Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR CARBON DIOXIDE IN DIFFERENT CONCENTRATIONS USING A TAPERING METHOD

NUR HANIS SURAYA BINTI HASBULLAH

Bachelor of Electronics Engineering Technology with Honours

2022/2023

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NUR HANIS SURAYA BINTI HASBULLAH

A project report submitted
in partial fulfillment of the requirements for the degree of
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology with Honours

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DEDICATION

My special thanks go to my parents, siblings, and friends, who have always supported me and encouraged me to complete my final year project successfully. Meanwhile, I'm dedicating this thesis to my beloved supervisor, Dr. Aminah binti Ahmad, and co. supervisor Dr. Md Ashadi bin Md Johari who has given me a lot of guidance on how to achieve success for my final year project. Thank you very much. It means a lot to me. I am grateful for their inevitable sacrifice, tolerance, and consideration in making this effort feasible. I cannot provide the appropriate words that can accurately describe my appreciation for their loyalty, support, and belief in my ability to achieve my dreams.

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ABSTRACT

Fiber optics, commonly referred to as optical fiber, is a medium and system for transmitting information as light pulses over a glass or plastic strand. When light signals are transmitted through fiber optic cable, they bounce off the core and cladding in a sequence of zig-zag bounces, a phenomenon known as total internal reflection. Recently, optical microfiber sensors have received considerable research efforts due to their high sensitivity, detection speed, high flexibility and low optical power consumption. This research will focuses on the optimisation performance of tapered silica microfiber as an sensing platform. The microfiber optics sensor were developed to detect the concentrations of different CO2. The objective of this project was to use microfiber optics as a sensor to detect carbon dioxide (CO2) using a tapering method. Furthermore, the reduced diameter of the tapered section of the optical microfiber can be beneficial when measuring physical parameters. This project requires an understanding, development and analysis on different concentrations of CO2 sensors from optical loop microfibers and needs to know how to perform microfiber splicing, cutting, stripping and methods used. There will be five samples of different concentrations of CO2 tested. The experimental findings will be described in terms of sensitivity, correlation, and graphical determination coefficients, all of which depend entirely on the CO2 concentration and the light source. At the end of the project, an optical microfiber different concentration sensor with high sensitivity readings was formed. Next, the results were analysed using the factorial design method. This will determine which samples of different CO2 concentrations that has the optimum performance in terms of concentration.

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ABSTRAK

Gentian optik, biasanya dirujuk sebagai gentian optik, ialah medium dan sistem untuk menghantar maklumat sebagai denyutan cahaya ke atas helai kaca atau plastik. Apabila isyarat cahaya dihantar melalui kabel gentian optik, ia melantun dari teras dan pelapisan dalam urutan lantunan zig-zag, fenomena yang dikenali sebagai pantulan dalaman total. Baru-baru ini, penderia mikrofiber optik telah menerima banyak usaha penyelidikan kerana kepekaan yang tinggi, kelajuan pengesanan, fleksibiliti tinggi dan penggunaan kuasa optik yang rendah. Penyelidikan ini akan memberi tumpuan kepada prestasi pengoptimuman mikrofiber silika tirus sebagai platform penderiaan. Sensor optik mikrofiber telah dibangunkan untuk mengesan kepekatan CO2 yang berbeza. Objektif projek ini adalah untuk menggunakan optik mikrofiber sebagai sensor untuk mengesan karbon dioksida (CO2) menggunakan kaedah tirus. Tambahan pula, diameter kecil bahagian tirus mikrofiber optik boleh memberi manfaat apabila mengukur parameter fizikal. Projek ini memerlukan pemahaman, pembangunan dan analisis tentang kepekatan berbeza penderia CO2 daripada mikrofiber gelung optik dan perlu mengetahui cara melakukan penyambungan, pemotongan, pelucutan dan kaedah yang digunakan. Akan ada lima sampel kepekatan CO2 yang berbeza diuji. Penemuan eksperimen akan diterangkan dari segi kepekaan, korelasi, dan pekali penentuan grafik, yang semuanya bergantung sepenuhnya pada kepekatan CO2 dan sumber cahaya. Pada akhir projek, sensor kepekatan berbeza mikrofiber optik dengan bacaan kepekaan tinggi telah dibentuk. Seterusnya, keputusan dianalisis menggunakan kaedah reka bentuk faktorial. Ini akan menentukan sampel kepekatan CO2 yang berbeza yang mempunyai prestasi optimum dari segi kepekatan.

