CHARACTERIZATION OF ZINC OXIDE COATED POLYMER OPTICAL FIBER FOR LIMONENE CONCENTRATION MEASUREMENT

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : CHARACTERIZATION OF ZINC OXIDE COATED POLYMER OPTICAL FIBER FOR LIMONENE CONCENTRATION

Sesi Pengajian : 2022/2023

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DEDICATION

This thesis is dedicated to the people who have supported me throughout my education. Thanks for making me see this adventure through to the end.

ABSTRACT

Limonene concentration detection based on ZnO coated polymer optical fiber (POF) by using the intensity modulation technique was proposed. Zinc oxide was prepared by using a hydrothermal method and to prove the success of ZnO coating, the POF surface morphology was observed by using Scanning Electron Microscope (SEM). The POF was tapered to a certain diameter by using the chemical etching method. The tapered waist diameters of the POF are 0.45 mm, 0.50 mm, 0.55 mm, 0.60 mm, 0.65 mm, and 0.70 mm at 10 cm fiber length, and the unclad length of 2 cm was coated with ZnO using the dip-coating method. The refractive index for different concentrations of limonene solution was studied in this project. It is observed that as the limonene concentration increase from 20% to 100%, the output voltage will decrease. The higher sensor's sensitivity was recorded at 0.205 V/%, and the slope has more than 99%, linearity for the 0.55 mm tapered POFs, respectively. Furthermore, the refractive index varied as the concentration of limonene changed.

ABSTRAK

Pengesanan kepekatan limonene berdasarkan gentian optik polimer bersalut ZnO (POF) dengan menggunakan teknik modulasi intensiti telah dicadangkan. Zink oksida telah disediakan dengan menggunakan kaedah hidroterma dan untuk membuktikan kejayaan salutan ZnO, morfologi permukaan POF telah diperhatikan dengan menggunakan Scanning Electron Microscope (SEM). POF ditiruskan kepada diameter tertentu dengan menggunakan kaedah etsa kimia. Diameter pinggang tirus POF ialah 0.45 mm, 0.50 mm, 0.55 mm, 0.60 mm, 0.65 mm, dan 0.70 mm pada panjang gentian 10 cm, dan panjang 2 cm yang tidak bersalut disalut dengan ZnO menggunakan kaedah salutan celup. Indeks biasan untuk kepekatan larutan limonene yang berbeza telah dikaji dalam projek ini. Adalah diperhatikan bahawa apabila kepekatan limonene meningkat daripada 20% kepada 100%, voltan keluaran akan berkurangan. Kepekaan sensor yang lebih tinggi telah direkodkan pada 0.205 V/%, dan cerun mempunyai lebih daripada 99%, leariti untuk POF tirus 0.55 mm, masing-masing. Tambahan pula, indeks biasan berubah apabila kepekatan limonene berubah.

ACKNOWLEDGEMENTS

I would like to praise and appreciate Allah Subhanahuwata'ala for giving me the time and strength during completing this Final Year Project.

I want to express my high appreciation and deepest gratitude to my supervisor, Dr. Hazura Binti Haroon for giving me the opportunity and trust, and also, I would like to thank her for her invaluable guidance, encouragement, and idea during completing this project.

Other than that, I would like to acknowledge with much appreciation to all my friends for their help all time during the experiment and for giving full support and recommendations throughout the process of completing it. Without her guidance and kindness, this project might not have been done on time.

Lastly, many thanks to my family for their support and faith in me by spending more time and money on this project. Same goes for my friends who help to assist me by giving me some ideas and supporting each other weaknesses during completing this project.

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LIST OF SYMBOLS AND ABBREVIATIONS

ZnO	:	Zinc Oxide
POF	:	Plastic Optical Fiber
RI	:	Refractive Index
Zn	:	Zinc
O	:	Oxygen
C	:	Carbon
Pt	:	Platinum
SEM	:	Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

1.1 Project Background

Plastic Optical Fiber, also known as POF is very useful, particularly for data transmission from one location to another. POF has been widely used because of its advantages such as high flexibility in bending, low cost, and high sensitivity[1]. For this project, POF was used as a sensor to detect the limonene concentration. At high doses, limonene can cause human diseases such as liver disease, breast cancer, and others. The use of a fiber as a sensor is a non-invasive method for detecting limonene inside the human body

The performance of the POF sensor can be increased by tapered the fiber at a certain length[2]. The waist diameter of the fiber was reduced so that a high portion of the evanescent field can travel inside the fiber[3]. ZnO is frequently used in sensing applications to enhance the sensing capability of the sensor. This is due to the high sensitivity of ZnO after the manual dip-coating technique ZnO [4]. ZnO has a direct wide bandgap of 3.37 eV, making it appealing for short-wavelength light-emitting devices [5]. There are many advantages of using ZnO as a sensing material such as high transmittance, good electrical conductivity, non-toxic and low cost[6]. As a result, ZnO has a wide range of applications, including biosensors, photodetectors, gas sensors, and many others [7]. Limonene or also known as d-limonene, l-limonene, and dl-limonene has been widely used as a flavor or fragrance for food and perfumes. At room temperature, limonene is a clear, colorless liquid [8]. This limonene can also be absorbed by humans and other mammals. It will quickly disperse in various organs and be converted into active metabolites [9].

