



UniMAP

**EPOXIDIZED NATURAL RUBBER 50 POLYMER
COATED FBG SENSOR FOR PRESSURE
APPLICATIONS**

By

**SITI FATIMAH BINTI HARUN
(1330810876)**

A thesis submitted
In fulfillment of the requirements for the degree of
Master of Science in Communication Engineering

**School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS**

2017

ACKNOWLEDGEMENTS

Thanks Allah in helping and giving me strength

My deepest gratitude goes to;

My husband, Usamah bin Abdol Hamid;

Thanks for your fully support.

My fathers, Harun Bin Ruslan and Abdol Hamid Bin Manan;

My mothers, Zahidah Binti Mohd Shah and Rashidah Binti Abdul Rashid;
for their doa and patient.

My family.

I love you all with my heart.

My supervisor: Thanks Dr. Ir. Anuar Mat Safar for your patient and guidance.

My co-supervisors: Thanks Prof. Dr. Syed Alwee Aljunid Bin Syed Junid;
Dr. Rashidi Bin Che Beson, Ir Rosdiham Bin Endut, and all CoE ACE SCCE Optic's cluster friends;

Who always help me.

My friends & my buddies who always there for me.

TABLE OF CONTENTS

	PAGE
THESIS DECLARATION	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF ABBREVIATIONS	xiv
LIST OF SYMBOLS	xv
ABSTRAK	xvii
ABSTRACT	xviii
CHAPTER 1 INTRODUCTION	1
1.1 Introduction.	1
1.2 Problem statements and motivation.	3
1.3 Objective of the Research.	6
1.4 Thesis Organization.	6
1.5 Contribution	7
CHAPTER 2 LITERATURE REVIEW	11
2.1 Introduction.	11
2.2 Pressure sensor technology.	12
2.2.1 Mechanical pressure sensor.	12
2.2.1.1 Bellows.	12
2.2.2 Bourdon tube.	14
2.2.3 Diaphragm.	16
2.2.3.1 Spring and piston.	18
2.2.4 Electronic pressure sensor.	19
2.2.5 MEMS- based pressure sensor.	20

2.2.6	Fiber optic pressure sensor.	21
2.2.6.1	Intensity based fiber optic sensor.	24
2.2.6.2	Phase-modulated optic pressure sensor.	28
2.2.6.3	Wavelength based fiber optic sensors	34
2.3	Fiber Bragg Grating Pressure Sensor.	34
2.4	Polymer as the coating for the Fiber Bragg Grating Pressure Sensor.	40
2.5	Epoxydized Natural Rubber (ENR 50)	47

CHAPTER 3 METHODOLOGY **51**

3.1	Introduction.	51
3.2	Theoretical for bare and ENR50 coated FBG pressure sensor	53
3.2.1	Pressure sensing equation.	53
3.2.2	Sensitivity of pressure sensor	57
3.2.3	Pressure sensing equation for bare FBG	57
3.2.4	Pressure sensing equation for FBG with ENR50 polymer coated	59
3.2.5	Theoretical calculation for pressure measurement techniques	60
3.2.5.1	Weight sensing application	61
3.2.5.2	Level or depth sensing application.	62
3.3	Experimental for ENR50 coated FBG pressure sensor testing.	63
3.3.1	Fabrication of ENR50 as FBG sensor coating.	63
3.3.2	Experimental setup for FBG pressure sensor testing.	65
3.3.2.1	Weight pressure sensor sensitivity.	66
3.3.2.3	Level or depth measurement	67
3.3	Conclusion	68

CHAPTER 4 RESULT AND DISCUSSION **70**

4.1	Introduction.	70
4.2	Theoretical result of Bragg Wavelength shifting for bare FBG.	70
4.2.1	Theoretical result for bare FBG pressure sensor based on weight application.	71
4.2.2	Theoretical result for bare FBG pressure sensor based on level or depth application.	76
4.2.3	Comparison for theoretical result of Bragg wavelength shifting for each type of pressure.	77

