FORMALDEHYDE (CH_2O) SENSING BASED ON GLASS SUBSTRATE PLATFORM

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A report submitted
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2021

DECLARATION

I declare that this thesis entitled FORMALDEHYDE (CH_2O) SENSING BASED ON GLASS SUBSTRATE PLATFORM is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled "Formaldehyde Sensing Based On Glass Substrate Platform" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

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Date : 5 JULY 2021

DEDICATIONS

To my beloved parents, family, lecturers and friends.

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ABSTRACT

The main purpose of this proposed project is to develop a formaldehyde sensing that are simple design, low-cost production and environmentally friendly device. This sensing device can detect the amount of the concentration level in food since this chemical compound can be harmful to the humans if contents higher amount of formaldehyde. This proposed will use the glass substrate to transmitted light with a certain incident angle and critical angle. The light transmit through the glass substrate will affect the output voltage. Hence, to obtained a stable system the glass substrate is coated with Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel while the length of glass also being optimized. Therefore, this proposed project is to fabricate glass substrate platform coated with Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel for formaldehyde sensing application. The length of glass that effect the output voltage also been optically characterize and optimized. This project was validating the proposed experiment for formaldehyde sensing application. The output voltage is obtained from the simulation by using Arduino Uno.

ABSTRAK

Tujuan utama projek yang dicadangkan ini adalah untuk membina penderiaan formaldehid yang mempunyai reka bentuk mudah, pengeluaran kos rendah dan peranti mesra alam. Peranti penderiaan ini dapat mengesan jumlah tahap kepekatan dalam makanan kerana sebatian kimia ini boleh membahayakan manusia jika kandungannya mempunyai jumlah formaldehid yang tinggi. Projek cadangan ini akan menggunakan substrat kaca untuk menghantar cahaya dengan sudut kejadian tertentu dan sudut kritikal. Penghantaran cahaya melalui substrat kaca akan menjejaskan voltan output. Oleh itu, untuk mendapatkan sistem yang stabil substrat kaca disalut dengan Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) dan Agarose Gel sementara panjang kaca juga dioptimumkan. Selain itu, projek yang dicadangkan ini adalah untuk membuat platform substrat kaca yang disalut dengan Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) dan Agarose Gel untuk aplikasi penderiaan formaldehid. Panjang kaca memberi kesan kepada voltan keluaran perlu dioptimumkan. Projek ini telah mengesahkan cadangan eksperimen untuk permohonan penderiaan formaldehid. Voltan keluaran diperolehi daripada simulasi dengan menggunakan Arduino Uno.

TABLE OF CONTENTS

PAGE

DECLARATION

APPROVAL

DEDICATIONS

ACKNOWLEDGEMENTS **2**

ABSTRACT **3**

ABSTRAK **4**

TABLE OF CONTENTS **5**

LIST OF TABLES **7**

LIST OF FIGURES **9**

LIST OF SYMBOLS AND ABBREVIATIONS **11**

LIST OF APPENDIX **12**

CHAPTER 1 INTRODUCTION **13**
1.1 Motivation 13
1.2 Problem Statement 15
1.3 Objectives 16
1.4 Scope of Project 17
1.5 Report Outlines 18

CHAPTER 2 LITERATURE REVIEW **19**
2.1 Overview 19
2.2 Optical Sensor 19
2.3 Optical Sensor Application 21
2.3.1 Biomedical Application 22
2.3.2 Civil Infrastructure 24
2.4 Formaldehyde 25
2.5 Visible Light 26
2.6 Agarose Gel 27
2.7 Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) 28

CHAPTER 3 METHODOLOGY **29**
3.1 Introduction 29
3.2 Flowchart 30
3.3 Preparation of Coated Materials 32
3.3.1 Preparation for Agarose Gel 32
3.3.2 Preparation for Hydroxyethyl Cellulose/Polyvinylidene fluoride (HEC/PVDF) 33
3.4 Methodology of Fabricated Formaldehyde Sensing 34

3.4.1 The Flow Diagram of the Fabricated Sensor 34
3.4.2 The Model of Fabricated Sensor 36
3.5 Mechanism of the Formaldehyde Sensing 38