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LIST OF SYMBOLS

θ_1	-	The incident angle between the light beam and the normal
θ_2	-	The refractive angle between the light ray and the normal
n_1	-	The refractive index of the medium the light is leaving
n_2	-	Refractive index of the material the light is entering
v_1	-	is the speed of light at the first medium
v_2	-	is the speed of light at the second medium
λ	-	Wavelength
μm	-	Micrometer
nm	-	Nanometer
ηEF	-	Fraction of power
λ/r	-	Normalized wavelength
$\surd$	-	Square root
R^2	-	Coefficient of determination

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LIST OF ABBREVIATIONS

$CO2$	-	Carbon dioxide
dBm	-	Decibels per milliwatts
EMI	-	Electromagnetic interference
SMF	-	Single mode fiber
RI	-	Refractive index
FBG	-	Fiber bragg gratings
LPG	-	Long period grating
PCF	-	Photonic crystal fiber
MF	-	Microfiber
MMF	-	Multimode fiber
MCR	-	Microfiber coil resonator
MLR	-	Microfiber loop resonator
MKR	-	Microfiber knot resonator

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CHAPTER 1

INTRODUCTION

1.1 Background

Optical fiber were widely used in the field of telecommunications during the last century due to their special features, such as low transmission loss, high bandwidth, and multiplexing capability. Optical fiber applications have recently shifted to other areas such as sensing to take advantage of its unique properties. Despite the fact that established electronic sensors have lower prices, optical sensors may be able to find a target application by utilising their unique features. Low losses, remote sensing, immunity to electromagnetic interference, no electrical biassing is required to guide light, and the ability to use in an explosion risk environment are some of the special features.

Currently, optical fiber sensors are being pursued for a variety of bio-chemical sensing applications, including ethanol, sodium hypochlorite, formaldehyde, and human chorionic gonadotropin. It is driven by the rapid development of micro or nanotechnology and the need to reduce sensor size while maintaining the key requirements of the sensor such as low power consumption, faster response, better spatial resolution, and higher sensitivity.

Microfibers have unique features such as large optical confinement, configurability, flexibility, strong optical confinement and a large evanescent field, which make them ideal for physical sensing applications such as ultra-sensitive surface absorption spectroscopy, hydrogen detection, chemical and refractive index sensors. It is extremely sensitive to changes in the ambient refractive index because of the large evanescent wave propagating outward from the microfiber. The refractive index of the surrounding material rises as the proportion of power transmitted in the evanescent field increases. It has good evanescent coupling with metal, semiconductor, and substrate waveguides.

The purpose of this study is to develop the optical microfiber sensor to detect Carbon dioxide (CO2) using a tapering method. An SMF28 optical cable or fiber optic pigtail under test, a laser source with a wavelength of 1550nm, an Optical Power Level and Optical Power Meter, and five samples of different concentrations of CO2 are required for this project. There will be five samples of different concentrations of CO2 tested, with the results being the loss (dBm) at the peak of the spectrum obtained with the Optical Power Level and Optical Power Meter equipment. The outcome of the experiment will be described in terms of sensitivity, correlation, and graph coefficient of determination, all completely dependent on the CO2 concentration and light source.