4.3	Theoretical result Bragg wavelength of coated FBG sensor for various type of pressure.	78
4.3.1	Theoretical result for ENR50 coated FBG pressure sensor based on weight application.	78
4.3.2	Theoretical result ENR50 coated FBG pressure sensor based on level or depth application.	84
4.3.3	Comparison of ENR50 coated FBG theoretical result of Bragg wavelength shifting for each type of pressure.	84
4.4	Experimental result for ENR50 coated FBG	86
4.4.1	Experimental result for ENR50 coated FBG based on weight application.	86
4.4.2	Experimental result for ENR50 coated FBG based on level or depth application.	92
4.4.3	Comparison for experimental result for each type of pressure	96
4.5	Comparison result for experimental and theoretical for coated FBG	98
4.5.1	Comparison result for experimental and theoretical for coated FBG for weight application	98
4.5.2	Comparison result for experimental and theoretical for coated FBG for level or depth application	109
4.5.3	Comparison result for all experimental and theoretical for coated FBG.	101
4.6	Comparison result for theoretical bare FBG and theoretical coated FBG.	104
4.6.1	Comparison result for theoretical bare FBG and theoretical coated FBG for weight application	106
4.6.2	Comparison result for theoretical bare FBG and theoretical coated FBG for level or depth	106
4.6.3	Comparison result for all theoretical bare FBG and all theoretical coated FBG .	107
4.7	Comparison result for theoretical bare, coated and experimental FBG	108
4.7.1	Comparison result for theoretical bare, coated and experimental FBG for weight application	108
4.7.3	Comparison result for theoretical bare, coated and experimental FBG for level or depth application.	109
4.8	Theoretical comparison result of Bragg wavelength shifting and sensitivity of various type of coated FBG pressure sensor.	111

4.9	Theoretical comparison result of Bragg wavelength shifting and sensitivity of various type of coated FBG pressure sensor.	112
CHAPTER 5 CONCLUSION		114
5.1	Introduction	114
5.2	Summary	114
5.3	Future Work	116
REFERENCES		120
APPENDIX A		124
APPENDIX B		125
APPENDIX C		126
LIST OF PUBLICATIONS AND AWARDS		127

©This item is protected by original copyright

LIST OF TABLES

NO.		PAGE
2.1	Bragg wavelength shifting for different thickness of Teflon FBG sensor.	44
2.2	Comparison of previous research on polymer as FBG coating	46
2.3	Mechanical parameters for ENR50.	47
4.1	Theoretical calculation of Bragg grating wavelength for weight pressure application.	71
4.2	Theoretical calculation of Bragg grating wavelength for level or depth pressure application.	74
4.3	Comparison result of Bragg wavelength shifting for all types of pressure application.	77
4.4	Theoretical calculation of Bragg grating wavelength for weight pressure application.	79
4.5	Theoretical calculation of Bragg grating wavelength for level or depth pressure application.	85
4.6	Comparison result of Bragg wavelength shifting for all types of pressure application.	89
4.7	Experimental result of Bragg wavelength shifting for weight pressure application.	92
4.8	Experimental result of Bragg wavelength shifting for level or depth pressure application	102
4.9	Comparison result of Bragg wavelength shifting for all types of pressure application.	106
4.10	Comparison result of Bragg wavelength shifting for theoretical and experimental for weight application.	107
4.11	Comparison sensitivity for experimental and theoretical for coated FBG for level or depth application	110
4.12	Comparison result sensitivity of Bragg wavelength shifting for all types of	

	pressure application.	111
4.13	Comparison result sensitivity of Bragg wavelength shifting for weight pressure application.	113
4.14	Comparison result sensitivity of Bragg wavelength shifting for level or depth pressure application.	116
4.15	Comparison result sensitivity of Bragg wavelength shifting for all pressure applications	116
4.16	Comparison result sensitivity of Bragg wavelength shifting for weight application.	118
4.17	Comparison result sensitivity of Bragg wavelength shifting for level or depth application.	121