CHAPTER 4 RESULTS AND DISCUSSIONS 40
4.0 Introduction 40
4.1 Optimization of length of glass substrate 40
4.1.1 Glass Substrate coated with Agarose Gel 40
4.1.2 Glass Substrate coated with HEC/PVDF 43
4.2 Repeatability Test with the Length of Glass Substrate 45
4.2.1 Repeatability Test for the Uncoated Glass Substrate 45
4.2.2 Repeatability Test for the Glass Substrate Coated with Agarose Gel 48
4.2.3 Repeatability Test for the Glass Substrate Coated with HEC/PVDF 50
4.2.4 Comparison of Data for the Repeatability Test 53
4.3 The Trendline for the Uncoated, Agarose Gel and HEC/PVDF 54
4.3.1 The Trendline between Glass Substrate Coated with Agarose Gel vs HEC/PVDF 54
4.3.2 The Trendline between Uncoated Glass Substrate vs Glass Substrate Coated with HEC/PVDF 56
4.3.3 The Trendline between Uncoated Glass Substrate vs the Glass Substrate Coated with Agarose Gel 58
4.4 Hysteresis Curve 60
4.4.1 Hysteresis on Uncoated Glass Substrate 60
4.4.2 Hysteresis on Glass Substrate coated with Agarose Gel 61
4.4.3 Hysteresis on Glass Substrate coated with HEC/PVDF 63
4.5 Stability Test 64
4.5.1 Stability Test on Uncoated Glass Substrate 64
4.5.2 Stability Test on Glass Substrate Coated with Agarose Gel 65
4.5.3 Stability Test on Glass Substrate Coated with HEC/PVDF 67
4.6 The Time Response Time 68
4.6.1 Time Response Test for Uncoated Glass Substrate 68
4.6.2 Time Response Test for Glass Substrate Coated with Agarose Gel 70
4.6.3 Time Response Test for Glass Substrate Coated with HEC/PVDF 72

CHAPTER 5 CONCLUSION 75
5.1 Overview 75
5.2 Conclusion 75
5.3 Future Works 76

REFERENCES 77

APPENDICES 82

LIST OF TABLES

Table 4.1 The tabulated data for Output Voltage of the glass substrate coated with Agarose Gel 41

Table 4.2 The tabulated data for Sensitivity and Linearity of the Glass Substrate Coated with Agarose Gel 41

Table 4.3 The tabulated data for Output Voltage of the glass substrate coated with HEC 43

Table 4.4 The tabulated data for Sensitivity and Linearity of the Glass Substrate Coated with HEC 43

Table 4.5 The tabulated data for Output Voltage and Standard Deviation of the Uncoated Glass Substrate 45

Table 4.6 The tabulated data for Sensitivity, Linearity and Resolution of the Uncoated Glass Substrate 46

Table 4.7 The tabulated data for Average Output Voltage and Standard Deviation of the Glass Substrate Coated with Agarose Gel 48

Table 4.8 The tabulated data for Sensitivity, Linearity and Resolution of the Glass Substrate Coated with Agarose Gel 48

Table 4.9 The tabulated data for Average of Output Voltage and Standard Deviation of the Glass Substrate Coated with HEC 51

Table 4.10 The tabulated data for Average of Output Voltage and Standard Deviation of the Glass Substrate Coated with HEC 51

Table 4.11 The tabulated data of Uncoated, Agarose Gel and HEC for repeatability test 53

Table 4.12 The tabulated data for the Average Output Voltage for Glass Substrate Coated with Agarose Gel and HEC 54

Table 4.13 The tabulated data for the Sensitivity and Linearity of Glass Substrate Coated with Agarose Gel vs the Glass Substrate Coated with HEC 55

Table 4.14 The tabulated data of Average Output Voltage for Uncoated Glass Substrate vs the Glass Substrate Coated with HEC 56

Table 4.15 The tabulated data for Uncoated Glass Substrate vs the Glass Substrate Coated with HEC 56

Table 4.16 The tabulated data for Uncoated Glass Substrate vs the Glass Substrate Coated with Agarose Gel 58
Table 4.17 The tabulated data for Uncoated Glass Substrate vs the Glass Substrate Coated with Agarose Gel 58
Table 4.18 The tabulated data for Output Voltage of Forward and Reverse for Uncoated Glass Substrate 60
Table 4.19 The tabulated data for Output Voltage of Forward and Reverse for Glass Substrate Coated with Agarose Gel 62
Table 4.20 The tabulated data for Output Voltage of Forward and Reverse for Glass Substrate Coated with HEC 63

