

**FIELD OF STUDY**

**Power Systems**

**THESIS TOPIC**

**“A Study of Electromigration from Superconducting to Normal Conducting Metals”**

**EXAMINING COMMITTEE**

Dr. Satish Mahajan, Committee Chairperson  
(Director, Center for Energy Systems Research)

Dr. R. Wayne Johnson  
(Chair, Electrical & Computer Engineering)

Dr. Holly Stretz  
(Associate Professor, Chemical Engineering)

**ABSTRACT**

A study of the potential for electromigration to occur in indium solder balls at liquid helium temperature was conducted. The solder balls were interconnected by means of niobium traces, which transitioned from niobium to indium throughout a flip-chip assembly. The niobium traces were superconducting in the liquid helium. By observation of Black's equation, it was reasonable to assume that electromigration does not occur in normal conducting metals at cryogenic temperatures. However because of reliability concerns with the use of indium in superconductivity applications, the potential for electromigration to occur at the superconducting niobium to normal conducting indium transitions was conducted. Because electromigration is a function of current density, temperature, and geometry, flip-chips were manufactured with indium solder balls of varying pitches. The flip-chips were stressed at a current level that was 90% of the niobium's critical current, and two tests were conducted. Each stress test lasted a period of 21 days, and the solder ball pitches for the first test were 15 micrometers; for the second test, the solder ball pitches were 25 micrometers and 35 micrometers. Resistance of all samples was monitored constantly by automating the test equipment with Labview, and the resistance did not change. With electromigration, an increase in the samples' resistance was expected to occur, and no test samples exhibited any increases in their resistance, validating the notion that it is very unlikely for electromigration to occur at liquid helium temperature.

## BIOGRAPHICAL SKETCH

Jonathan M. Dugas was born in Winchester, Tennessee, on December 2, 1981. He attended elementary school in the Franklin County School District and graduated from Franklin County High School in June 2000. Jonathan began working after high school and attended Tennessee Technology Center in McMinnville, Tennessee, where he earned an Electronics Installer and Tester Level 2 Certificate. After working in the technology field for several years, he decided to go to Motlow State Community College, where he earned an Associate degree in May 2011. The following Fall, Jonathan attended Tennessee Tech University, where he earned a Bachelor of Science in the Field of Electrical and Computer Engineering degree in 2014. He entered Tennessee Tech University once more in the Spring of 2015 and anticipates receiving his Master of Science in the Field of Electrical and Computer Engineering at the end of the Fall 2017 semester.

His research interests are number, particularly prime number theorems and algorithms, electromagnetics, and electronics. He is currently researching electromigration as a potential failure mechanism for superconducting electronics. Jonathan will also be published in the Journal of Mathematics and Statistics for the discovery of a new prime number algorithm.

## EDUCATION

M.Sc., Electrical Engineering  
Tennessee Technological University  
Cookeville, TN, expected August 2017

B.Sc., Electrical & Computer Engineering  
Tennessee Tech University  
Cookeville, TN, May 2014



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The Department of

**Electrical & Computer Engineering**

Announces the Thesis Defense

Of

*Jonathan Maurice Dugas*

In Partial Fulfillment of the Requirements

For the degree of

*Master of Science*

Monday, July 24, 2017 at 1:30 p.m.

Held at

Brown Hall, Room 208  
115 W 10<sup>th</sup> Street  
Tennessee Tech University  
Cookeville, TN 38505