©This item is protected by original copyright

LIST OF FIGURES

NO.		PAGE
2.1	Scope of research.	10
2.2	Examples of bellows and capsules.	13
2.3	Example of Bourdon tube	14
2.4	(a) Spiral tubes (b) Helical tubes	16
2.5	Diaphragm mechanism	17
2.6	Example of diaphragm.	17
2.7	Spring and piston mechanism.	18
2.8	Example of MEMS pressure sensor.	20
2.9	Basic arrangement of a fiber optic pressure sensor.	22
2.10	Intrinsic sensor: a part of the fiber is being used as a sensing element.	22
2.11	Extrinsic sensor: the sensing element is not an integral part of the fiber.	23
2.12	Operating principle for fiber optic pressure sensor.	24
2.13	Total internal reflection	24
2.14	Mechanism of total internal reflection	25
2.15	Example of total internal reflection	25
2.16	Mechanism of micro bending pressure sensor.	26
2.17	Addition of corrugated cylindrical plates to cause the light intensity.	27

2.18	Mechanism of light loss	27
2.19	Example of the micro bending pressure sensor applications.	27
2.20	Concept of phase modulated pressure sensor	28
2.21	Concept of Mach Zehnder	29
2.22	Mach Zehnder acoustic energy sensor	30
2.23	Mechanism of Mach Zehnder.	31
2.24	Mechanism of Fabry Perot Interferometer	32
2.25	Concept of Intrinsic Fabry Perot Interferometer	33
2.26	Concept of Fiber Bragg Grating	33
2.27	Transmission spectra of Fiber Bragg Gratings	35
2.28	Mechanism of Fiber Bragg grating concept.	36
2.29	Fiber Bragg Grating effect towards pressure applications.	37
2.30	Example of multiple FBGs	38
2.31	Result and experimental setup of real time monitoring of railway traffic using fiber Bragg grating sensor	38
2.32	Result and experimental setup for FBG for Biomedical applications.	39
2.33	Bragg wavelength shift of FBG against applied pressure recorded by OSA.	40
2.34	Comparison between theoretical and experimental result.	40
2.35	Polymer coated FBG with aluminium cylinder shielded.	41
2.36	Result sensitivity of Polymer coated FBG with aluminium cylinder shielded.	42
2.37	Fiber Bragg Grating pressure sensor using metal tube packaging.	42

2.38	Reflection spectra of FBG pressure sensor under different pressures (a) 0, (b) 0.44MPa.	43
2.39	Bragg wavelength shift of the sensors with different temperatures and with coating of different thickness versus RH at 25°C	43
2.40 (a)	Metal bar under tension increases in length and decreases in cross section;	48
2.40 (b)	Poisson ratio's concept.	49
3.1	Research methodology.	52
3.2 (a)	Sample of ENR50 solution	52
3.2 (b)	ENR50 coated FBG sensor after complete fabricated.	65
3.3	Pressure Measurement of using Fiber Bragg Grating Sensor	66
3.4	Pressure measurement techniques	67
3.5	Experimental setup for pressure measurement of weight application	67
3.6	Experimental setup for pressure measurement of level or depth application	68
4.1	Theoretical graph of Bragg grating wavelength for weight pressure application	72
4.2	Theoretical graph of Bragg grating wavelength for weight pressure application.	77
4.3	Comparison graph for Bragg wavelength shifting towards all types of pressure application.	80
4.4	Theoretical graph of Bragg grating wavelength for weight pressure application	83
4.5	Theoretical graph of Bragg grating wavelength for level or depth pressure application.	87
4.6	Comparison graph for Bragg wavelength shifting towards all types of pressure application	85
4.7	Experimental result from OSA for weight pressure application.	87
4.8	Highlight of Bragg wavelength shifting for weight pressure application.	88
4.9	Experimental result from OSA for weight pressure application.	90

