# UNIVERSITI TEKNOLOGI MARA

# EFFECTS OF Tl AND Sr SITE SUBSTITUTIONS ON SUPERCONDUCTIVITY, STRUCTURE AND EXCESS CONDUCTIVITY OF $TlSr_2CaCu_2O_{7-\delta}$ CERAMICS

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## Candidate's Declaration

I declare that the work in this thesis was carried out in accordance with the regulation of Universiti Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledged as referenced work. This topic has not been submitted to any other degree or qualification.

In the event that my thesis be found to violate the conditions mentioned above, I voluntary waive the right of conferment of my degree and agree be subjected to the disciplinary rules and regulations of Universiti Teknologi MARA.

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# ABSTRACT

The study involves four different compounds of TlSr1212 superconductors. There are $Tl_{1-x}Cu_xSr_{1.8}Yb_{0.2}CaCu_2O_{7-\delta}$ ($x$=0.0-0.6), $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.5), $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ($x$=0–1.0) and $Tl_{0.5}Pb_{0.5}Sr_{2-x}Yb_xCaCu_2O_{7-\delta}$ ($x$ = 0.1-0.4) series. All the samples were synthesized using the solid state synthesis method. Temperature dependent electrical resistance measurements on $Tl_{1-x}Cu_xSr_{1.8}Yb_{0.2}CaCu_2O_{7-\delta}$ ($x$ = 0.0-0.6) series showed the best superconducting behavior at $x$=0.4 with zero resistance critical temperature ($T_{c\ zero}$) of 77.6 K. On the other hand, electrical resistance measurements on $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.5) series showed gradual decrease in $T_{c\ zero}$ followed by a sudden increase in $T_c$ at $x$ = 0.3. Further substitution of Cu at $x \geq 0.4$ however caused $T_c$ to be suppressed. Electrical resistance measurement in $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ($x$=0-1.0) showed increasing semiconductor-like normal state behavior and gradual suppression of $T_c$ with Mg. In addition, superconducting fluctuation behavior (SFB) in $Tl_{1-x}Cu_xSr_{1.8}Yb_{0.2}CaCu_2O_{7-\delta}$ ($x$=0.0-0.4), $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.3), $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ($x$=0) and $Tl_{0.5}Pb_{0.5}Sr_{2-x}Yb_xCaCu_2O_{7-\delta}$ ($x$= 0.1-0.4) ceramics were analyzed by using Asmalazov-Larkin (AL) theory as a framework. In $Tl_{1-x}Cu_xSr_{1.8}Yb_{0.2}CaCu_2O_{7-\delta}$ ($x$=0–0.4), the analysis showed characteristic cross-over from 2D to 3D behavior with decreasing temperature. Cu substitutions in this series is suggested to give effect on $c$-axis coherence length, $\xi_c(0)$ and hole concentration of carrier. For $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.3) ceramics revealed 2D to 3D transition and showed Cu substitution affects the $AL_{3D}$ constant and increases $c$-axis coherence length, $\xi_c(0)$. Excess conductivity of $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ceramics ($x$=0.0) showed exclusively 1D to 2D transition behavior. In addition, superconducting fluctuation behavior in sintered polycrystalline samples of $Tl_{0.5}Pb_{0.5}Sr_{2-x}Yb_xCaCu_2O_{7-\delta}$ ($x$=0.1-0.4) revealed transition from 2-D to 3-D behavior. This study also suggests that there is a close correlation between the amounts of Yb substitution and the behavior of $AL$ constant ($A$). Fourier Transform Infrared (FTIR) spectroscopy analyses was performed on $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.5) and $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ($x$=0–1.0) samples. In $Tl_{1-x}Cu_xSr_{1.6}Yb_{0.4}CaCu_2O_{7-\delta}$ ($x$=0-0.5), the results showed $CuO_2$ planar oxygen mode observed was softened with increased Cu substitution indicating enhanced coupling between $CuO_2$ planes. FTIR absorption data for $Tl_{0.5}Pb_{0.5}Sr_{2-x}Mg_xCa_{0.8}Yb_{0.2}Cu_2O_{7-\delta}$ ($x$=0–1.0) indicate possible tilt of oxygen atoms in the $CuO_2$ plane as a result of unequal bond lengths and enhanced $CuO_2$ inter-plane coupling.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Superconductivity is one of the interesting modern day discoveries that excite researchers all over the world. It is the phenomenon when materials below critical temperature ($T_c$) show zero electrical resistance (R=0) and zero magnetic field (B=0). Above $T_c$, it turns into normal state with non-zero resistance. Zero electrical resistance in superconductors means that the superconductors conduct electrical currents flow infinitely and incur no energy loss. The Meissner effect is the phenomena when magnetic fields are expelled from the interior of superconductors. This phenomena makes a magnet levitate above superconducting materials.

In 1911, conventional superconductivity with $T_c$ less than 30 K was first discovered in solid mercury at 4.2 K by Heike Kamerlingh Onnes, a Dutch physicist. Subsequently, lead and niobium nitride was found superconducting at 7 K and 16 K, respectively. Other examples of conventional superconductors are Zn ($T_c$ =0.88 K), Al ($T_c$ =0.88 K), Sn ($T_c$ =3.72 K), Hg ($T_c$ =4.15 K), Pb ($T_c$ =7.18 K), Nb ($T_c$ =9.46 K), $Nb_3Sn$ ($T_c$ =18.05 K) and $Nb_3Ge$ ($T_c$=23.2 K) (Doss, J. D. et.al (1989) & Tinkham, M. (1996)).

The next important discovery was in 1957 when John Bardeen, Leon Cooper, and Robert Schrieffer proposed a theory what is commonly called the BCS theory which successfully explained the mechanism of conventional superconductors (J. Bardeen et.al (1957)). Generally, the basic concept in this theory is about the pairing of electrons called Cooper pairs through interaction with the crystal lattice. Lattice vibrations namely