THE DEVELOPMENT AND IMPLEMENTATION OF COMPUTER-BASED MEASUREMENT SYSTEM FOR ENERGY BAND GAP OF SEMICONDUCTOR DIODE

NOR SHAIDA BINTI MOHD SAUFI

THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR
THE DEGREE OF MASTER OF SCIENCE
**(MASTER BY RESEARCH)

FACULTY OF SCIENCE AND MATHEMATICS
UNIVERSITY PENDIDIKAN SULTAN IDRIS

2018

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

Please tick (√)
Project Paper
Masters by Research
Master by Mixed Mode
PhD

√

INSTITUTE OF GRADUATE STUDIES

DECLARATION OF ORIGINAL WORK

This declaration is made on the 18 day of NOV 2019.

i. Student's Declaration:

I, NOR SHAIDA BINTI MOHD SAUFI (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled THE DEVELOPMENT AND IMPLEMENTATION OF COMPUTER-BASED MEASUREMENT SYSTEM FOR ENERGY BAND GAP OF SEMICONDUCTOR DIODE is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

Signature of the student

ii. Supervisor's Declaration:

I Dr. Nurul Syafiqah Yap Abdullah (SUPERVISOR'S NAME) hereby certifies that the work entitled The Development and Implementation of Computer-Based Measurement System for Energy Band Gap of Semiconductor Diode. (TITLE) was prepared by the above named student, and was submitted to the Institute of Graduate Studies as a * partial/full fulfillment for the conferment of Master of Science (Physics). (PLEASE INDICATE THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work.

18/11/19
Date

Signature of the Supervisor

UNIVERSITI PENDIDIKAN SULTAN IDRIS
اونيۏرسيتي قنديديقن سلطان ادريس
SULTAN IDRIS EDUCATION UNIVERSITY

INSTITUT PENGAJIAN SISWAZAH /
INSTITUTE OF GRADUATE STUDIES

BORANG PENGESAHAN PENYERAHAN TESIS/DISERTASI/LAPORAN KERTAS PROJEK
DECLARATION OF THESIS/DISSERTATION/PROJECT PAPER FORM

Tajuk / *Title*: THE DEVELOPMENT ~~OF~~ AND IMPLEMENTATION OF COMPUTER BASED MEASUREMENT SYSTEM FOR ENERGY BAND GAP OF SEMICONDUCTOR DIODE

No. Matrik /*Matric's No.*: M 2015 1000689

Saya / *I* : NOR SHAIDA BINTI MOHD SAUPI

(Nama pelajar / *Student's Name*)

mengaku membenarkan Tesis/Disertasi/Laporan Kertas Projek (Doktor Falsafah/Sarjana)* ini disimpan di Universiti Pendidikan Sultan Idris (Perpustakaan Tuanku Bainun) dengan syarat-syarat kegunaan seperti berikut:-
acknowledged that Universiti Pendidikan Sultan Idris (Tuanku Bainun Library) reserves the right as follows:-

1. Tesis/Disertasi/Laporan Kertas Projek ini adalah hak milik UPSI.
   The thesis is the property of Universiti Pendidikan Sultan Idris
2. Perpustakaan Tuanku Bainun dibenarkan membuat salinan untuk tujuan rujukan sahaja.
   Tuanku Bainun Library has the right to make copies for the purpose of research only.
3. Perpustakaan dibenarkan membuat salinan Tesis/Disertasi ini sebagai bahan pertukaran antara Institusi Pengajian Tinggi.
   The Library has the right to make copies of the thesis for academic exchange.
4. Perpustakaan tidak dibenarkan membuat penjualan salinan Tesis/Disertasi ini bagi kategori **TIDAK TERHAD**.
   The Library are not allowed to make any profit for 'Open Access' Thesis/Dissertation.
5. Sila tandakan (√) bagi pilihan kategori di bawah */ Please tick (√) for category below:-*