4.10	Graph sensitivity of Bragg wavelength shifting for weight pressure application.	90
4.11	Experimental results from OSA for level or depth pressure application	92
4.12	Highlight of Bragg wavelength shifting for level or depth pressure application	93
4.13	Graph sensitivity of Bragg wavelength shifting for level or depth pressure application	95
4.14	Comparison graph for Bragg wavelength shifting towards all types of pressure application	97
4.15	Theoretical and experimental Bragg Wavelength shifting for weight application.	99
4.16	Theoretical and experimental Bragg Wavelength shifting for level or depth pressure application.	100
4.17	Comparison graph for Bragg wavelength shifting towards all types of pressure application	103
4.18	Theoretical Bragg Wavelength shifting bare and coated FBG for weight pressure application.	105
4.19	Theoretical Bragg Wavelength shifting bare and coated FBG for level or depth pressure application.	106
4.20	Comparison of Bragg Wavelength for theoretical bare, coated and experimental coated FBG for weight application.	108
4.21	Comparison of Bragg Wavelength for theoretical bare, coated and experimental coated FBG for level or depth application.	110
4.22	Theoretical comparison of Bragg Wavelength for theoretical bare, coated and experimental coated FBG for level or depth application.	112
4.23	Experimental comparison of Bragg Wavelength for theoretical bare, coated and experimental coated FBG for level or depth application.	113
5.1	Example of pressure chamber.	117
5.2	Bragg wavelength shifting.	118

5.3	Bragg wavelength shifting measurement without oscillator.	118
5.4	Oscillator.	119

©This item is protected by original copyright

LIST OF ABBREVIATIONS

Db	Decible
ENR50	Epoxydized Natural Rubber
FBG	Fiber Bragg Grating
FS	Full scale
FTIR	Frustrated Total Internal Reflection
LVDT	Linear Variable Differentiation Transmitter
MEMS	Microelectromechanical System
NR	Natural Rubber
OSA	Optical Spectrum Analyzer
Pa	Pascal
RH	Relative Humidity
SLED	Single Light Emitting Diode
UV	Ultraviolet

LIST OF SYMBOLS

$^{\circ}$	Degree
%	Percentage
F	Force
A	Area
L_0	Original Length
L_n	New Length
ε	Strain
d	Depth
ν	Poisson Ratio
E	Young Modulus
m	mass
g	gravity
Λ	grating
λ_B	Bragg wavelength
$\Delta\lambda_B$	Bragg wavelength shift
n_{eff}	Effective refractive index
K	Gauge factor

P	Pressure
ρ	Density of fluid
ΔP	Pressure change
ρ_e	Photo elastic coefficient
ρ_{11}	Strain Optic tensor strain
ρ_{12}	Strain Optic tensor strain
h	Height
N	Newton

