



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

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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 V_F) under 12mA constant current source are measured to calculate energy band gap and wavelength of emitted photon. Measurement was carried from 5°C to 95°C with temperature intervals of 5°C . 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 5°C hingga 95°C dengan selang suhu 5°C. Hasil ujian menunjukkan sistem ini telah berjaya mengukur tenaga jurang jalur ke semua diod yang diuji. Tenaga jurang jalur untuk diode silikon, 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

	Page
DECLARATION	
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
ABSTRAK	v
TABLE OF CONTENT	vii
LIST OF TABLE	x
LIST OF FIGURE	xi
LIST OF ABBREVIATIONS	xii
LIST OF APPENDICES	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Introduction	1
1.2 Background of the Study	1
1.3 Problem Statement	4
1.4 Objective of the Study	5
1.5 Significance of the Study	5
1.6 Scope and Limitation of Study	6
1.7 Thesis Summary	6

CHAPTER 2	LITERATURE REVIEW	7
2.1	Introduction	7
2.2	Classification of Semiconductors	7
2.3	The p-n junction	8
2.4	Principle of Energy Band Gap	10
2.4.1	Temperature Dependence of the Energy band gap	12
2.5	Method of Measuring Energy Band Gap	12
2.5.1	Using Temperature-Voltage Characteristics	13
2.5.2	Using Reverse Saturation Current vs Temperature Characteristics	18
2.5.3	Using Resistivity-Temperature Characteristics	19
2.6	Relation between Energy band gap and Wavelength of Emitted Light	19
2.7	Computer-based Measurement of Energy band gap	22
2.8	Summary	24
CHAPTER 3	METHODOLOGY	27
3.1	Introduction	27
3.2	Devices Under Test (DUT) Preparation	27
3.3	Description of Measurement System	29
3.4	Hardware of the System	30
3.4.1	Personal Computer	31
3.4.2	Direct Current Power Supply	32

3.4.3	Interface Board	32
3.4.4	Voltage Sensor	34
3.4.4.1	Calibration of Phidget Precision Voltage Sensor 1135	34
3.4.5	Temperature Sensor	35
3.4.6	Current Sensor	36
3.4.7	Circuit for DUT	38
3.5	Software of the System	40
3.5.1	Software for Development of Computer-based Measurement System	41
3.5.2	User Interface of Computer-based Measurement System	42
3.5.2.1	Connection and Control Panel	42
3.5.2.2	Display Panel of The System	44
3.5.3	Block Diagram of Computer-based Measurement System	44
3.5.3.1	Block Diagram for Connection and Control Panel	45
3.5.3.2	Block Diagram for Conversion of Sensor Value	46
3.5.3.3	Block Diagram for Output Value Acquisition Control	47
3.5.3.4	Block Diagram for Temperature-Voltage Characteristics	49
3.5.3.5	Block Diagram for Determination of Energy band gap and wavelength	49
3.5.4	Flow Chart of Computer-based Measurement System	50
3.6	Energy band gap Measurement	52
3.7	Summary	53

CHAPTER 4	RESULT AND DISCUSSION	54
4.1	Introduction	54
4.2	Performance of the System	54
4.2.1	Temperature vs. Voltage Graph	55
4.2.2	Energy band gap, E_g	57
4.2.3	Wavelength of Emitted Lights, λ	58
4.3	System Validation	58
4.4	Summary	59
CHAPTER 3	CONCLUSION AND RECOMMENDATION	60
5.1	Introduction	60
5.2	Conclusion	60
5.2.1	Objective 1:	61
5.2.2	Objective 2:	61
5.2.3	Objective 3:	61
5.3	Limitations of the Study	62
5.4	Significance of the Study	62
5.5	Recommendation for Further of the Study	62
REFERENCE		64
APPENDIX A: KNOWLEDGE DISSEMINATION		67
APPENDIX B: GRAPHICAL USER INTERFACE OF SYSTEM		68
APPENDIX C: SOFTWARE INTERFACES		69



LIST OF TABLES

No. Tables	Page
2.1 The LED Colour, Wavelength and Materials.	21
2.2 Table 2.2 Summary of previous study on measurement of energy band gap of semiconductor diode	25
4.1 Types of Diode with their a, b, and Energy Band Gap Value	57
4.2 Energy band gap and wavelength of DUT	58



LIST OF FIGURES

No. Figures	Page
2.1 Schematic details of a p-n junction diode	9
2.2 Basic symbols of p-n junction diode	9
2.3 E-K diagram for (a) direct band gap semiconductor and (b) indirect band gap semiconductor.	11
2.4 The electrodes of LED attached directly to the mercury reservoir	16
2.5 Block diagram of LabVIEW-based system for measurement of band gap energy	23
3.1 (a). Silicon diode 1N4007 and germanium diode 1N34A, (b) Four types of LEDs; green, red, yellow and blue	28
3.2 Equipment in LabVIEW-based measurement system for energy band gap measurement	29
3.3 Block diagram for hardware of the system	30
3.4 The connection of hardware of the system	31
3.5 Personal Computer	31
3.6 DC power supply to drive circuit and current sensor	32
3.7 Phidget Interface Board 8/8/8	33
3.8 Schematic diagram for analog input of Interface Board 8/8/8	33
3.9 Phidget Precision Voltage Sensor	34
3.10 Phidget Precision Temperature Sensor 1124	36
3.11 Mechanical drawing of 3513 DC Current Sensor	37

3.12 Phidget Current Sensor 3513	37
3.13 Schematic circuit with LED as device under test and LM317 as constant current regulator	39
3.14 Set up of the constant current circuit to run DUT	40
3.15 Iconic label of LabVIEW software	41
3.16 Connection and sensors ratiometric state panel	43
3.17 Selection of device under test and output parameter panel	43
3.18 Block diagram objects for connection block for (a) connection between interface board and personal computer and (b) terminating the acquisition	45
3.19 Block diagram objects for conversion of sensor values into voltage, temperature and current values	46
3.20 Block diagram codes for acquisition control of output values	48
3.21 Block diagram codes for acquisition control of output values	48
3.22 Block diagram codes to display Temperature vs. Forward Voltage	49
3.23 Block diagram codes to calculate energy band gap and wavelength	50
3.24 Flow chart of the computer-based energy band gap measurement system	51
4.1 Temperature-Voltage characteristics for LED red, orange, blue and green LED obtained from the system	56
4.2 Temperature-Voltage characteristics for 1N4007 Si diode and 1N34 Ge diode	56



LIST OF ABBREVIATIONS

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





LIST OF APPENDICES

- A KNOWLEDGE DISSEMINATION
- B GRAPHICAL USER INTERFACE OF SYSTEM
- C SOFTWARE INTERFACES





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 inexperienced 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 5° to 95° 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



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.