☐	**SULIT/*CONFIDENTIAL***	Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub dalam Akta Rahsia Rasmi 1972. / *Contains confidential information under the Official Secret Act 1972*
☐	**TERHAD/*RESTRICTED***	Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan ini dijalankan. / *Contains restircted information as specified by the organization where research was done.*
☑	**TIDAK TERHAD / *OPEN ACCESS***	

(Tandatangan Pelajar/ Signature)

Tarikh: 18/11/17

(Tandatangan Penyelia / *Signature of Supervisor*)
& (Nama & Cop Rasmi / *Name & Official Stamp*)

DR. NURUL SYAFIQAH YAP ABDULLAH
Pensyarah Kanan
Jabatan Fizik
Fakulti Sains dan Matematik
Universiti Pendidikan Sultan Idris

Catatan: Jika Tesis/Disertasi ini **SULIT @ TERHAD**, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu dikelaskan sebagai **SULIT** dan **TERHAD**.

Notes: If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

ACKNOWLEDGEMENT

First and foremost I offer my sincerest gratitude to Allah SWT for his blessing and permission, this thesis is completed successfully.

My greatest appreciation is toward my supervisor, Dr Nurul Syafiqah Yap for her constant encouragement, and advice throughout my thesis with her patience and knowledge whilst allowing me the room to work in my own way. I attribute the level of my Masters degree to her encouragement and effort and without her this thesis, too, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

My appreciation also goes to Dr. Ikhwan Hadi, who has provided me a workstation which much of the work has been done on and offered much advice and insight throughout my work in this study. Thank you to Dr. Shahrul Kadri for provided me with the LabVIEW software license.

The Department of Physics has provided the support and equipment I have needed to complete my thesis and the MyBrain15 has funded my studies. My appreciation also goes to Institut Pendidikan Siswazah UPSI for providing workshop and seminars for us postgraduate students to succeed in our research.

In my daily work I have been blessed with a friendly and cheerful group of fellow students, Yunus bin Hamid, Faralina Asrab, Husna and Safuan. They have provided me good information and arguments about related topics of my research.

Finally, I would like to express my heartfelt thanks to my husband, Suhaimi Jumri and my for supporting me throughout all my studies. Without their selfless love and endless support, I cannot be me today.

ABSTRACT

This study is conducted to develop computer-based measurement system to obtain energy band gap of semiconductor diode. The forward voltage technique is a common technique used to determine energy band gap of diode driven by constant current source. The system is developed to adapt and implement an equation of energy band gap deduced from previous research using computer-based measurement in order to produce more accurate and reliable result of energy band gap. The system is consisted of personal computer, interface board, sensors and circuit. The graphical user interface (GUI) of the system is developed using LabVIEW from National Instruments. The developed system is tested on silicon and germanium diode and four types light-emitting diode (LED) which are red, orange, blue and green. Their temperature-forward voltage characteristics (T versus VF) under 12mA constant current source are measured to calculate energy band gap and wavelength of emitted photon. Measurement was carried from 5ºC to 95ºC with temperature intervals of 5ºC. Result shows that the system successfully measured energy band gap of all tested diode. The band gaps of silicon diode 1N4007 and germanium diode 1N34 were determined to be 1.99 ± 0.05 eV and 0.88 ± 0.03 eV respectively. The band gaps of orange, red, blue and green LEDs were obtained to be 1.82 ± 0.03 eV, 1.98 ± 0.02 eV, 3.90 ± 0.03 eV and 2.58 ± 0.05 eV. This study implies that this computer-based measurement system has improved and simplifies the experiment set-up and process to obtain the energy band gap as reported in previous studies.

