HEAT TREATMENT EFFECT IN PREPARATION OF YBCO SYSTEM

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I hereby declare that this thesis is my own work, except for certain quotations and references that have been duly cited.

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ABSTRACT

The purpose for doing this project is to determine the effect of heat treatment to the superconductor on critical temperature. Three samples of $YBa_2Cu_3O_7$ powder is annealed under the heat treatment of 900^0C, 1000^0C and 1200^0C. The pellets are then tested for critical temperature, T_c by using four-point-probe machine when the temperature is increased. The mobility of the carriers depends upon temperature, crystal defect density, and all impurities present. Comparison among the T_c graphs and data are collected and drawn by with Microsoft Excel. From the results, sample which is annealed under the temperature of 900^0C achieved the highest T_c which is 90K. Besides testing for T_c, the samples was also scanned with X-ray diffraction (XRD) to determine their crystal structures through lattice a, b, and c. The results showed that 900^0C and 1000^0C annealed samples are orthorhombic structure which stands in 3.82Å, 3.80Å, 11.87Å and 3.85Å, 3.88Å, 11.82Å respectively. As a conclusion, different temperatures of the heat treatment will strongly affect its crystal structures from orthorhombic to tetragonal and critical temperature value.

ABSTRAK

Tujuan penyelidikan tesis ini adalah untuk membezakan kesan suhu genting, Tc di bawah suhu pemanasan superkonduktor yang berbeza bagi system YBCO. Tiga sampel YBCO disediakan dan dipanaskan pada suhu rawatan haba yang berlainan iaitu 900^{0}C, 1000^{0}C dan 1200^{0}C. Pelet-pelet diuji untuk mengukur kerintangan dengan menggunakan kaedah penduga empat titik apabila suhu dinaikkan. Perbandingan antara graf T_c dan data-data dikumpul dan diplotkan dengan menggunakan perisian Excel. Dari kajian yang dijalankan, didapati sampel yang dipanaskan di bawah suhu 900^{0}C boleh mencapai suhu genting, T_c yang paling tinggi iaitu sebanyak 90K. Selain itu, sampel-sampel juga diuji dengan *X-ray diffraction (XRD)* untuk menentukan struktur kekisi a,b,c YBCO. Keputusan telah menunjukkan pemanasan YBCO pada 900^{0}C dan 1000^{0}C mampu memenuhi syarat kekisi YBCO jenis fasa 123 di mana kekisi a,b,c adalah 3.82Å, 3.80 Å, 11.87 Å dan 3.85 Å, 3.88 Å, 11.82 Å masing-masing. Kesimpulannya, suhu pemanasan $YBa_2Cu_3O_7$ dari 900^{0}C hingga 1200^{0}C boleh menukarkan struktur ortorombik ke tetragonal.

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SYMBOLS AND ABBREVIATIONS

K	Kelvin
C	Celsius
A	Ampere
T_c	Critical Temperature
T_c-on	Onset critical temperature / Onset T_c
T_c-off	Offset critical temperature / Offset T_c
J_c	Critical current density
F	Fahrenheit
BCS	Barden-Copper-Schrieffer
SQUID	Superconductor Quantum Interference Devices
ρ	Resistivity
YBCO	Yttrium Barium Copper Oxide
XRD	X-ray diffraction
h, k, l	Miller Index
a, b, c	lattice parameter
V	Voltage
I	Current

CHAPTER 1

INTRODUCTION

1.1 HISTORY OF SUPERCONDUCTOR

Superconductors are materials that have no resistance to the flow of electricity, are one of the last great frontiers of scientific discovery. Not only have the limits of superconductivity not yet been reached, but the theories that explain superconductor behavior seem to be constantly under review. In 1911 superconductivity was first observed in mercury by Dutch physicist Heike Kamerlingh Onnes of Leiden University. When he cooled it to the temperature of liquid helium, 4 degrees Kelvin (-452F, -269C), its resistance suddenly disappeared. The Kelvin scale represents an "absolute" scale of temperature. Thus, it was necessary for Onnes to come within 4 degrees of the coldest temperature that is theoretically attainable to witness the phenomenon of superconductivity. Later, in 1913, he won a Nobel Prize in physics for his research in this area.