1.2 Problem Statement

Limonene has been used for many years as a flavor in foods and beverages. In previous studies, it was reported that limonene at high doses caused several effects on human beings. Some experiments have been done on volunteers to dissolve gallstones by infusing limonene directly into the bile system, and pain in the upper abdomen, nausea, vomiting, and diarrhea was reported associated with increases in serum aminotransferase and alkaline phosphatase. To detect the limonene inside a human body, the equipment that has been used is quite expensive. To address this issue, this project employs a low-cost material called fiber optics. The goal of this study is to create a low-cost, high-sensitivity, and simple optical sensing technology for limonene concentration characterization, which is a bio-marker for the early detection of liver disease.

1.3 Objectives

a) To design a polymer optical fiber (POF) based sensor for limonene concentration characterization.

b) To enhance sensing capability of ZnO coated POF by hydrothermal method.

c) To analyze the sensor's performance for limonene detections in terms of sensitivity and linearity.

1.4 Scope of Work

For this project, the type of fiber that can be used is Polymer Optical Fiber (POF). Zinc oxide (ZnO) acts as a sensitive solution that used to be coated with POF. The method used to prepared ZnO is a hydrothermal method and to prove the successful coating of ZnO into the POF by using Scanning Electron Microscope (SEM). Some of the components used to estimate the output value for the limonene concentration from the photodetector are red LED, POF sensor, receiver circuit, and LCD to display the output. The tapered waist diameter of the POF is 0.45 mm, 0.50 mm, 0.55 mm, 0.60 mm, 0.65 mm, and 0.70 mm at the fiber length of 10 cm, and the unclad length of 2 cm was coated with ZnO.

1.5 Significant and Important

a) One of the benefits of using fiber as a based sensor for concentration characterization is low cost, easy to handle, and also good flexibility.

b) Many applications can be done using POF as a sensor-based that is coated with specific materials which are used in humidity measurement, detection of gas, and liquid levels.

1.6 Thesis Organization

Chapter 1 explained about introduction which includes the project description, problem statement, objective, scope of work, and significance and importance of this project. Chapter 2 explained the research results from a previous study that is relevant to this project. Some theoretical explanations related to this project have also been discussed in this chapter. Chapter 3 explained the whole process of the implementation to achieve the objective. All the equipment and the material used were discussed in detail. The experiment process of the tapered POF, ZnO coating by using a hydrothermal method, and the experimental setup for the sensor were explained in detail. All the result and the analysis of this project was explained in chapter 4. Chapter 5 was a summary of the whole project and suggestions for future work.

1.7 Summary

This chapter provides a description of the project, the main objectives, the scope of work for the whole process of the project, the thesis organization, and the significance and importance of this project.

CHAPTER 2

LITERATURE REVIEW

This chapter contains the research results from a previous study that is relevant to this project. These studies also serve as the primary source of information, with the theoretical, methodology, and interpretation of the studies assisting in the support of the project's material.

2.1 Limonene Characterization

Limonene is normally found in orange peels, lemon, and mint. It is colorless and clear and be classified as cyclic monoterpene that occurs naturally in nature. It contains 90-95% orange peel oil and 75% lemon peel oil [10]. Limonene can be absorbed quickly into the human body. It will transform it into an active metabolite that can be present in serum, liver, lung, and various parts of the human body[9].

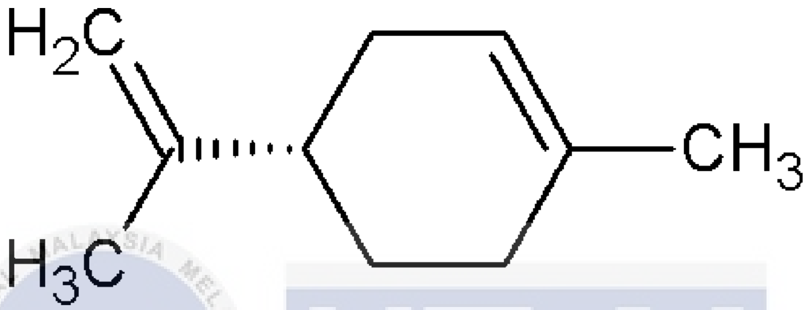

Figure 2.1 Chemical Structure of limonene.

