







EFFECT OF BaZrO<sub>3</sub> NANOPARTICLES ADDITION ON THE  
STRUCTURAL AND MAGNETIC PROPERTIES OF  
YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> SUPERCONDUCTOR

By  
LIM JEE KHAN

Thesis submitted in partial fulfilment of the  
requirement for the award of the degree of  
Bachelor of Applied Science (Electronics and Instrumentation Physics)

SCHOOL OF OCEAN ENGINEERING  
UNIVERSITI MALAYSIA TERENGGANU  
2018

## THESIS CONFIRMATION AND APPROVAL

This is acknowledged and confirmed that thesis entitled: *Effect of BaZrO<sub>3</sub> Nanoparticles Addition on the Structural and Magnetic Properties of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Superconductor* by Lim Jee Khan. Matric No.: S39180 have been checked and all the suggested corrections have been done. The thesis is submitted to School of Ocean Engineering, Universiti Malaysia Terengganu in partial fulfillment of the requirements for the award of the degree of Bachelor of Applied Science (Electronics and Instrumentation Physics).

Authorized by:



Date: .....

30/5/18

.....  
Main Supervisor

Name: Dr. Lee Oon Jew

Official Stamp:

DR. LEE OON JEW  
Lecturer  
School of Fundamental Science  
Universiti Malaysia Terengganu  
21030 Kuala Terengganu  
Terengganu, Malaysia

Date: .....

.....  
Co-Supervisor

Name: Assoc. Prof. Dr. Chen Soo Kien

Official Stamp:



Date: .....

04/06/18

.....  
PITA Coordinator

Bachelor of Applied Science

(Electronics and Instrumentation Physics)


Name: Assoc. Prof. Dr. Mohammad Ismail

Official Stamp:

DR. MOHAMMAD BIN ISMAIL  
Lecturer  
School of Ocean Engineering  
Universiti Malaysia Terengganu

## DECLARATION

I hereby declare that this thesis is the result of my own research except as cited in the references.

Signature :  .....

Name : Lim Jap Khan .

Matric No. : 539180

Date : 4 June 2018 .

## ACKNOWLEDGEMENTS

First and foremost, i would like to express my appreciation and gratitude to my project supervisor, Dr. Lee Oon Jew and co- supervisor, Dr. Chen Soo kien. With all the advices, encouragement, guidance and patience, I was able to make this project a successful and meaningful one.

My appreciation and gratitude is extended to all the members of superconductor and thin film laboratory, faculty of science, Universiti Putra Malaysia, for all the heart-warming support and assistance. They had indeed helped and assisted me a lot in completing this project in various way.

My next gratitude will be to all the staffs of Universiti Malaysia Terengganu for willing to accept me into this big family. Without all the immense help and support, this project can never be so smooth. Besides, i am very grateful to my family and friends for their understanding, tolerance and infinite support in every aspect.

My appreciation would be incomplete without giving credit to Dr. Ahmad Nazri Dagang, Dr. Aima Ramli and Puan Hasiah Salleh for their advices and fair assessment.

## EFFECT OF BaZrO<sub>3</sub> NANOPARTICLES ADDITION ON THE STRUCTURAL AND MAGNETIC PROPERTIES OF YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> SUPERCONDUCTOR

### ABSTRACT

Superconductor is a green material that conducts electricity without any energy loss and expels penetration of magnetic flux when it is cooled below a certain temperature called critical temperature,  $T_c$ . YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> is one of the high temperature superconductors (HTS) discovered to show  $T_c$  above the boiling point of liquid nitrogen. This implies that YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> is a potential candidate for a wide range of usage since it can be cooled to below its  $T_c$  economically using liquid nitrogen. Magnetic levitation (Maglev) train is among the applications that benefits tremendously from this. To warrant YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> for the applications, its flux pinning properties and intergranular critical current density,  $J_{cm}$  have to be improved. This is exactly the focus of this project. To do so, 2, 5, and 7 mol. % of BaZrO<sub>3</sub> nanoparticles (< 50 nm) are added into YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> respectively, to form a composite superconductor via solid state reaction technique. BaZrO<sub>3</sub> is selected for this study because the compound remains inert to reaction with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> and previous studies found that BaZrO<sub>3</sub> leads to highest increase in  $J_{cm}$ . Consequently, the  $T_c$  is not degraded (around 90 K) and the distribution of the nanoparticles within the matrix of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> serves as effective pinning centers leading to enhancement of flux pinning capability. In this study, it is found that with 2 mol. % addition of BaZrO<sub>3</sub> nanoparticles,  $J_{cm}$  is increased the most, from 3.57 A/cm<sup>2</sup> to 3.74 A/cm<sup>2</sup>. To sum up, this project provides a room for transformation of Maglev train. This project is in line with the government policy in supporting green technology for better living environment. The outcome of the product is also greatly beneficial to advancing the state-of-art technology of high speed train which is expected to be in full operation in Malaysia by 2026.

**KESAN PENAMBAHAN NANOZARAH BaZrO<sub>3</sub> TERHADAP  
SIFAT-SIFAT STRUKTUR DAN MAGNETIK BAGI  
SUPERKONDUKTOR YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>**

**ABSTRAK**

Superkonduktor merupakan sejenis bahan hijau yang mengalirkan arus elektrik tanpa kehilangan tenaga dan menyingkirkan fluks magnet apabila disejukkan di bawah suhu tertentu yang dikenali sebagai suhu kritikal,  $T_c$ . YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> ialah salah satu superkonduktor bersuhu tinggi yang ditemui mempunyai suhu kritikal yang lebih tinggi daripada suhu didih nitrogen cecair. Ini menunjukkan YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> merupakan superkonduktor yang berpotensi untuk digunakan secara meluas kerana ia boleh disejukkan ke bawah suhu  $T_c$  secara ekonomi dengan menggunakan cecair nitrogen. Kereta api pengapungan magnetik merupakan salah satu aplikasi yang menggunakan sifat istimewa superkonduktor. Ketumpatan arus genting antara butiran,  $J_{cm}$  dan pengepitan fluks superkonduktor harus ditingkatkan untuk memastikan YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> dapat diaplikasikan. 2, 5, dan 7 mol. % BaZrO<sub>3</sub> nanozarah (< 50 nm) telah dicampurkan ke dalam YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> secara berasingan untuk menghasilkan komposit superkonduktor melalui teknik reaksi pepejal. BaZrO<sub>3</sub> telah dipilih untuk kajian ini kerana sebatian ini tidak bertindak balas dengan YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> dan kajian terdahulu telah membuktikan BaZrO<sub>3</sub> memberi peningkatan  $J_{cm}$  yang tertinggi. Oleh itu,  $T_c$  tidak akan merosot (kira-kiranya 90 K) dan taburan nanozarah dalam matriks YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> akan berfungsi sebagai pusat pengepitan yang efektif untuk meningkatkan keupayaan pengepitan fluks. Dalam kajian ini, penambahan 2 mol. % BaZrO<sub>3</sub> menunjukkan peningkatan  $J_{cm}$  yang paling berkesan, daripada 3.57 A/cm<sup>2</sup> hingga 3.74 A/cm<sup>2</sup>. Keseluruhannya, projek ini memberi peluang untuk perkembangan dalam kereta api pengapungan magnetik. Projek ini selaras dengan sektor kerajaan yang menyokong teknologi hijau untuk persekitaran kehidupan yang lebih baik. Hasil kajian ini akan memberi manfaat untuk memajukan teknologi kereta api berkelajuan tinggi yang disasarkan untuk beroperasi sepenuhnya di Malaysia pada tahun 2026.