EFFECT OF TIN DOPING IN BSCCO SUPERCONDUCTORS TO ITS PHYSICAL AND SUPERCONDUCTING PROPERTIES

IRENE SIM MEI MEI

THESIS SUBMITTED IN FULFILMENT PART OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE WITH HONOURS

PROGRAMME PHYSICS WITH ELECTRONICS
SCHOOL OF SCIENCE AND TECHNOLOGY
UNIVERSITI MALAYSIA SABAH

MARCH 2005

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS@

JUDUL: EFFECT OF TIN DOPING IN BSCCO SUPERCONDUCTORS TO ITS PHYSICAL AND SUPERCONDUCTING PROPERTIES

Ijazah: IJAZAH SARJANA MUDA SAINS DENGAN KEPUJIAN (FIZIK DENGAN ELEKTRONIK

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I hereby declare that this thesis is my own work except for certain quotations and summary that has been duly cited.

14th March 2005

IRENE SIM MEI MEI
HS2002-4043

AUTHORIZED BY

Signature

1. SUPERVISOR
   (MDM. ZULISTIANA ZULKIFLI)
   25/3/05

2. EXAMINER 1
   (MR. ALVIE LO SIN VOI)

3. EXAMINER 2
   (DR. JEDOL DAYOU)
   24.3.2005

4. DEAN
   (ASSOC. PROF. DR. AMRAN AHMED)

ACKNOWLEDGMENTS

First of all I'd like to thank the almighty God, for without His generous love, grace and guidance; I could not have successfully cross over obstacles and difficulties, and thus completed my thesis. This thesis is made possible by the strength of the almighty God and all those who have helped and supported me.

My sincere appreciation to my respectively supervisors, Mdm. Zulistiana Zulkifli and Mr. Alvie Lo Sin Voi, for both of them have provide me a lot of help, guidance and insights into my thesis. Special thanks to Mdm. Zulistiana Zulkifli, who never tired of guiding and supervising me, even when on an outstation trip to Japan. I would also like to thank Dr. Jedol Dayou and Ms. Teh Meng Teng for their concern and support too.

My sincere appreciation to Prof. Dr. Roslan Abdul Roslan Shukor, for giving me an opportunity to characterize my thesis samples using the Four Point Probe equipment, in Universiti Kebangsaan Malaysia; and I'm also grateful to his post-graduate student Ms. Yip Wei Yui, for helping me with the characterization laboratory work. She is a very dedicated and helpful person.

My sincerely appreciation also goes to Dr. Imad Hamedneh, for giving me an opportunity to characterize my thesis samples using the X-ray Diffractometer, in Universiti Putra Malaysia. Besides that, he has also provided me some valuable advises. I'm also most grateful to the X-ray Diffractometer laboratory assistance, Cik. Yusnita Osman, she is also a dedicated and helpful person.

My sincere appreciation also goes to the Tropical Biology and Conservation Unit, especially En. Nordin, for helping me to characterize my thesis sample with the Scanning Electron Microscope equipment.

My special thanks to my family and all my supportive friends, for their love, understanding, support and kind assistances.

Last but not least, I also like to thank all individuals and staffs of the School of Science and Technology, whom I have not mention here, for all your help, care and support, may God bless you all.

ABSTRACT

A series of tin doped $Bi_{1.6}Pb_{0.4}Sr_2(Ca_{1-x}Sn_x)Cu_3O_\delta$ superconducting samples, with tin concentration ranging from 0 to 0.20, were prepared using the sol-gel methodology. The samples were sintered at 850 °C for 150 hours. The effect of tin doping on the critical temperature, structure and microstructural of these samples were investigated by the three characterization test, namely the Four Point Probe equipment, the X-ray Diffraction (XRD) equipment and the Scanning Electron Microscope (SEM). Evaluation of the results produced by these characterization tests indicated that the incorporation of tin (stanum) into the calcium site for the samples has led to a deterioration effect on both the transition temperature and the high temperature phase (2223) of the samples. As the tin doping concentration increases, the co-existence of the high temperature phase (2223) and the low temperature phase (2212) of the samples becomes more obvious. The morphology studies of the samples showed that there are brittle, flaky, porous and plate-liked grains widely distributed all over the surface of the sample. And as the tin doping concentration increases, the grains become more cluster and compact. All the results show that there is a correlation existed between the transition temperatures, phases, the microstructures and the starting material compounds. And thus this concluded that the doping of tin has indeed attribute to the physical and superconducting properties of the BSCCO samples.