The next great milestone in understanding how matter behaves at extreme cold temperatures occurred in 1933. Walter Meissner and Robert Ochsenfeld discovered that a superconducting material will repel a magnetic field. A magnet moving by a conductor induces currents in the conductor. This is the principle upon which the electric generator operates. But, in a superconductor the induced currents exactly mirror the field that would have otherwise penetrated the superconducting material - causing the magnet to be repulsed. This phenomenon is known as diamagnetism and is today often referred to as the "Meissner Effect". The Meissner effect is so strong that a magnet can actually be levitated over a superconductive material.

In subsequent decades other superconducting metals, alloys and compounds were discovered. In 1941 niobium-nitride was found to superconduct at 16K. In 1953 vanadium-silicon displayed superconductive properties at 17.5 K. In 1962 scientists at Westinghouse developed the first commercial superconducting wire, an alloy of niobium and titanium. High-energy, particle-accelerator electromagnets made of copper-clad niobium-titanium were then developed in the 1960s at the Rutherford-Appleton Laboratory in the United Kingdom, and were first employed in a superconducting accelerator at the Fermilab Tevatron in the United States of America in 1987.

The first widely-accepted theoretical understanding of superconductivity was advanced in 1957 by American physicists John Bardeen, Leon Cooper, and John Schrieffer. Their Theories of Superconductivity became know as the BCS theory which derived from the first letter of each man's last name - and won them a Nobel Prize in 1972. The mathematically-complex BCS theory explained superconductivity at temperatures close to absolute zero for elements and simple alloys. However, at higher temperatures and with different superconductor systems, the BCS theory has subsequently become inadequate to fully explain how superconductivity is occurring.

Another significant theoretical advancement came in 1962 when Brian D. Josephson, a graduate student at Cambridge University, predicted that electrical current would flow between 2 superconducting materials - even when they are separated by a non-superconductor or insulator. His prediction was later confirmed and won him a share of the 1973 Nobel Prize in Physics. This tunneling phenomenon is today known as the "Josephson effect" and has been applied to electronic devices such as the SQUID, an instrument capable of detecting even the weakest magnetic fields.

The 1980's were a decade of unrivaled discovery in the field of superconductivity. In 1964 Bill Little of Stanford University had suggested the possibility of organic (carbon-based) superconductors. The first of these theoretical superconductors was successfully synthesized in 1980 by Danish researcher Klaus Bechgaard of the University of Copenhagen and 3 French team members.

Then, in 1986, a truly breakthrough discovery was made in the field of superconductivity. Alex Müller and Georg Bednorz researchers at the IBM (International Business Machine) Research Laboratory in Rüschlikon, Switzerland, created a brittle ceramic compound that superconducts at the highest temperature then known 30 K(Blatt,1964). What made this discovery so remarkable was that ceramics are normally insulators. They don't conduct electricity well at all. So, researchers had not considered them as possible high-temperature superconductor candidates. The Lanthanum, Barium, Copper and Oxygen compound that Müller and Bednorz synthesized, behaved in a not-as-yet-understood way. The discovery of this first of the superconducting copper-oxides won the 2 men a Nobel Prize the following year. It was later found that tiny amounts of this material were actually superconducting at 58 K, due to a small amount of lead having been added as a calibration standard - making the discovery even more noteworthy.

Müller and Bednorz' discovery triggered a flurry of activity in the field of superconductivity. Researchers around the world began "cooking" up ceramics of every imaginable combination in a quest for higher and higher T_c. In January of 1987 a research team at the University of Alabama-Huntsville substituted Yttrium for Lanthanum in the Müller and Bednorz molecule and achieved an incredible 92 K T_c. For the first time a material (today referred to as YBCO) had been found that would superconduct at temperatures warmer than liquid nitrogen - a commonly available coolant. Additional milestones have since been achieved using exotic - and often toxic - elements in the base perovskite ceramic. The current class (or "system") of ceramic superconductors with the highest transition temperatures are the mercuric-cuprates. The first synthesis of one of these compounds was achieved in 1993 by Prof. Dr. Ulker Onbasli at the University of Colorado and by the team of A. Schilling, M. Cantoni, J. D. Guo, and H. R. Ott of Zurich, Switzerland. The world record T_c of 138 K is now held by a thallium-doped, mercuric-cuprate comprised of the elements Mercury, Thallium, Barium, Calcium, Copper and Oxygen. The T_c of this ceramic superconductor was confirmed by Dr. Ron Goldfarb at the National Institute of Standards and Technology-Colorado in February of 1994. Under extreme pressure its T_c can be coaxed up even higher - approximately 25 to 30 degrees more at 300,000 atmospheres.