©This item is protected by original copyright

ABSTRAK

Pegesan Fiber Bragg Grating (FBG) bersalut ENR50 adalah hampir menjadi pilihan terbaik yang memenuhi keperluan ciri-ciri sebuah pengesan tekanan. Pengesan tekanan yang konvensional tidak dapat mengukur dengan sangat tepat, disamping terdedah dengan kuasa elektromagnetik, tenaga elektrik yang tidak stabil dan penyambungan kabel yang terlalu banyak. Pengesan Fiber Bragg Grating (FBG) mempunyai saiz yang kecil, rintangan yang rendah, cepat bertindak balas, imuniti kepada gangguan elektromagnetik, boleh digunakan dalam persekitaran berbahaya, dan mempunyai sistem yang fleksibel. Walaubagaimanapun, sifat semulajadi FBG yang rapuh agak berbahaya jika digunakan tanpa mempunyai salutan atau pembungkusan yang baik. Oleh itu, ENR50 telah dipilih di dalam penyelidikan in memandangkan ianya juga mampu untuk meningkatkan sensitiviti pengesan FBG. ENR50 menjadi calon terbaik di dalam penyelidikan ini kerana ia mempunyai Poisson's ratio dan Young Modulus yang rendah yang membawa maksud ianya lebih fleksibel dan tidak terlalu keras. Analisis secara teori dan eksperimen dijalankan untuk menyiasat prestasi ENR50 sebagai pembalut pengesan FBG. Oleh itu, nisbah peningkatan sensitiviti diantara keputusan sensitiviti eksperimen dan teori telah dikira. Di samping itu, nisbah perbezaan sensitiviti secara teori untuk nilai sensitiviti pengesan FBG bersalut ENR50 dan FBG yang asal juga dikira. Prestasi pengesan FBG bersalut ENR50 terhadap aplikasi tekanan juga dikaji seperti berat dan kedalaman air untuk mengetahui yang aplikasi yang paling sesuai diukur menggunakan pengesan ini. Keputusan teori menunjukkan bahawa pengesan FBG bersalut ENR50 telah meningkatkan sensitiviti pengesan FBG asal sebanyak 4.146×10^5 untuk aplikasi berat dan 4.11×10^5 untuk aplikasi kedalaman air dan ini sekaligus membuktikan pengesan FBG bersalut ENR50 dapat meningkatkan sensitiviti pengesan FBG yang asal. Walaubagaimanapun, keputusan eksperimen tidak dapat menjadi sebaik keputusan teori kerana terdapat beberapa kekangan ketika eksperimen dijalankan seperti ketepatan nilai tekanan yang diberikan yang dibuat berdasarkan formula fizik tidaklah setepat nilai tekanan yang diberikan oleh kebuk tekanan. Oleh itu, nilai sensitiviti teori menunjukkan ianya 5.313×10^{13} lebih tinggi daripada nilai sensitiviti eksperimen untuk aplikasi berat dan 5.2916×10^{15} untuk aplikasi kedalaman air. Secara kesimpulannya, teori telah membuktikan bahawa pengesan FBG bersalut ENR50 dapat meningkatkan sensitiviti pengesan FBG yang asal sebanyak 4.11×10^5 hingga 4.146×10^5 kali ganda tetapi untuk eksperimen, pelbagai penambahbaikan perlu dilakukan untuk mencapai nilai sebaik teori.

ENR50 Polymer Coated for FBG Sensor towards Pressure Applications

ABSTRACT

ENR50 Polymer coated Fiber Bragg Grating sensor is almost a perfect choice for satisfying requirement characteristic of pressure sensor. The conventional pressure transducers are not too precise in measurement, besides being highly exposed to electromagnetic interference, power fluctuations and has complicated cabling. FBG sensor shows that it has small size, low attenuation, quick response on time, immunity to electromagnetic interference, safety in hazardous environment, and flexible configuration. However, the nature of frangible of FBG sensor is quite dangerous without packaging and coating. Therefore, the ENR50 polymer selected in this study to be a coating as it also can enhances the sensitivity of FBG sensor. ENR50 becomes a good candidate in this research because it has lower Poisson Ratio, ν and Young Modulus, E which means it more flexible and less stiffness. Theoretical and experimental analysis was done to investigate the performance of ENR50 as FBG's coating. Thus, the ratio sensitivity enhanced between the theoretical and experimental result of sensitivity was calculated. Beside, the ratio differentiation sensitivity of theoretical of ENR50 polymer coated FBG with bare FBG was also calculated. The performance of ENR50 coated FBG for type of pressure applications such weight and level or depth also analyzed to investigate which type of pressure applications more compatible with this kind of sensor. Theoretical result shows that ENR50 coated FBG was enhanced the sensitivity of bare FBG about 4.146×10^5 times higher for weight applications and 4.11×10^5 times higher for level or depth application, and this totally proved that ENR50 polymer can enhance the sensitivity of FBG bare sensor. However, experimental result not achieves the theoretical expectation due to the some limitations in the experimental setup such as the accuracy of value pressure given based on physics calculation is not as accurate compared to pressure value from the pressure chamber. So, the theoretical result shows that it was 5.313×10^{13} times higher than the experimental result for weight application and 5.2916×10^{15} times higher for level or depth applications. As conclusion, theoretically, it was proved that ENR50 can enhances sensitivity of FBG sensor for about 4.11×10^5 to 4.146×10^5 times higher, but experimentally, there some improvements need to be done in the experimental setup to achieve as per theoretical results.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Pressure sensors can be defined as a device which senses pressure and converts it into an analog electric signal whose magnitude depends upon the pressure applied. Since the device convert the pressure into an electrical signal, it was also termed as pressure transducers. Pressure sensors are used for controlling and monitoring in thousands of every day applications. It is a key technology for the safe operation of different technical products, systems and technologies. Pressure sensors can be classified according to four types of sensors which are optical, electronic, mechanical, and Microelectromechanical systems (MEMS) sensors.