In past research, some experiment has been done to determine the limonene in adipose tissue by using a gas chromatography-mass spectrometer (GC-MS). GC-MS was chosen for the experiment because it can measure the trace level of volatile, organic molecules, and this molecule will be considered a "gold standard." This equipment is sensitive, accurate, and precise for the quantification of limonene in adipose tissue. The sample of adipose tissue will be spiked with 30 µL of d-limonene calibration working standard. It will be incubated in the water bath at a temperature of 37°C for about 2 hours and 30 minutes with 200 µL of 30% potassium hydroxide. Then the sample will be analyzed using GC-MS at 300°C and held for about 5 minutes[11]. The result of the mass spectra of d-limonene from past research is shown in Figure 2.2.

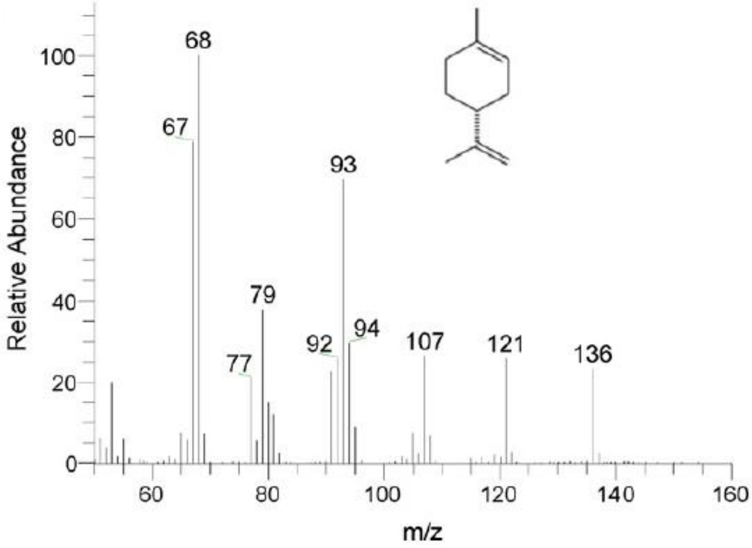

Figure 2.2 Mass spectra of d-limonene.

2.2 Polymer Optical Fiber (POF)

POF is made of polymers including polymethylmethacrylate (PMMA) and the core diameter and step-index of the commercial POF with typical core and cladding are 1.49 and 1.41, respectively[12]. Plastic Optical Fiber also known as POF have a lot of benefits such as flexibility, high fracture, and high sensitivity[1]. POF also can make a sensor to measure the distance from one place to another, location, color, brightness, and many more[13]. Some basic structures of POF with core, cladding, and coating (buffer), as shown in Figure 2.3. The process of tapering the plastic optical fiber is at the core.

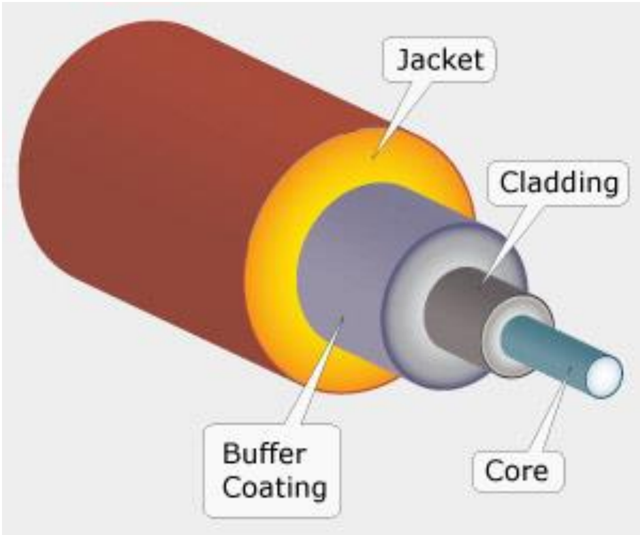

Figure 2.3 Basic structure of POF.

POF fiber must be tapered at a certain diameter to improve its performance. Fabrication of the fiber can be accomplished using acetone, de-ionized water, and sandpaper. Because the fiber is tapered, the power of the evanescent wave (EW) inside the POF cladding is increased when the diameter of the tapered POF is decreasing. Tapered POF is good to make as a sensing application especially when it is coated with appropriate material that can make it enhance at a correct thickness. Some of the optical parameters for this optical sensor to detect are refractive index (RI), absorbance, reflectance, and fluorescence depending on the application of the fiber[14]. When the tapered fiber is tapered at a good diameter, it can produce good sensitivity. From the last research, a diameter of 0.50 mm and below shows good performance compared to a diameter above 0.50 mm[2].

2.3 Zinc Oxide (ZnO)

Zinc oxide (ZnO) has unique characterization for physical and chemical properties. ZnO has good absorption of radiation and also high chemical stability. For use in short-wavelength optoelectronic applications, ZnO is a desirable material because has a direct bandgap of 3.3 eV at 300K, high transmittance, and good electrical