The first company to capitalize on high-temperature superconductors was Illinois Superconductor (today known as ISCO International), formed in 1989. This amalgam of government, private-industry and academic interests introduced a depth sensor for medical equipment that was able to operate at liquid nitrogen temperatures (> 77K). While no significant advancements in superconductor T_c's have been achieved in recent years, other discoveries of equal importance have been made. In 1997 researchers discovered that at a temperature very near absolute zero an alloy of gold and indium was both a superconductor and a natural magnet. Conventional wisdom held that a material with such properties could not exist! Since then, over a half- dozen such compounds have been found. Recent years have also seen the discovery of the first high-temperature superconductor that does not contain any copper and the first all-metal perovskite superconductor.

1.2 PROJECT SCOPE

There are three scopes of topics need to cover in this project:

i) Resistivity and critical temperature, T_c measurement.

ii) Determine the effect of different YBCO heat treatment.

iii) YBCO system without considering the value of δ.

1.3 PROJECT OBJECTIVE

i) Compare the critical temperature, T_c of the YBCO samples with standard YBCO.

ii) The effect of heat treatment effect in preparation of YBCO system.

iii) Using X-ray diffraction (XRD) to determine the characteristics and structure of YBCO lattice.

CHAPTER 2

LITERATURE REVIEW

2.1 FUNDAMENTAL OF SUPERCONDUCTOR

The theoretical understanding of superconductivity is extremely complicated and involved. It is far beyond the scope of this video booklet to attempt to discuss the quantum mechanics of superconductors. However, in this section fundamental terms and phenomena of superconductors will be discussed.

Superconductors have the ability to conduct electricity without the loss of energy. When current flows in an ordinary conductor, for example copper wire, some energy is lost. In a light bulb or electric heater, the electrical resistance creates light and heat (Frederick, 1995). In metals such as copper and aluminum, electricity is conducted as outer energy level electrons migrate as individuals from one atom to another. These atoms form a vibrating lattice within the metal conductor; the warmer the metal the more it vibrates. As the electrons begin moving through the maze, they collide with tiny impurities or imperfections in the lattice. When the electrons bump into these obstacles they fly off in all directions and lose energy in the form of heat. Figure 2.1 is a drawing that shows atoms arranged in a crystalline lattice and moving electrons bouncing off the atoms that are in their way.

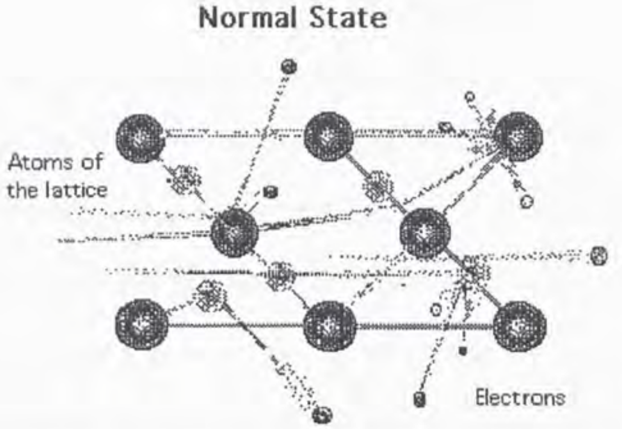
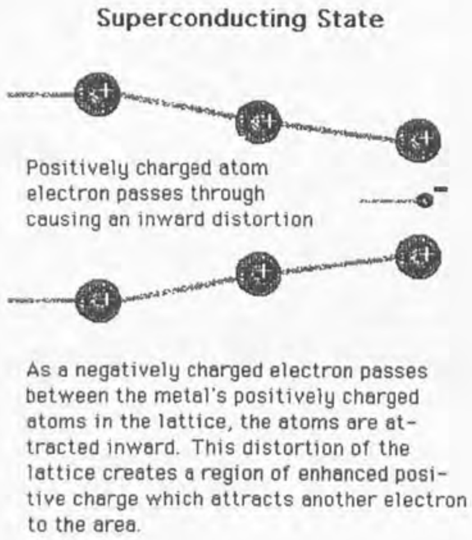