1.2 Problem Statement

The purpose of this study is to analyse the performance of microfiber optics as a gas sensor in detecting CO2 of three different concentrations using a tapering method. Human activities such as deforestation, coal and tree combustion have increased the concentration of CO2 in the atmosphere. CO2 concentrations are rising because of the fossil fuels that people use for energy. According to studies, human activities contribute up to 110.5 million tons of CO2 to the atmosphere every day [1]. The carbon dioxide at a normal level will not show more impact on the environment. However, when it increases due to some human activities, it will show more impact on global warming. Too much carbon dioxide can also be harmful to one's health. This includes dizziness, headaches, restlessness, difficulty breathing, tiredness, and increased heart rate. For each different concentration of CO2 gas released has its own results of the concentration, thus it will determine the reading value due to the different concentrations of CO2 at the highest sensitivity.

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Next, there are numerous sensors available for measuring of different concentration, particularly when employing electronic devices. Despite the fact that electronic sensors perform well in practise, they are not user-friendly due to their flammability due to electromagnetic interference (EMI). This difficulty can be remedied by utilising a microfiber optic sensor composed of silica glass, which is EMI resistant. During the monitoring procedure, it solely employs light pulses to send the signal. As a result, no EMI from the environment will impair its performance.

Besides, to monitor the different concentration, the electronic sensor requires a large amount of power. The cost of employing a microfiber optic sensor, on the other hand, can be decreased because it only requires a tiny amount of electricity to provide the optical power source for detection. Therefore, the idea development of microfiber optic sensor is to determine which measurements require a low or high sensitivity. As a result, an optical microfiber sensor will be used in this investigation to analyse and check the performance of five different samples of concentrations using a tapering method.

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1.3 Project Objective

The objectives are stated as below:

a) To study microfiber optics as a gas sensor to detect Carbon dioxide (CO_2).

b) To develop the microfiber optics as a gas sensor to detect Carbon dioxide (CO_2) using atapering method.

c) To analyse the performance of microfiber optics as a gas sensor in detecting Carbon dioxide (CO_2).

1.4 Scope of Project

Scope of this project mainly focused on develop the microfiber optics as a gas sensor to detect carbon dioxide (CO2) using a tapering method. The performance of the developed sensors will also be evaluated. A coating length of several cm is removed from the Single Mode Fiber (SMF) to fabricate tapered fiber. Then, microfiber optic sensor is spliced using a commercial splicer Fujikura FSM-18R. The fibers are cleaned with alcohol to remove dust and cleaved with a Fujikura CT-30 Fiber Cleaver to obtain a smooth cleavage surface and clean end-uncoated fiber before the sensors are spliced. The 1550nm input wavelength was collected from an Optical Power Level source during the testing process, and the output signal was measured in (dBm) units using an Optical Power Meter.

Next, the splicer connects the two fiber optics by splicing the sensors together. Then, for each microfiber optic sensor, an Optical Power Level supply and an Optical Power Meter are connected to detect and analyse different concentrations of CO2. Furthermore, three samples of different concentrations of CO2 are ready to be placed into airtight container. As a result, there are four processes in this project for testing the different concentration of CO2. The tapered silica microfiber is tested using the sensors created as part of this project. By utilising an Optical Power Meter, the findings are converted to watts (dBm). This project gurantees that the project is moving in the right path to achieve its objectives.

Table 1.1 Equipment used during this project

Equipment	Experiment Details
Airtight plastic container	Used to trap the CO2 through the experiment
Microfiber optic	Single mode fiber (1550nm)
Gas	Carbon dioxide (CO2)

Impra board	To lay the tapered silica fiber
Straw	The medium used to released the CO2 gas through respiration into the airtight plastic container that containing tapered silica microfiber
Plasticine	The medium used to tightly compress the airtight container so that no air can get in or out
Hardware	Optical Power Meter Optical Power Level/Source (1550nm) Commercial Splicer Fujikura FSM-18R Fujikura CT-30 Fiber Cleaver

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