanical properties. In manyplastic materials, molecules contain polar parts or side groups (cotton or cellulose,PVC, Teflon). Van der Waals forces provide an extra binding force between the chains of these polymers [2].

Polymers in which van der Waals forces are stronger tend to be relatively stiffer andexhibit relatively higher glass transition temperatures (T_g). The glass

transition temperature is a temperature below which some polymers tend to behave as brittle materials (they show poor ductility) [2].

As a result, polymers with van der Waals bonding (in addition to the covalent bonds in the chains and side groups) are relatively brittle at room temperature (PVC). In processing such polymers, they need to be "plasticized" by adding other smaller polar molecules that interact with the polar parts of the long polymer chains, thereby lowering the T_g and enhancing flexibility [2].

2.4.5 Mixed Bonding:

In most materials, bonding between atoms is a mixture of two or more types. Iron, for example, is bonded by a combination of metallic and covalent bonding that prevents atoms from packing as efficiently as we might expect.

Compounds formed from two or more metals (intermetallic compounds) may be bonded by a mixture of metallic and ionic bonds, particularly when there is a large difference in electronegativity between the elements. Because lithium has an electronegativity of 1.0 and aluminum has an electronegativity of 1.5, we would expect Al_3Li to have a combination of metallic and ionic bonding. On the other hand, because both aluminum and vanadium have electronegativity's of 1.5, we would expect Al3V to be bonded primarily by metallic bonds[2].

2.5 Crystal Solid:

The properties of some materials are directly related to their crystal structures. For example, pure and unreformed magnesium and beryllium, having one crystal structure, are much more brittle (fracture at lower degrees of deformation) than are pure and unreformed metals such as gold and silver that have yet another crystal structure[1].

Furthermore, significant property differences exist between crystalline and noncrystalline materials having the same composition. For example, noncrystalline ceramics and polymers normally are optically transparent; the

same materials in crystalline (or semi-crystalline) form tend to be opaque or, at best, translucent [1].

2.5.1 Fundamental Concepts:

Solid materials may be classified according to the regularity with which atoms or ions are arranged with respect to one another. A crystalline material is one in which the atoms are situated in a repeating or periodic array over large atomic distances; that is, long-range order exists, such that upon solidification, the atoms will position themselves in a repetitive three-dimensional pattern, in which each atom is bonded to its nearest-neighbor atoms. All metals, many ceramic materials, and certain polymers form crystalline structures under normal solidification conditions [1].

Some of the properties of crystalline solids depend on the crystal structure of the material, the manner in which atoms, ions, or molecules are spatially arranged. There is an extremely large number of different crystal structures all having long-range atomic order; these vary from relatively simple structures for metals to exceedingly complex ones, as displayed by some of the ceramic and polymeric materials. The present discussion deals with several common metallic crystal structures [1].

When describing crystalline structures, atoms (or ions) are thought of as being solid spheres having well-defined diameters. This is termed the *atomic hard spheremodel* in which spheres representing nearest-neighbor atoms touch one another. An example of the hard sphere model for the atomic arrangement found in some of the common elemental metals In this particular case all the atoms are identical. Sometimes the term lattice is used in the context of crystal structures; in this sense "lattice" means a three-dimensional array of points coinciding with atom positions (or sphere centers) [1].

2.5.2 Unit Cells:

The atomic order in crystalline solids indicates that small groups of atoms form a repetitive pattern. Thus, in describing crystal structures, it is often convenient to subdivide the structure into small repeat entities called unit cells. Unit cells for most crystal structures are parallelepipeds or prisms having three sets of parallel faces; one is drawn within the aggregate of spheres , which in this case happens to be a cube. A unit cell is chosen to represent the symmetry of the crystal structure, wherein all the atom positions in the crystal may be generated by translations of the unit cell integral distances along each of its edges. Thus, the unit cell is the basic structural unit or building block of the crystal structure and defines the crystal structure by virtue of its geometry and the atom positions within. Convenience usually dictates that parallelepiped corners coincide with centers of the hard sphere atoms. Furthermore, more than a single unit cell may be chosen for a particular crystal structure; however, we generally use the unit cell having the highest level of geometrical symmetry [1].