LIST OF FIGURES

Figure 1.1	Foods that contain formaldehyde	13
Figure 2.1	Snell's Law	20
Figure 2.2	Picture of Fibre optic Endoscope	22
Figure 2.3	Illustration of endoscopes application	23
Figure 2.4	Optical Fiber Sensor in Oil and Gas Industry	24
Figure 2.5	Wavelength based on colour of LED	26
Figure 3.1	The Concentration of the Formaldehyde solution	29
Figure 3.2	Flow chart for the process of project	31
Figure 3.3	The Agarose Gel	32
Figure 3.4	The Hydroxyethyl Cellulose/Polyvinylidene fluoride (HEC/PVDF) in gel texture	33
Figure 3.5	Flow Diagram of the Fabricated Sensor	35
Figure 3.6	a) glass substrate coated with Hydroxyethyl Cellulose /Polyvinylidene fluoride (HEC/PVDF) b) glass substrate coated with Agarose Gel	36
Figure 3.7	The Drawing of Fabricated Sensor Model	37
Figure 3.8	The Fabricated Formaldehyde Sensor	37
Figure 3.9	Block diagram of Formaldehyde Sensing Device	38
Figure 4.1	The Graph Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate Coated with Agarose Gel	42
Figure 4.2	The Graph Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate Coated with HEC	44
Figure 4.3	The Linearity Graph for the Average of Output Voltage vs Concentration of Formaldehyde for Uncoated Glass Substrate	46
Figure 4.4	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Uncoated Glass Substrate	47
Figure 4.5	The Linearity Graph for Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate with Agarose Gel	49
Figure 4.6	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate with Agarose Gel	50
Figure 4.7	The Linearity Graph for Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate Coated with HEC	52
Figure 4.8	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate Coated with HEC	52
Figure 4.9	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Glass Substrate Coated with Agarose Gel and Glass Substrate Coated with HEC	55
Figure 4.10	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Uncoated Glass Substrate and Glass Substrate Coated with HEC	57
Figure 4.11	The Graph for Average of Output Voltage vs Concentration of Formaldehyde for Uncoated Glass Substrate and Glass Substrate Coated with Agarose Gel	59
Figure 4.12	The Graph of Average Output Voltage vs The Concentration of Formaldehyde for Uncoated Glass Substrate	61

Figure 4.13 The Graph of Average Output Voltage vs The Concentration of Formaldehyde for Glass Substrate Coated with Agarose Gel 62
Figure 4.14 The Graph of Average Output Voltage vs The Concentration of Formaldehyde for Glass Substrate Coated with HEC 64
Figure 4.15 The Graph of Output Voltage vs The Time Taken for the Uncoated Glass Substrate 65
Figure 4.16 The Graph of Output Voltage vs The Time Taken for the Glass Substrate Coated with Agarose Gel 66
Figure 4.17 The Graph of Output Voltage vs The Time Taken for the Glass Substrate Coated with HEC 67
Figure 4.18 The Graph for Output Voltage vs The Time Taken for the Uncoated Glass Substrate 68
Figure 4.19 The Graph for Time Response of Output Voltage vs The Time Taken for the Uncoated Glass Substrate 69
Figure 4.20 The Graph for Time Recovery of Output Voltage vs The Time Taken for the Uncoated Glass Substrate 69
Figure 4.21 The Graph of Output Voltage vs The Time Taken for the Glass Substrate Coated with Agarose Gel 70
Figure 4.22 The Graph for Time Response of Output Voltage vs The Time Taken for the Glass Substrate Coated with Agarose Gel 71
Figure 4.23 The Graph for Time Recovery of Output Voltage vs The Time Taken for the Glass Substrate Coated with Agarose Gel 71
Figure 4.24 The Graph of Output Voltage vs The Time Taken for the Glass Substrate Coated with HEC 72
Figure 4.25 The Graph for Time Response of Output Voltage vs The Time Taken for the Glass Substrate Coated with HEC 73
Figure 4.26 The Graph for Time Recovery of Output Voltage vs The Time Taken for the Glass Substrate Coated with HEC 74

LIST OF SYMBOLS AND ABBREVIATIONS

ZnO	-	Zinc Oxide
TiO2	-	Titanium Dioxide
ppm	-	Parts per million
mg/kg	-	Miligram per kilogram
mg/d	-	Miligram per day
cm	-	Centimeter
TMAO	-	Trimethylamine Oxide
FOCS	-	Fiber Optic Chemical Sensor
HEC/PVDF	-	Hydroxyethyl Cellulose/Polyvinylidene Fluoride