PEMBANGUNAN DAN PELAKSANAAN SISTEM PENGUKURAN BERASASKAN KOMPUTER UNTUK TENAGA JURANG JALUR UNTUK DIOD SEMIKONDUKTOR

ABSTRAK

Kajian ini dijalankan untuk membina sistem pengukuran berasaskan komputer untuk menentukan tenaga jurang jalur bagi semikonduktor diod. Teknik voltan maju ini merupakan teknik yang biasa digunakan untuk menentukan tenaga jurang jalur sumber arus berterusan. Sistem ini dibina untuk menyesuaikan dan melaksanakan algoritma untuk mengira tenaga jurang jalur yang didapati dari kajian lepas menggunakan pengukuran berasaskan komputer untuk mendapatkan nilai tenaga jurang jalur yang lebih tepat dan dipercayai. Sistem ini terdiri daripada komputer, papan antaramuka, penderia dan litar. Antara muka pengguna grafik (GUI) di dalam sistem ini dibina menggunakan perisian LabVIEW. Sistem yang dibina diuji pada diod jenis silikon, germanium dan empat jenis diod pemancar cahaya (LED) iaitu oren, merah, hijau dan biru. Ciri-ciri suhu-voltan hadapan (T lawan VF) di bawah sumber arus berterusan 12mA diukur untuk pengiraan tenaga jurang jalur dan panjang gelombang foton yang dipancarkan. Pengukuran dilaksanakan dari julat suhu 5ºC hingga 95ºC dengan selang suhu 5ºC. Hasil ujian menunjukkan sistem ini telah berjaya mengukur tenaga jurang jalur ke semua diod yang diuji. Tenaga jurang jalur untuk diode silicon, 1N4007 dan germanium, 1N34 adalah 1.99 ± 0.05 eV dan 0.88 ±0.05 eV. Tenaga jurang jalur untuk LED oren, merah, biru dan hijau pula didapati 1.82 ±0.05 eV, 1.98 ± 0.05 eV, 3.90 ± 0.05 eV dan 2.58 ± 0.05 eV. Kajian ini memberi implikasi bahawa sistem pengukuran berasaskan komputer ini telah menambahbaik persediaan dan proses eksperimen untuk mendapatkan tenaga jurang jalur seperti yang dilaporkan dalam kajian-kajian lepas.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DUT	Device under test
I-V	Current-Voltage Characteristics
T-V	Temperature-Voltage Characteristics
GUI	Graphical User Interface

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the study on the development of a computer-based energy band gap measurement system of a semiconductor diode. This chapter consists of five parts; background of the study, problem statement, research objectives, significance of the study and limitation of the study and scope of the thesis.

1.2 Background of the Study

Semiconductor diodes are the basis of active device in electronics. The technology of semiconductor is continuously being researched and developed in terms of its design, performance, efficiency, cost goals in a number of growing applications. These led to development and invention of more powerful measurement system, and more efficient method to measure and study the characteristics of semiconductor in order to stay current.

In any semiconductor, there is a forbidden energy range in which allowed states cannot exist. The upper bands are called conduction band and the lower bands are called valence band. Each semiconductor has a specific band gap. The difference between the highest valence band and lowest conduction band energies which is the energy band gap provide idea into useful materials for optical application. The energy band gap is the energy to promote an electron from the lower energy valence band into the higher energy conduction band. After an electron is excited by heat or electricity into the conduction band, it could return to the lower energy valence band causes a release of a photon of light. This concept of energy band gap provides idea into potentially useful materials for optical application.

Obtaining temperature-voltage characteristics under constant current is the common technique to measure energy band gap of semiconductor diode. This method of experimental determination of energy band gap of LED, silicon and germanium diode has been reported in (Precker & da Silva, 2002; Mukaro, Taele & Tinarwo, 2006; Precker, 2007; Ocaya & Luhanga, 2011; Eugene & Wagner, 2016; Petit, Michez, Raimundo & Dumas, 2016). Most of the studies mentioned aim to produce a method and experimental set up which is suitable for undergraduate laboratories on semiconductor study. Therefore, a method or experimental set up which are simple, convenient, less and suitable time-consuming, yet produce reliable result are the feature of a measurement system should have.