2.5.3 Metallic Crystal Structures:

The atomic bonding in this group of materials is metallic and thus nondirectional in nature. Consequently, there are minimal restrictions as to the number and position of nearest-neighbor atoms; this leads to relatively large numbers of nearest neighbors and dense atomic packing for most metallic crystal structures. Also, for metals, using the hard sphere model for the crystal structure, each sphere represents an ion core. Three relatively simple crystal structures are found for most of the common metals: face centered cubic, body-centered cubic and hexagonal close-packed [1].

2.5.3.1 The Face-Centered Cubic Crystal Structure (FCC):

The crystal structure found for many metals has a unit cell of cubic geometry, with atoms located at each of the corners and the centers of all the cube faces. It is aptly called the face-centered cubic (FCC) crystal structure.

Some of the familiar metals having this crystal structure are copper; aluminum, silver, and gold. These spheres or ion cores touch one another across a face diagonal; the cube edge length a and the atomic radius R:

$$a = 2R\sqrt{2} \tag{2.1}$$

For the FCC crystal structure, each corner atom is shared among eight unit cells, whereas a face-centered atom belongs to only two. Therefore, one-eighth of each of the eight corner atoms and one-half of each of the six face atoms, or a total of four whole atoms, may be assigned to a given unit cell [1].

Corner and face positions are really equivalent; that is, translation of the cube corner from an original corner atom to the center of a face atom will not alter the cell structure.Two other important characteristics of a crystal structure are the coordination number and the atomic packing factor (APF). For metals, each atom has the samenumber of nearest-neighbor or touching atoms, which is the coordination number.For face-centered Cubic's, the coordination number is 12.The APF is the sum of the sphere volumes of all atoms within a unit cell (assumingthe atomic hard sphere model) divided by the unit cell volume—that is

$$APF = \frac{volume\ of\ atoms\ in\ a\ unit\ cell}{total\ unit\ cell\ volume} \tag{2.2}$$

For the FCC structure, the atomic packing factor is 0.74, which is the maximum packing possible for spheres all having the same diameter. Computation of this APF is also included as an example problem. Metals typically have relatively large atomic packing factors to maximize the shielding provided by the free electron cloud [1].

2.5.3.2 The Body-Centered Cubic Crystal Structure (BCC):

Another common metallic crystal structure also has a cubic unit cell with atoms located at all eight corners and a single atom at the cube center. This is called a body-centered cubic (BCC)crystal structure. Center and corner atoms touch one another along cube diagonals, and unit cell length $a$and atomic radius R:

$$a = \frac{4R}{\sqrt{3}}$$
(2.3)

Two atoms are associated with each BCC unit cell: the equivalent of one atom from the eight corners, each of which is shared among eight unit cells, and the single center atom, which is wholly contained within its cell. In addition, corner and center atom positions are equivalent. The coordination number for the BCC crystal structure is 8; each center atom has as nearest neighbors its eight corner atoms. Since the coordination number is less for BCC than FCC, so also is the atomic packing factor for BCC lower—0.68 versus 0.74 [1].

2.5.3.3 The Hexagonal Close-Packed Crystal Structure (HCP):

Not all metals have unit cells with cubic symmetry; the final common metallic crystal structure to be discussed has a unit cell that is hexagonal.

The top and bottom faces of the unit cell consist of six atoms that form regular hexagons and surround a single atom in the center. Another plane that provides three additional atoms to the unit cell is situated between the top and bottom planes. The atoms in this mid-plane have as nearest neighbors atoms in both of the adjacent two planes. The equivalent of six atoms is contained in each unit cell; one-sixth of each of the 12 top and bottom face corner atoms, one-half of each of the 2 center face atoms, and all 3 mid-plane interior atoms.The coordination number and the atomic packing factor for the HCP crystal structure are the same as for FCC: 12 and 0.74, respectively. The HCP metals include cadmium, magnesium, titanium, and zinc [1].

2.6 The electrical conductivity:

By applying an electric field E to the metal every electron will be acted upon by a force. This force may act so as either to increase or decrease the magnitude of the velocity of the electron[4]:

$$F = -Ee$$
(2.4)

Ohm's law: voltage = current x resistance

$$R = \frac{V}{I} \tag{2.5}$$

To make the terms independent of shape and length we relate the current density J to the electric field E. consider a piece of metal with a uniform cross-sectional area A and length l. Then we can state Ohm's law in terms of the shape independent conductivityσ:

$$\mathbf{J} = \sigma E \tag{2.6}$$

$$\mathbf{J} = \frac{I}{A} \tag{2.7}$$

$$\mathbf{E} = \frac{V}{L} \tag{2.8}$$

I,V are current and voltage respectively

Substitute equations (2.7) and (2.8) into equation (2.6):

$$\therefore \sigma = \frac{IL}{AV} \tag{2.9}$$

from Ohm's law The electrical conductivity[5]:

$$\therefore \sigma = \frac{L}{A\mathbf{R}} \tag{2.10}$$

Chapter Three

Result and calculation

3.1 Introduction:

In this chapter we tacked readable for all samples and calculateresistance by ohm's law after that calculate the value of electrical conductivity.