ABSTRAK

Satu siri $Bi_{1.6}Pb_{0.4}Sr_2(Ca_{1-x}Sn_x)Cu_3O_\delta$ sample telah didopkan dengan timah, di mana kepekatan timah adalah dari 0 hingga 0.20, telah disediakan dengan menggunakan metadologi sol-gel. Sampel-sampel ini telah disinter pada 850 °C selama 150 jam. Kesan pendopan timah terhadap suhu peralihan, struktur dan mikrostruktur sampel-sampel tersebut telah disiasat dengan tiga ujian pencirian, iaitu kaedah Penduga Empat Titik, teknik Pembelauan Sinar-X dan Mikroskop Imbasan Elektron. Pentafsiran yang dibuat pada keputusan-keputusan hasil daripada ketiga-tiga ujian pencirian tersebut telah menunjukkan bahawa kemasukkan timah untuk penggantian pada tapakan kalsium sampel telah mengakibatkan satu kesan yang memudaratkan kepada suhu peralihan dan fasa suhu tinggi (2223) sampel. Peningkatan pendopan timah telah dapat menunjukkan kewujudan dua fasa iaitu fasa suhu tinggi 2223 dan fasa suhu rendah 2212 dengan lebih jelas. Kajian morforlogi sampel telah menunjukkan bahawa terdapat butiran yang rapuh, berkelupas, berliangan dan berkepingan, bertaburan di permukaan sampel. Apabila kepekatan pendopkan timah semakin meningkat, butiran-butiran tersebut menjadi semakin padat dan berkelompokan. Kesemua keputusan telah menunjukkan kewujudan satu hubungan kolerasi di antara suhu peralihan, fasa-fasa, mikrostruktur dan bahan-bahan mentah yang digunakan. Maka, kesimpulannya ialah pendopan timah telah memberi kesan kepada ciri-ciri fizikal dan superkonduktor sample BSCCO .

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LIST OF SYMBOLS AND ABBREVIATIONS

a, b, c	Lattice Parameters
a.m.u	Atomic Mass Unit
B_0, B_1, B_2	Critical field strength
BCS	Barden, Cooper and Schrieffer
BSCCO	Bismuth-Strontium-Calcium-Copper-Oxide system
C	Heat capacity
°C	Celsius degree (Temperature)
CuO	Copper-oxide
FFP	Four Point Probe
H_0, H_1, H_2	Applied magnetic fields
Hc_0, Hc_1, Hc_2	Critical magnetic fields
h, k, l	Miller Indices
HTS	High Temperature Superconductors
J_c	Critical current density
K	Kelvin degree (Temperature)
λ	Wave length
l	Length
SEM	Scanning Electron Microscope
T_c	Critical Transition Temperature
ρ	Resistivity
R	Resistance
XRD	X-Ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The era of superconductivity is born; when, in 1911, Dutch physicist Kamerlingh Onnes discovered the resistivity of mercury absolutely drop to zero at temperatures below 4 K. From then onwards, the works around the field of superconductivity has never been stopped.

Superconductors are a special kind of material that possess two unique characteristic, namely zero resistivity towards electricity and perfect diamagnetism, which means it has the ability to repel a magnetic field. These characters are shown in a superconductor when the superconducting's sample is cooled below a specific temperature, that is the critical transition temperature, T_c.

All known superconductors are solids, none are gases or liquids. A superconductor needs to be put into extreme cold temperature, mostly below their T_c, before the superconductor is able to perform superconductive qualities. If a current is set up in a closed loop of superconducting material, the current will flow forever, with no other source of energy to maintain it! This is because superconductors have zero electrical resistivity, therefore no energy losses is produced when currents flows through it.

Superconductors can be classified into Type 1 and Type 2 superconductors. The type 1 superconductor or also known as low temperature superconductors, is comprised of metals and metalloids. The type 2 category or also known as High Temperature Superconductors (HTS) that compromised of metallic compounds and alloys. The differences between the two types are their temperature transition behavior and their magnetic properties.

Superconductivity is a much different phenomenon from conductivity. In fact, good conductors can not become superconductors at any given temperature. However, astonishing, ceramic an insulator, displays superconducting state when put into extreme cold temperature. This theory has been proven when two scientist, Bednorz, J.G and Müller, K.A, have discovered the very first High Temperature Superconductors, a ceramic (copper-oxide based) superconductor, that is the Lanthanum-Barium-Copper-Oxide compound that have T_c up to 35 K, in 1986. Since then, scientists all over the world have paid serious attentions to high temperature superconductors, and soon then after, a lot of copper-oxide based high temperature superconductors have been found. For example, the Yttrium-Barium-Copper-Oxide

(YBCO) system, discovered in 1987 has Tc 90 K, the Bismuth-Strontium-Calcium-Copper-Oxide (BSCCO) system, that was discovered by *Maeda et al.* with $T_c = 110$ K in 1988.

