Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF DOUBLE SIDE-POLISHED TAPERED PLASTIC OPTICAL FIBER SENSOR FOR HUMIDITY APPLICATION

NURUL HASANAH BINTI IBRAHIM

Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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DEVELOPMENT OF DOUBLE SIDE-POLISHED TAPERED PLASTIC OPTICAL FIBER SENSOR FOR HUMIDITY APPLICATION

NURUL HASANAH BINTI IBRAHIM

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(COP DAN TANDATANGAN PENYELIA)

SITI HALMA BINTI JOHARI
Pensyarah Kanan (DS52)
Jabatan Teknologi Kejuruteraan Elektronik dan Komputer
Fakulti Teknologi Kejuruteraan Elektrik dan Elektronik
Universiti Teknikal Malaysia Melaka

Tarikh: 26/01/2023

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DECLARATION

I declare that this project report entitled "Development of Double Side-Polished Tapered Plastic Optical Fiber Sensor for Humidity Application" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

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DEDICATION

To my beloved parents, Ibrahim bin Basar and Almarhumah Rokiah binti Awang, and my siblings, who have always been there for me and supported me throughout my studies and also during my bachelor's degree project.

I would also like to express my appreciation and give special thanks to my supervisor, Ts. Siti Halma binti Johari, who has been helpful with stimulating suggestions and encouragement and has helped me coordinate my project as well as the writing of this report.

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ABSTRACT

Humidity levels that are too low might have a negative influence on human health and the environment. Humidity levels that are too high might lead to mould, wetness and also can affect electronics. Humidity sensing is important in a variety of sectors, including industrial processes, agriculture, engineering, medicine, and more. Humidity is a measurement of how much water vapour is present in the air. The amount of water in the air is measured in relation to the greatest amount of water vapour in the atmosphere (moisture). Plastic optical fibers (POF) are a material that can be used as a humidity sensor element. This report examines a simple and small optical fiber that uses a tapered plastic optical fiber (POF) in a U-shape design and is based on modulated light intensity. This project's purpose is to develop a low-cost sensing device for humidity sensing applications. To get the waist diameters of POF for 400 µm, 500 µm, 600 µm, and 700 µm, the POF was tapered manually using a polishing method employing sand paper with a 3 cm tapering length to reduce the waist diameter of the POF. To discover the ideal tapered waist diameter and evaluate how effectively the proposed structure could perceive, three distinct wavelengths of 470 nm, 530 nm, and 645 nm were used in this project. A substantial reaction was recorded for humidity concentration values ranging from 35% RH to 80% RH. This project's data analysis includes repeatability, trendline, hysteresis, stability, sensitivity, linearity, and resolution. For the proposed sensor, 500 µm is the best waist diameter, and the best wavelength of 645 nm has been chosen.

Keywords: Plastic optical fiber, Taper, U-Shaped, relative humidity (RH).

ABSTRAK

Tahap kelembapan yang terlalu rendah mungkin mempunyai pengaruh negatif terhadap kesihatan manusia dan alam sekitar. Tahap kelembapan yang terlalu tinggi mungkin membawa kepada kulat, kebasahan dan juga boleh menjejaskan elektronik. Pengesanan kelembapan adalah penting dalam pelbagai sektor, termasuk proses perindustrian, pertanian, kejuruteraan, perubatan dan banyak lagi. Kelembapan ialah ukuran berapa banyak wap air yang terdapat di udara. Jumlah air di udara diukur berhubung dengan jumlah terbesar wap air di atmosfera (lembapan). Gentian optik plastik (POF) adalah bahan yang boleh digunakan sebagai elemen sensor kelembapan. Laporan ini mengkaji gentian optik ringkas dan kecil yang menggunakan gentian optik plastik tirus (POF) dalam reka bentuk bentuk-U dan berdasarkan keamatan cahaya termodulat. Tujuan projek ini adalah untuk membangunkan peranti penderiaan kos rendah untuk aplikasi pengesan kelembapan. Untuk mendapatkan diameter pinggang POF untuk 400 µm, 500 µm, 600 µm, dan 700 µm, POF ditiruskan secara manual menggunakan kaedah penggilap menggunakan kertas pasir dengan panjang tirus 3 cm untuk mengurangkan diameter pinggang POF. Untuk mengetahui diameter pinggang tirus yang ideal dan menilai sejauh mana keberkesanan struktur yang dicadangkan dapat dilihat, tiga panjang gelombang berbeza 470 nm, 530 nm, dan 645 nm telah digunakan dalam projek ini. Tindak balas yang besar telah direkodkan untuk nilai penumpuan kelembapan antara 35% RH hingga 80% RH. Analisis data projek ini termasuk kebolehulangan, garis arah aliran, histerisis, kestabilan, kepekaan, kelinearan dan resolusi. Untuk sensor yang dicadangkan, 500 µm ialah diameter pinggang terbaik, dan panjang gelombang terbaik 645 nm telah dipilih.

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CHAPTER 1

INTRODUCTION

1.1 Background

Plastic optical fiber, also known as polymer optical fibre or POF, is a plastic optical fiber. It typically consists of fluorinated polymers as the cladding material and PMMA (acrylic) as the core, which promotes light transmission (96% of the cross section in a fibre 1 mm in diameter) [1]. Plastic optical fiber emits a harmless green or red light that is visible to the human eye. Plastic optical fibers is more durable and flexible than glass fiber.

1.2 Problem Statement

The equipment being built is lightweight and portable, thanks to recent technical advancements. The experimental setup is the issue here. The current optical fiber sensor is big and expensive to manufacture. Because the cost of glass optical fiber is higher than that of plastic optical fiber, choosing based on optical fiber quality could have an impact on cost.