3.2 Instruments:

- Power supply.
- Voltmeter.
- Ammeter.
- Amplifier (10^4).
- Samples.

3.3 Methodology and experimental procedures:

We tacked readable (volte, current) and charting the relationship and calculate the slope (resistance), we but the value of amplifier,after that calculate the value of electrical conductivity.

3.4Results and calculation:

3.4.1 Sample one

Table (3.1): the value of current and voltage for sample one

I(A) ±0.1	V(v)) ±0.003
0.3	0.024
0.6	0.054
0.9	0.069
1.2	0.096
1.4	0.112

Calculations:

The circuit of the experiment is Ohm's (except the amplification that is used to amplify the voltage 10^4 to make it readable by a digital multimeter).

Linear regression through the origin for Fig (3.1) , from Ohm's law:

$$R=V/I$$

∴the resistance of Alloy is calculated to be:

$R=0.024/0.32 =0.075\times 10^{-4}$

$R=7.5\times 10^{-6}\Omega$

The electrical conductivity is determined by resistance R of the Alloy and its geometric dimensions (L=0.055m, A=$0.15\times 10^{-4}m^2$). By using:

$$\sigma=\frac{L}{AR}$$

$$\sigma_1=\frac{0.055}{0.15\times10^{-4}\times7.5\times10^{-6}}=48.889\times 10^7 (\Omega.\,m)^{-1}$$
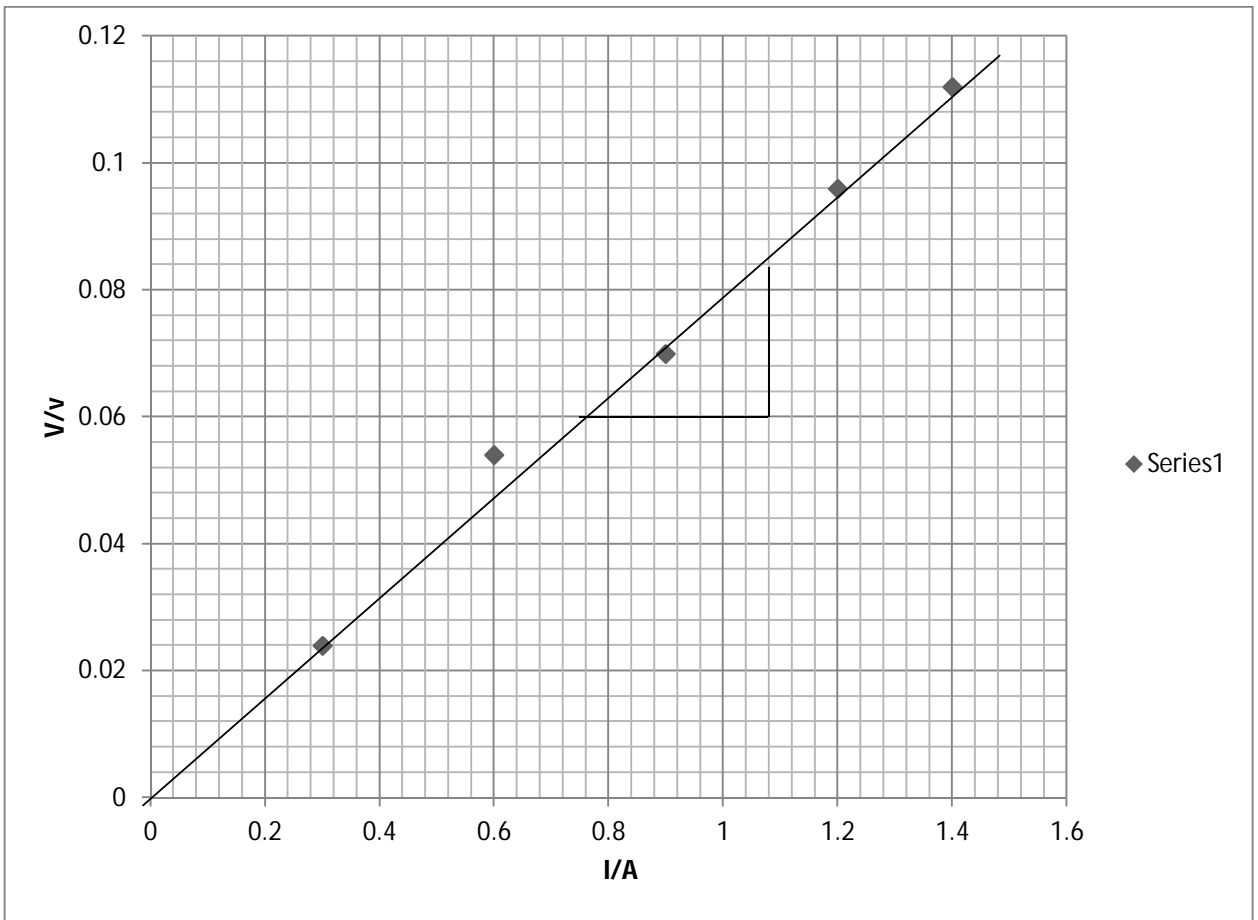
Figure (3.1): Current and voltage for the Sample one