A traditional pressure sensor has very limited usage in heavy industrial environments, particularly in explosive or electromagnetically noisy environments. Utilization of optics in these environments eliminates all surrounding influences. The main benefit of this solution consists of increasing sensitivity, low attenuation, immunity to electromagnetic interference, small size, flexible configuration, lightweight, quick response of time, chemically inert, and safety in hazardous environments (anti corrosion and absence of sparks sources hazard for flammable and explosive environments) (D. R. Sparks,1998).

Wavelength modulated fiber sensor happens when light moves from a medium of a given refractive index, n_1 into a second medium with refractive index, n_2 . Thus, both

reflection and refraction may occur. Consequently when another region or different refractive index is introduced inside an optical fiber which already has different refractive indexes in the core and cladding, reflection of light can occur. The new region with a different index of refraction from the core and cladding is known as Bragg Grating.

Fiber Bragg Grating (FBG) has many types of structures such as uniform and chirped structure, but the most important aspect is that it has constant pitch that will reflect certain incoming wavelengths to yield Bragg wavelength.

A coating is needed on the FBG pressure sensor as fiber will affect the pressure given. Epoxidized Natural Rubber 50 (ENR50) is a good candidate material as it has lower Young's Modulus and Poisson's ratio compare to another polymer. It also had stiffness compare to natural rubber so it is more suitable to be used compared to natural rubber even natural rubber show the lowest poisson ratio. This means that the material is a type of rubber that can assist the FBG sensor to improve the sensitivity of results.

In order to accomplish the investigation on FBG sensors towards pressure applications, there are three main pressure applications which are pressure due to weight, and level or depth. Pressure due to weight application expressed that weight is directly proportional to the pressure applied. So this sensor can be used to measure weight of objects. Lastly, pressure due to level or depth can also be measured because different depth of water has different value of pressure. Therefore, it is not only useful to detect the depth of water but it can also be used to detect altitude.

In this research, how FBG acts as a pressure sensor and provide many benefits in terms of various aspects were studied. The technique that has been formed for each applications and the level of sensitivity were investigated. A study to compare the theoretical performance of bare and coated FBG was done to investigate the optimal condition of FBG

as a pressure sensor. An experimental was also conducted to investigate the performance of ENR50 as the coating material for FBG pressure sensors. The main motivation of this research is to prove that ENR50 can act as a protection and sensitivity enhancer for FBG pressure sensors. The result of the experimental then will be compared to the theoretical results.

1.2 Problem statements and motivation

The existing pressure transducers are not too precise in measurement, besides being highly exposed to electromagnetic interference and power fluctuations. Most transducers require complicated cabling which is not suitable for the pressure sensor application. Pressure sensors are usually applied in harsh environment applications such as oil and gas industry, power plants, train sites and river streams (Aulakh, N. S., 2010).

Mainly three technologies are currently commercially available for pressure measurement with fiber-optic sensors which are based on intensity, phase modulated and wavelength modulated (Eric Pinet, 2011). The first one is probably the simplest and cheapest but it is limited to applications where having 2 fixed or up to 4 flexible fibers, whereas the two other technologies require only one fiber. The intensity based sensor had risk which the reflectivity of target can be alter relative position of the transmitting and receiving fibers in relation to the target which means this type of sensor is quite not too robust for high pressure application (Suhairi Saharuddin, 2016).