Figure 2.1 Atoms arranged in a crystalline lattice and moving electrons bouncing off the atoms that are in their way (Plakida, 1995)

Inside a superconductor the behavior of electrons is vastly different. The impurities and lattice are still there, but the movement of the superconducting electrons through the obstacle course is quite different. As the superconducting electrons travel through the conductor they pass unobstructed through the complex lattice because they bump into nothing and create no friction they can transmit electricity with no appreciable loss in the current and no loss of energy (Laurent,1998).

The ability of electrons to pass through superconducting material unobstructed has puzzled scientists for many years. The warmer a substance is the more it vibrates. Conversely, the colder a substance is the less it vibrates. Early researchers suggested that fewer atomic vibrations would permit electrons to pass more easily. However this predicts a slow decrease of resistivity with temperature. It soon became apparent that these simple ideas could not explain superconductivity. It is much more complicated than that.

The understanding of superconductivity was advanced in 1957 by three American physicists- John Bardeen, Leon Cooper, and John Schrieffer, through their Theories of Superconductivity, know as the BCS Theory. The BCS theory explains superconductivity at temperatures close to absolute zero. Cooper realized that atomic lattice vibrations were directly responsible for unifying the entire current (Rowell, J., 1991). They forced the electrons to pair up into teams that could pass all of the obstacles which caused resistance in the conductor. These teams of electrons are known as Cooper pairs. Cooper and his colleagues knew that electrons which normally repel one another must feel an overwhelming attraction in superconductors. The answer to this problem was found to be in phonons, packets of sound waves present in the lattice as it vibrates. Although this lattice vibration cannot be heard, its role as a moderator is indispensable.



As a negatively charged electron passes between the metal's positively charged atoms in the lattice, the atoms are attracted inward. This distortion of the lattice creates a region of enhanced positive charge which attracts another electron to the area.

Figure 2.2 A wave of lattice distortion due to attraction to a moving electron (Wong-Ng, W. & Freiman S.W., 1994)

According to the theory, as one negatively charged electron passes by positively charged ions in the lattice of the superconductor, the lattice distorts. The forces exerted by the phonons overcome the electrons' natural repulsion. The electron pairs are coherent with one another as they pass through the conductor in unison. The electrons are screened by the phonons and are separated by some distance. When one of the electrons that make up a Cooper pair and passes close to an ion in the crystal lattice, the attraction between the negative electron and the positive ion cause a vibration to pass from ion to ion until the other electron of the pair absorbs the vibration. The net effect is that the electron has emitted a phonon and the other electron has absorbed the phonon. It is this exchange that keeps the Cooper pairs together. It is important to understand, however, that the pairs are constantly breaking and reforming because electrons are indistinguishable particle; it is easier to think of them as permanently paired.

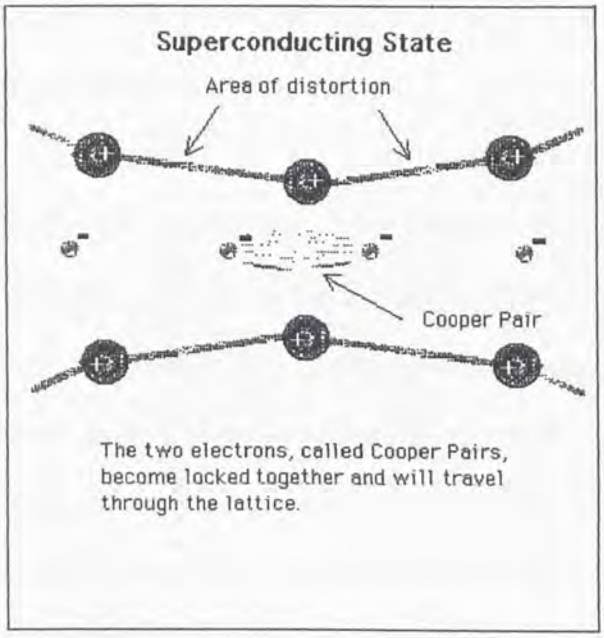


Figure 2.3 How two electrons called Cooper pairs become locked together

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