3.4.2 Sample Two

Table (3.2): the value of current and voltage for sample Two

I(A)	V(v))
$\pm$0.1	$\pm$0.003
0.3	0.024
0.6	0.069
0.9	0.090
1.2	0.099
1.4	0.117

Calculations:

The circuit of the experiment is Ohm's (except the amplification that is used to amplify the voltage 10^4 to make it readable by a digital multimeter).

Linear regression through the origin for Fig (3.2) , from Ohm's law:

$$R=V/I$$

∴the resistance of Alloy is calculated to be:

R=0.02/0.2 =0.10$\times 10^{-4}$

R=10.0$\times 10^{-6}\Omega$

The electrical conductivity is determined by resistance R of the Alloy and its geometric dimensions (L=0.077m, A=8.74$\times 10^{-4}m^2$). By using:

$$\sigma=\frac{L}{A R}$$

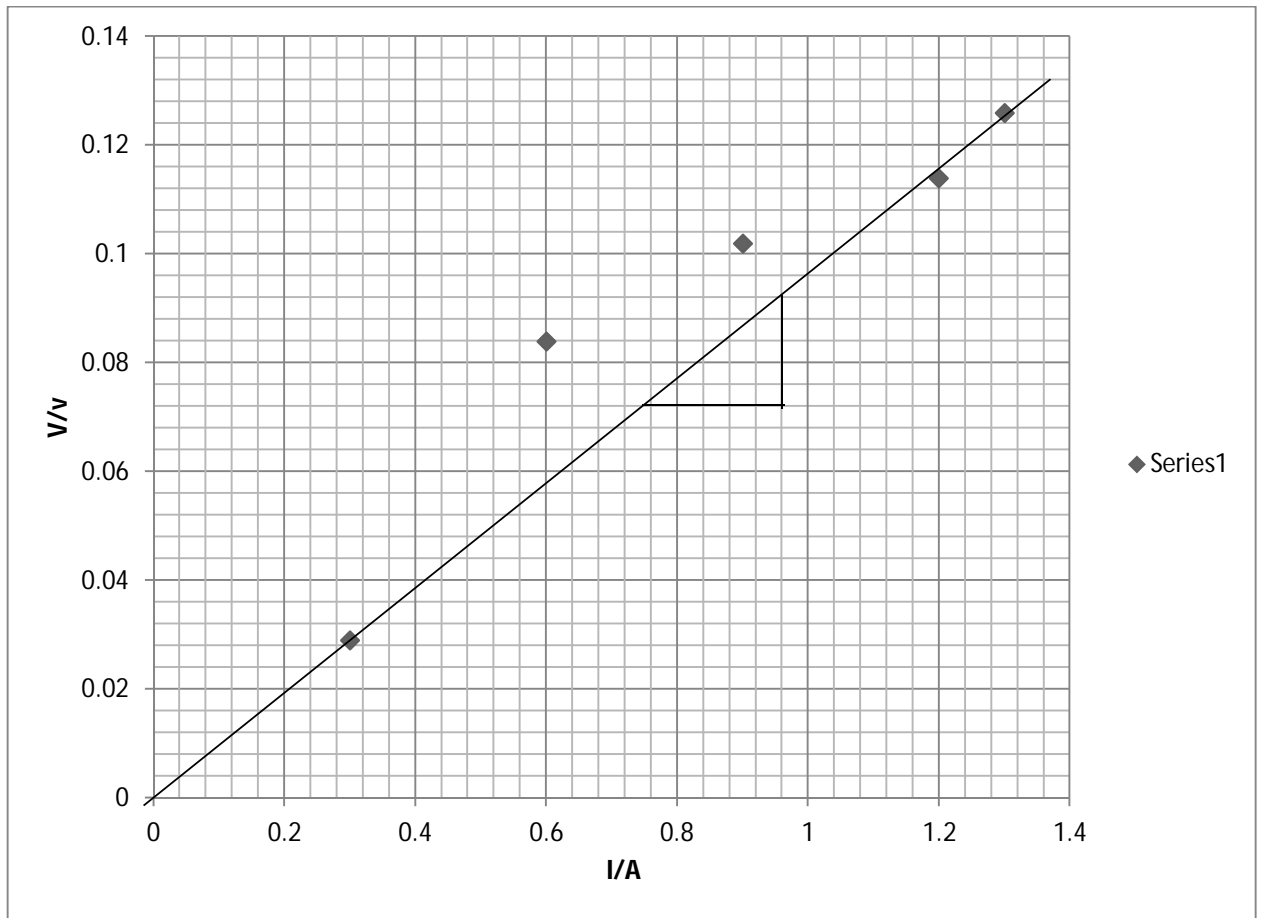$\sigma_2=\dfrac{0.077}{8.74\times10^{-4}\times10.0\times10^{-6}}$ =0.881$\times 10^7 (\Omega.\,m)^{-1}$