LIST OF APPENDIX

APPENDIX A	PROGRAMMING CODE FOR ARDUINO UNO	82
APPENDIX B	GANTT CHART	84

CHAPTER 1

INTRODUCTION

1.1 Motivation

Formaldehyde is best known for its preservative and anti-bacterial properties but it is also a natural breakdown product that can be very harmful to human beings. The formaldehyde that being used in some food might contents higher level concentration and harmful towards human being. Though it is a harmful agent but human digestive system can digest in a certain level. This formaldehyde can be naturally found in foods for example fruits and veggies with a concentration of up to 300 to 400 mg/kg. There is no specific amount for daily consumption of formaldehyde for one person but the World Health Organization (WHO) has estimated it to be between 1, 5 and 14 mg/d for average adult and according to European Food Safety Authority (EFSA) the formaldehyde consumption should not exceed 100mg per day [1]. The higher contains of this chemical compound can cause food poisonous and a lot of diseases such as damage to liver and kidney, leukaemia and cancer. Figure 1.1 shows the foods that contain formaldehyde such as fish, foods and vegetables.

Figure 1.1 Foods that contain formaldehyde [1]

The main purpose of this project is to develop a formaldehyde sensing based on glass substrate platform. The main focus of this project is to detect different concentration level of formaldehyde in foods. This project is performed by conducting output voltage analysis from the proposed sensor when exposed to the different concentration level of formaldehyde (CH_2O). It also required the characterization and optimization of different length of glass substrate coated with Hydroxyethyl cellulose/ Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel to achieve the optimum length which produce the maximum output voltage. The sensing response is determined using several performance parameters such as sensitivity, linearity, response time, stability and hysteresis.

1.2 Problem Statement

The formaldehyde sensing is developed to detect the amount of the concentration level in food since this chemical compound can be harmful to the humans. It can also be used to prevent the food poisoning which could cause detrimental health effect to the human. This formaldehyde sensor could assist to ensure persons involve in this food industry comply the appropriate procedure in consuming allowable amount of formaldehyde. This is due to some irresponsible person in the food processing industry illegally put exceeding amount of formaldehyde to make their food look fresher and appealing in the market. This works also aims to detect the concentration amount more accurately and efficiently.

This proposed project employs the transmitted light and glass substrate as a platform which it exhibits several advantages such as a simple design, low-cost production and environmentally friendly device. It will use the glass substrate to transmitted light with a certain incident angle and critical angle. As the light transmit through the sensing region of the glass substrate, transmission losses would happen. The length of the glass substrate effects the output voltage. These parameters can experience changes because the light is defined by phase, intensity, frequency and polarisation [2]. This is mainly because behaviour of the light travel would be difference with difference glass substrate's length. As the exposed region varies when the length increase, output voltage would also change due to the interaction with the surround medium. The output voltage will affect the performance of the sensing device. In order to generate optimum output voltage, the length of the glass substrate need to be optimized.

The sensing response of the uncoated glass substrate is quite low due to small refractive index difference. In order to increase the sensing response, the glass substrate will be coated with a higher refractive index which is Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel. The porosity of agarose is high and allowing the gel to absorb moisture [3]. Besides that, Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel has a great transparency property and is capable of working in visible light. These properties could increase the interaction with the surround analyte and increase the

sensitivity performance of the proposed sensor. The sensing response for uncoated glass substrate produces a low performance and sensitivity as the output voltage produces losses is higher. To controlled this problem, the Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel been coated to the glass substrate will produces a good performance as the output voltage will reduces the losses.

The concentration level of formaldehyde will vary the output voltage produces. Higher formaldehyde concentration level will lower the output voltage due to light absorption around the sensing region. Therefore, this study will investigate the characteristic of the output voltage at the output of the proposed structure when exposed to different formaldehyde concentration level. Prior of that, the most optimum length of glass substrate will be optimized to produce maximum output voltage.

1.3 Objectives

The objectives for this project are:

i. To fabricate glass substrate platform coated with the polymer blend of Hydroxyethyl cellulose/ Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel for formaldehyde sensing application.

ii. To optically characterize and optimize the length of glass that effect the output voltage.

iii. To validate the proposed sensor for formaldehyde sensing application.

1.4 Scope of Project

The scopes for this project are stated as below:

i. The length of glass substrate will be optimized ranging from 1 cm to 7 cm.

ii. The work focuses on detection of difference concentration of Formaldehyde around 20% to 100%.

iii. The light source used as the input to the proposed sensor is a green Light Emitting Diode (LED).

iv. Analysis of the formaldehyde sensing is conducted based on output voltage that is monitor using Arduino Software.