Phase modulated based sensor such as Fabry-Perot system can provide higher accuracy, the interrogation system and the sensor design are sophisticated, but the cost is unaffordable.

Wavelength modulated based pressure sensor which is Fiber Bragg Grating pressure sensors are still limited to marginal applications as it was had no higher accuracy. However, with applied the polymer coating on the fiber Bragg Grating sensor, the sensitivity of this sensor enhanced for a lot compared to the bare one. The nature of the frangible FBG also quite dangerous if it is applied without coating or packaging. Thus, the coating or packaging that can enhance the sensitivity of FBG sensors is the most important criteria to produce a good sensor. There are researches in this field which shows the importance of coating as protector and sensitivity enhancer towards FBG sensors (Indu, F. S., and Kaleo, H.,(2010) ; Saidi, P. et. al. (2011) ; Yun Q. L. (2000)).

There are several types of pressure applications such as weight and level or depth. The problem is most researches were done the experimental by directly using the pressure chamber. Because of that, there is no record of sensitivity comparisons for pressure sensor applications. This comparison is an important criterion that can show the ability of FBG sensors towards type of applications. Thus, with the comparison of sensitivity for each type of applications, the performance of every pressure applications can be analyzed and the suitability to choose FBG sensors as a pressure measurement device can be determined.

This project tries to solve this entire problem by proposing sensitivity investigations towards ENR50 as the polymer coating for FBG sensor and their performance on each application for pressure sensor measurement. This project will take into account the type of FBG coating material that can enhance the sensitivity of pressure sensors. The type of material or polymer were chosen by considering the value of Poisson's ratio and Young Modulus because low Poisson ratio and Young Modulus materials can enhance the sensitivity of pressure sensors. After the ENR50 polymer was decided to be choose,

theoretical and experimental measurements have been done to investigate the performance of these sensors.

Fundamental equation of Bragg grating formula is used before it will be modified by inserting the value of Young Modulus, E and Poisson ratio, ν into the equation (Ying Zhang et. al. , 2001). With this equation, the theoretical sensitivity of coated FBG sensors can be yielded. The equation for bare FBG had also been measured as a reference line to get the percentage of its sensitivity enhancement.

The problem statements of this research can be conclude as follows:

- 1.2.1 The mechanical pressure transducer are not precise in measurement.
- 1.2.2 Electronic transducer is expose to electromagnetic interference and power fluctutations and not suitable to be apply in the harsh environment.
- 1.2.3 MEMS pressure transducer sensitive to electromagnetic interference and the environmental temperature was limited.
- 1.2.4 Intensity modulated based optical pressure sensor had complicated cabling as it need 2 fixed or up to 4 flexible fibers.
- 1.2.5 Phase-modulated based pressure sensor was unaffordable in term of cost.
- 1.2.6 Bare FBG is frangible in nature and had low sensitivity.

1.3 Objective of the Research

Due to the problems discussed, the research to study the performance of ENR50 coated FBG sensor was done and compared with the bare FBG sensor. Then, the performance of ENR50 coated FBG was analyzed towards a few of pressure applications which os weight and level/depth.

The objectives of this research can be concluded as follows:

1. To design an ENR50 polymer coated FBG sensor tetsbed.
2. To compare the performance of ENR50 coated FBG sensor towards the bare FBG sensor through theoretical and experimental work.
3. To analyze the performance of ENR50 coated FBG for pressure applications which are weight and level or depth.

1.4 Thesis Organization

This paper consists of five chapters. Chapter 1 gives overview to the thesis title, ENR50 Polymer Coated for FBG Sensor towards Pressure Applications in a brief introduction. Problem statement and motivation, objectives, scopes of the thesis were also explained as well as the flow of this research project.

Chapter 2 details the literature review on pressure sensor systems that include the types of existing pressure sensors and their examples. Types of optical pressure sensors were also discussed to differentiate their methods with the FBG measurement method. A brief history background on FBG pressure sensor and previous research on the effectiveness