Figure (3.2): Current and voltage for the Sample Two

3.4.3 Sample Three

Table (3.3): the value of current and voltage for sample Three

I(A)	V(v))
±0.1	±0.003
0.3	0.096
0.6	0.186
0.9	0.270
1.2	0.411
1.4	0.423

Calculations:

The circuit of the experiment is Ohm's (except the amplification that is used to amplify the voltage 10^4 to make it readable by a digital multimeter).

Linear regression through the origin for Fig (3.3) , from Ohm's law:

$$R = V/I$$

∴the resistance of Alloy is calculated to be:

R=0.08/0.24 =0.3333× 10^{-4}

R=33.33× 10^{-6} Ω

The electrical conductivity is determined by resistance R of the Alloy and its geometric dimensions (L=0.083m, A=7.04× $10^{-4} m^2$). By using:

$$\sigma = \frac{L}{AR}$$

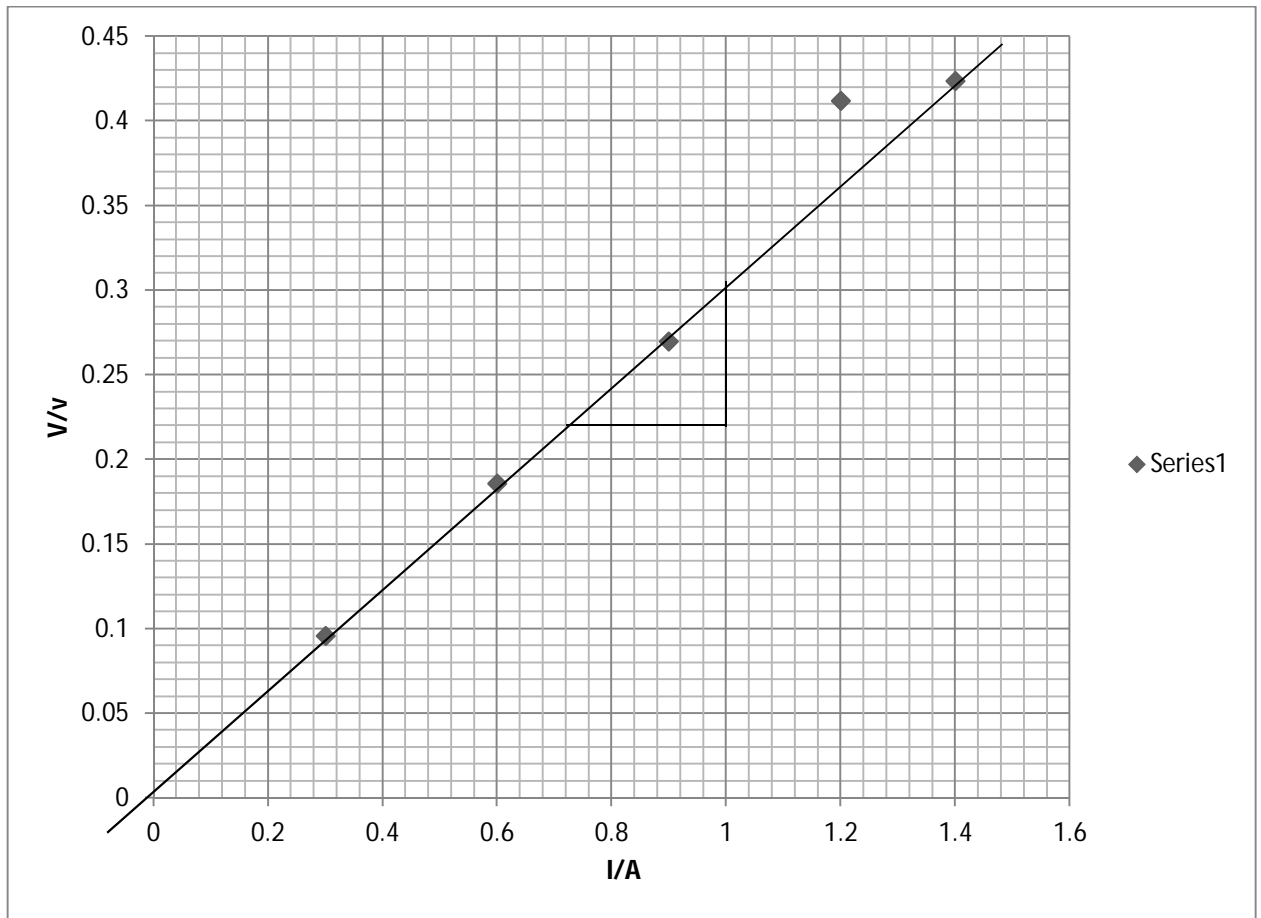$\sigma_3 = \frac{0.083}{7.04×10^{-4}×33.33×10^{-6}} = 0.3537× 10^7 (Ω.m)^{-1}$

Figure (3.3): Current and voltage for the Sample Three

3.4.4 Sample Four

Table (3.4): the value of current and voltage for sample Four

I(A)	V(v))
$\pm$0.1	$\pm$0.003
0.3	0.030
0.6	0.084
0.9	0.102
1.2	0.114
1.3	0.126

Calculations:

The circuit of the experiment is Ohm's (except the amplification that is used to amplify the voltage 10^4 to make it readable by a digital multimeter).

Linear regression through the origin for Fig (3.4) , from Ohm's law:

$$R=V/I$$

$\therefore$the resistance of Alloy is calculated to be:

R=0.036/0.36 =0.10$\times$ 10^{-4}

R=10.0$\times$ $10^{-6}\Omega$

The electrical conductivity is determined by resistance R of the Alloy and its geometric dimensions (L=0.046m, A=9.36$\times$ $10^{-4}m^2$). By using:

$$\sigma=\frac{L}{AR}$$

$\sigma_4=\frac{0.046}{9.36\times10^{-4}\times10.0\times10^{-6}}$ =0.4915$\times$ $10^7 (\Omega.\,m)^{-1}$
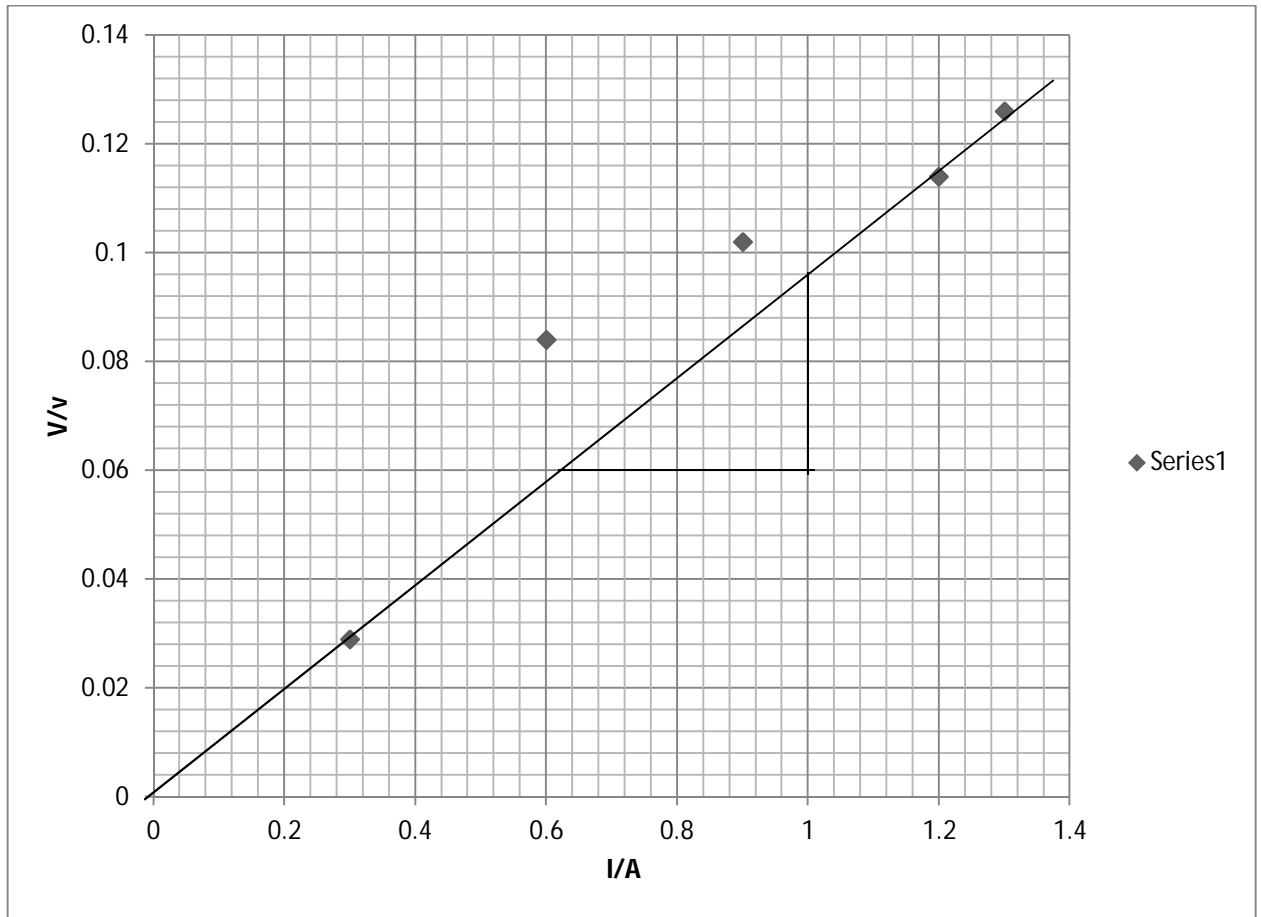
Figure (3.4): Current and voltage for the Sample Four

3.4.5 Average of the electrical conductivity:

The average of the electrical conductivity is given by:

$$\sigma_{average} = \frac{\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4}{4}$$

$$\sigma_{average} = \frac{(48.889 + 0.881 + 0.3537 + 0.4915)}{4} \times 10^7 = 12.65 \times 10^7 \, (\Omega.m)^{-1}$$

Chapter Four

Discussion and Conclusion

4.1 Discussion

The electrical conductivity depends on resistant R and length of conductor L and cross section area A.

In this study we create alloy of cast iron with copper, we remarking in sample one has smallest dimensions than other samples and biggest electrical conductivity.

We are remarking the average of the electrical conductivity of alloy bigger than copper and aluminum.

The value of this alloy (in my study) and wire of cooper and aluminum (in previous studies) given by:

	$\sigma \ (\ (10^7 (\Omega. m)^{-1})$
Alloy of copper and cast iron	12.65
Cooper	5.63
Aluminum	3.24

4.2 Conclusion:

The electrical conductivity of alloy was very high in normal temperature and that is the result we need to do it (the aim of study).

4.3 Recommendations

- We can use this alloy to create conductor in less cost.
- We can use this alloy to create superconductor.

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