In certain studies, the mentioned approach is known as electrical method as there is another method to obtain energy band gap by using optical method. In Petit et al. (2016), energy band gap of LED was determined optically by taking the light

spectrum emitted by the LED and using the wavelength of emitted light to calculate energy band gap.

Precker and Silva in 2002 proposed an algorithm to determine energy band gap from temperature versus forward voltage relationship when the device under test is driven by a constant current. They also reported the relation and measurement of energy band gap with wavelength of emitted light by LED.

This study introduces a computer-based measurement system of the energy band gap as an effort towards simplify the complexity of measurement set-up, save time for the measurement process and also produce more accurate and reliable result. The approach adopted is similar to that described by Precker and Silva. The algorithm to determine energy band gap is implemented in the software of the system. The obtained energy band gap is then used to calculate wavelength. The energy band gap is deduced from the algorithm implemented from the T-V characteristics.

The novel of this system development is the new hardware used to measure temperature, voltage and current in combination with software for data measurement and analysis. The circuit that used to run the tested diode as well as constant current while measuring the temperature and voltage of diode in this study has never been reported in previous research. The advancement of the developed system and what the system can offer make it suitable for band gap study in a variety of application.

1.3 Problem Statement

At present, existing measurement system for energy band gap have bulky size of hardware thus it is optimize the use of workbench. This system expected to produce more accurate and reliable data. The measurement of forward voltage variation with temperature under passing through of constant current is the most common technique used by previous researchers to measure energy band gap of diodes (Wagner, 2016; Precker & Silva, 2002; Precker, 2007. An algorithm for determine energy band gap from temperature-voltage characteristics has successfully deduced by Precker & Silva in 2002. However, even though many of the studies have reported the measurement of energy band gap of diodes, less of the identified studies reported the energy band gap that used computer-based tool. Most of the studies that used temperature-voltage technique to measure energy band gap used manual method and none of them using computer-based tools or automated measurement system to the effort of improving accuracy and process simplicity of measurement system.

Rather than using manual method reported in the study, the time consumed for measurement process could be shorten, the complexity of diode circuit could be simplified and reliability of result obtained could be improved using computer-based measurement. Besides, more sample of diode can be tested.

A computer-based measurement system was developed in order to perform the band gap measurement of semiconductor diodes.

1.4 Objective of the Study

The objectives of the study are:

1. To develop computer-based measurement system for determination energy band gap of silicon, germanium diode and LEDs.
2. To implement an equation of energy band gap obtained from previous research into computer-based measurement system.
3. To determine and to compare energy band gap of silicon diode, germanium diode and LEDs.

1.5 Significance of the Study

This study expects to produce a user-friendly and reliable computer-based energy band gap measurement system for semiconductor diode. The system is useful and beneficial for novice users such as undergraduate students and inexperience researchers who involving with characterisation of semiconductor diode. This study can be further by produce the prototype of the system in which it is applicable to be used in education. It expects to be a platform to provide users with the essential background, in-depth experiment experience and basic understanding of semiconductor diode and its band theory.

1.6 Scope and Limitation of Study

This study is only tested on the semiconductor of the form of encapsulated germanium, silicon and LED diode. This study will not be generalizable to other form of semiconductor sample. The temperature is only in the range of 5º to 95º because of the limit of the temperature sensor can read.

1.7 Summary

The thesis consists of five chapters. CHAPTER 1 is the current chapter which this chapter covers background of the study, statement of problem and objectives of the study, research questions, significance of the study and scope and limitation of the study.

CHAPTER 2 presents theory of temperature-voltage characteristics, energy band gap and review of related previous researches.

CHAPTER 3 presents the development process to build hardware and software of the computer-based measurement system. This chapter also discusses the selection of device under test as sample to test the performance of the system.

CHAPTER 4 describes the result obtain from the measurement, the performance and validation of the system.

Finally, CHAPTER 5 covers the conclusion of the thesis and proposes recommendation for further study.