The BSCCO superconducting system used in this thesis is prepared using the sol-gel methodology. The sol-gel technique is a versatile solution process for making ceramic and glass materials. In general, the sol-gel process involves the transition of a system from a liquid "sol" into a solid "gel" phase. The sol-gel method is used to make high temperature superconductors; this is because of the many advantages that the method can provide.

In this thesis the effect of tin doping in BSCCO superconductors to its physical and superconducting properties, is studied and discussed. The superconducting samples prepared are then characterized by three characterization tests, which is namely the Four Point Probe technique, the X-ray Diffraction (XRD) and the morphology studies run by the Scanning Electron Microscope (SEM). The results produce by these tests will be discussed in later chapters.

1.2 RESEARCH GOAL

The goal of the research is to provide observations and results of the effect of tin doping onto the physical and superconducting properties of the BSCCO superconductors samples prepared via sol-gel method.

1.3 RESEARCH OBJECTIVES

i). Determine the effect of tin doping onto the BSCCO sample's transition temperature.

ii). Determine the characteristics and structure of the tin doped BSCCO system using the X-Ray Diffraction (XRD) equipment.

iii). Morphological studies are done onto the tin-doped samples using the Scanning Electron Microscope. .

1.4 SCOPE OF RESEARCH

i). The effect of tin doping to the physical and superconducting properties of the BSCCO system.

ii). The effect of different tin concentration doping doped onto the BSCCO system, with tin concentration ranging from $x = 0 \sim 0.20$.

CHAPTER 2

LITERATURE REVIEW

2.1 THE GENERAL HISTORY OF SUPERCONDUCTORS

The phenomena of superconductivity was first witness by Dutch physicist Heike Kamerlingh Onnes in 1911, when he cooled a mercury sample to the temperature of liquid helium, 4 degrees Kelvin (-269 °C). He was studying the properties of pure mercury at those temperatures, when suddenly at his surprise; he found that the mercury suddenly lost all its resistance at 4.2 degree Kelvin (Poole, 1995). After some repeated experiments, he discovered the same effect in other elements too at different temperature. By then, he has confirmed to have found a new state of matter at low temperature, which he called "the Superconducting state". The temperature point where an element displayed the sharp transition of temperature is said to represents an "absolute" temperature, which is then called the 'critical transition temperature' or T_c. Later, in 1913, he won a Nobel Prize in physics for his research in this area.

The understanding of materials behaves at extreme cold temperature, has then help to gain another step into the understanding the nature of superconductivity. In 1933, Walter Meissner and Robert Ochsenfeld discovered that a superconducting material will repel a magnetic field, when it's cooled down below its transition temperature in a magnetic field. The repelling force is so great that the superconducting material can actually 'levitate' a magnet over itself. This observation is due to the fact, that when a magnet moves by a conductor, it induces current in the conductor. But in a superconductor, the magnetic field produced by the magnet is unable to penetrate it; this is because the induced current has mirrored the magnetic field. This causes the magnet being repulsed by the superconductor. The phenomenon is known today as the "Meissner effect". Through this discovery too, physicists have found out that superconductor also display the characteristic of perfect diamagnetism.

The understanding of superconductivity has comes to a significant advancement in 1957, when three American physicists John Bardeen, Leon Cooper and John Schrieffer had produced a theoretical understanding that is widely accepted by all. Their theory is known as the famous "BCS theory", which won them a Nobel Prize in 1972. The "BCS theory" explained the superconductivity states of elements and simple alloys, at low temperature nearing the absolute zero. However, the BCS theory is inadequate to provide reasonable explanations on how superconductivity can occur at higher temperatures with different superconducting system.

In 1986, another milestone has been achieved in superconductivity, when two researches Müller, K. A. and Bednorz, J. G. have sent a paper to the journal *Zeitschrift fur Physik*, to announce their discovery of a new oxide ceramic compound which exhibits superconductivity at about 30 K, the then known highest temperature! Both Müller and Bednorz were awarded the Nobel Prize at 1986 on their distinguishing discovery of the first superconducting copper-oxide in Lanthanum-Barium-copper-oxide [La(Sr,Ba) CuO] with T_c above 30 K (Roslan, 1996). The discovery has initiated the era of high-temperature superconductivity.