1.5 Report Outlines

There are five chapters in this report that need to be completed. Each of the chapter contains of the progress of the project which are Introduction, Literature Review, Methodology, Results and Discussions and Conclusion and Recommendation. As in the Chapter 1, it is a briefing introduction to the project such as motivation, problem statement, objectives and scopes. In Chapter 2, it contains of the literature review which is need to explains anything related to the project in some research paper. Chapter 3 is a methodology part so in this chapter, it will discuss about the mathematical expression and method to be compared to the others researcher paper. In this chapter also will stated about how the project will be tested in theoretically. For results and discussions in chapter 4, it will explain the result and discussion on the method that being used can be proven with the theoretical assumption as stated in chapter or it does not work out as stated theoretically. Lastly, chapter 5 is conclusion and recommendation. In this part, it will conclude of the overall of the project that being carried out and the recommendation for the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will review topic related to the project such as optical sensor, optical properties and the applications of the optical sensor. Besides that, the materials and method used to analyse the optical sensor based on the others research paper will also be review.

2.2 Optical Sensor

Optical fiber is a very thin line of silica glass in geometry similar as human hair but in fact it is very a long glass cylinder with some special properties. The light travels will reach one end of the optical fiber until it leaves the other end of fiber [4]. The optical fiber contains of the core and for the cladding which have various refractive indexes [5]. The light beam passes across the core and repetitively bounces off the wall of the cladding and the light beam passed through the fiber without any reduction of light quantity is distributed at an angle of approximately 60° and delivered to the destination [6] as shown in Figure 2.1. Generally, refraction is the distortion of a wave of light. change in speed from one medium to another medium or a slight change in the medium [7]. The relationship between the incidence and refraction angle and indices of the two medium is known as Snell's Law [8]. The angle can be achieved by using the Snell's Law formula.

The Snell's Law formula [8] as below:

$$n_r \sin \theta_r = n_i \sin \theta_i$$

n_r = index of refraction of the refractive medium

n_i = index of incidence of the incident medium

sin θ_r = angle of refraction

sin θ_i = angle of incidence

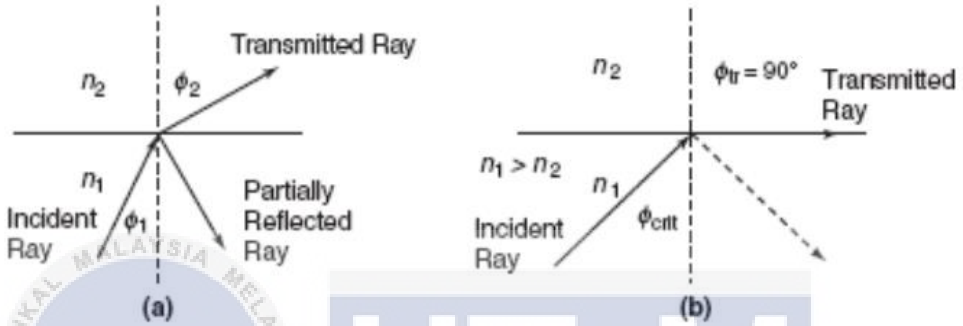

Figure 2.1 Snell's Law [6]

There are two types of optic fiber which is plastic type and glass type [9]. The glass type is usually used in optical technology [9]. The plastic form comprises a core of one or more acrylic-resin fibres which are roughly 0.25 to 1 mm in diameter and covered with a polyethylene sheath [10]. The advantages of the plastic type optic fiber are lightweight, save cost and flexible. For the optical fibre type glass, it contains of a diameter of approximately 10 to 100 um and is coated with stainless steel tubes which allow it to work at high temperatures [11]. The maximum temperatures that this glass fiber can operate is 350°C [11]. As the optical fiber sensor, it is a sensor that use the optical fiber as a sensing element which it can relays the signal from a remote system to the electronics through a transmitted light [6]. The optical fiber sensors are classified into two categories which are thru beam and reflective. The thru beam type consists of a transmitter and a receiver while the reflective type is a single unit that available in three type which are based on the shape of the cross sectional of the optical fiber [12]. The three types of reflective type are parallel, coaxial and separate. The parallel is usually used for plastic fiber type while the separate type consists of several glass fibers in diameter of 10µm and has