Although at the beginning people have doubts and criticize the findings of Müller and Bednorz, but then it was later supported and widely accepted, when in January 1987, a research team lead by Paul Chu and Wu, M. K., reproduced the Müller and Bednorz's original results. They were able to achieve a superb T_c – above 90 K, when they substituted yttrium for Lanthanum in the Müller and Bednorz model. The material was identified as the yttrium-barium-copper-oxide (YBCO) system. It was the first material to have found to superconduct at a temperature surpassing the liquid nitrogen's boiling point at 78 K. From this, the YBCO system, that has T_c at 90 K, was born. Then, in 1988, a team lead by Maeda has discovered another high temperature superconductor, the Bismuth-Strontium-Calcium-Copper-oxide (BSCCO) system, where the T_c of this system has reached 110 K. Later, Sheng, Z. Z. and Hermann, A. M. has found the TlBaCaCuO system, which exhibits a T_c ranging from 120 K to 125 K. Later, in 1993, a mercury series compound, the HgBaCaCuO system has been found by a group lead by A. Schilling to superconduct at temperatures up to 134 K (Muhhamad Yahaya, 1997). Now the world record of the highest T_c of any material's record holder, is currently held by a thallium-doped, mercury-cuprate comprised the elements of Mercury, Thallium, Barium, Calcium and Oxygen (HgTlBaCaCuO) system that had the highest T_c, which is at 138 K, which was found in 1995. The following Figure 2.1, summarize the history of superconductors and the increasing of higher transition temperature along the years of experiments, discoveries and breakthroughs.

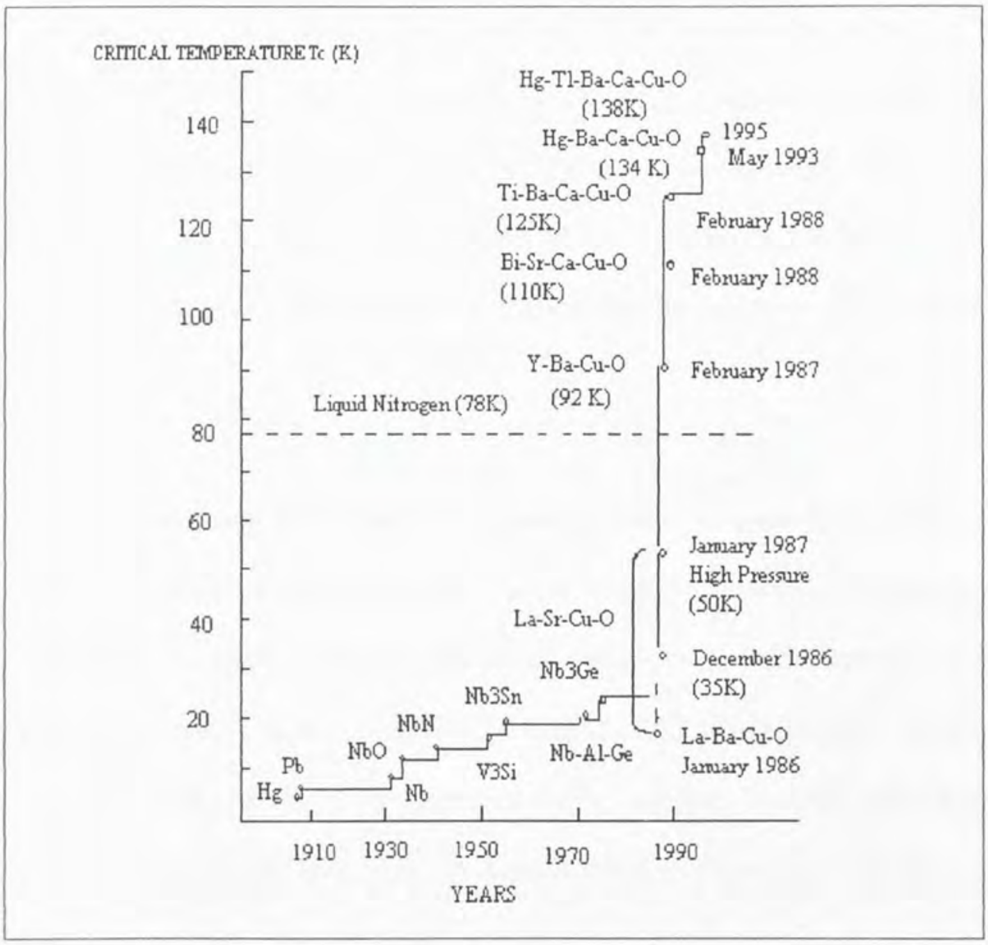

Figure 2.1 The history of superconductors and their transition temperatures (Muhhamad Yahaya, 1997).

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