1.3 Project Objective

i. To design LED light source and phototransistor circuits for Plastic Optical Fiber (POF).
ii. To optically characterize and optimize the polished fiber waist diameter.
iii. To validate experimentally the sensing application of the humidity sensor.

1.4 Scope of Project

The primary aim of this project is to use U-shaped tapered Plastic Optical Fiber (POF) with specific taper waist diameter, taper length, and bend radius to accurately measure the humidity. The waist diameters of polished POF were 400 µm, 500 µm, 600 µm, and 700 µm. The taper length was 3 cm, and the fiber was bent into a 3 cm radius. The light source has a parameter of LED wavelengths that is 470 nm for blue, 530 nm for green, and 645 nm for red. POF were exposed to relative humidity (RH) ranging from 35% to 80%. The output measurement for sensing performance is voltage (V). Sensitivity, linearity, average standard deviation, resolution, responsiveness, and stability are all sensor qualities. Relative humidity is the focus of the application.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The journal, the researcher, and the article about similar projects, past analyses, and comparisons between methodologies, analyses, and approaches will be the subject of this chapter. This chapter covers everything there is to know about plastic optical fibre sensors and humidity applications.

2.2 Related Previous Work

2.2.1 "Enhance sensitivity of plastic optical fiber sensor by spiral configuration for body temperature applications" by A Arifin, K R Amaliyah, A K Lebang, N Hamrun, S Dewang, and D Tahir (2020).

Optical fibres have been used in a number of research projects, including the use of Fiber Bragg Grating (FBG) sensors to measure body temperature during radio frequency medical therapy. The downsides of this tool include its high cost and low precision. To monitor body temperatures with a complex connection process, a Mach-Zehnder interferometer is used to measure temperature. The temperature sensor is based on a low-sensitivity Long Period Grating (LPG) optical fibre. FBG, which focuses on sensor sensitivity, is used in the body temperature sensor. The disadvantages of this sensor are its high cost and limited sensitivity. Another study used multicore optical fibre to assess temperature, but the methods were difficult.

Sensors to assess body temperature were produced utilising a macro-bending analysis based on POF in this journal. Variations in diameter and bend number cause fibre optic sensors to form a spiral pattern. The body temperature sensors are positioned under the armpit and attached to an elastic cloth. Body temperature affects the light from an LED sent into an optical fibre sensor, resulting in power loss in the sensor. The phototransistor and differential amplifier receive less light as a result of power loss [2]. The Arduino Uno microcontroller will display the sensor's power loss and temperature measurement information on the computer. The temperature range chosen was 28°C to 42°C. The best sensor characteristic values were found in a spiral arrangement with four bends and a diameter of 0 cm. The range values of 0.421 V, sensitivity of 30.071 mV/°C, and resolution of 0.033 °C are the best results recorded. The sensor's properties improve as the spiral's diameter decreases and the number of bends increases. The temperature sensor's sensitivity can be improved by using POF. This sensor is ideal for sensing body temperature because of its high sensitivity, low cost, ease of manufacture, and straightforward measurements.

2.2.2 "Plastic Optical Fibers: An Introduction to Their Technological Processes and Applications" by Joseba Zubia and Jon Arrue (2001).

As recently expressed, POFs enjoy a few huge upper hands over their glass partners. On account of their colossal measurement, which goes from 0.25 to 1 mm, low-accuracy plastic connectors can be used, bringing down the framework's overall cost. POFs are likewise remarkable for their expanded adaptability and resilience to shocks and vibrations, as well as the expanded light coupling from the light source to the fiber. Due to these benefits, an extensive variety of POF applications have been created and popularized, ranging from essential light transmission guides in presentations to sensors and broadcast communications links.

POFs are very flexible waveguides made of almost transparent dielectric materials that are used in optical communications. These fibres have a circular cross-section that can be divided into three layers. The core, cladding, and jacket, a protective cover, are the three layers. Specifically highlight that optical fibres' flexibility and small size enable them to attain high sensitivity without taking up a lot of space. Besides, a POF has been displayed to identify a large number of elements, including temperature, moisture, tension, natural and inorganic compound presence, wind speed, and refractive record. Then again, POF-based optical sensors lessen the gamble of electric flashes in dangerous conditions and can be perused from a far distance.

The most important characteristics of POFs are discussed, including the many varieties of POFs, how they are made, and what applications they may have now and in the future. Discussions include topics such as their bandwidth, absorption, and the effect of outside variables. These fibres are using in short-haul communications networks in place of glass fibres because they are simple to handle, adaptable, and affordable. Because of these advantages, a wide range of POF applications have been developed and marketed, ranging from simple light transmission guides to sensors and telecommunications cables. This journal provides a thorough overview of POFs. Furthermore, the large number of references makes additional research on the issue easier [3].

2.2.3 "POF-Type Optic Humidity Sensor and Its Application" by Osamu Suzuki, Masahiro Miura, Masayuki Morisawa and Shinzo Muto (2002).

A simple POF-type humidity sensor based on the structure change from leaky-POF to guided-POF was confirmed to work over a wide humidity range and can be employed as a breathing-condition monitor by employing a mixture of swelling polymers.

Certain types of polymers generate swelling by attracting water molecules and altering their refractive indices, as is well known. Therefore, by using these polymers as just a cladding material for POF, the POF-type humidity sensor unit may be easily produced. It acts as a leaky-type POF in this sensor head if the refractive index of the cladding layer is configured to be somewhat higher than that of the fibre core. When exposed to water vapour, however, the cladding layer's refractive index begins to fall and falls below that of the core. The POF structure then changes to guided mode, and the light intensity travelling through the sensor head increases dramatically. Create a humidity sensor of the POF type based on this method, utilising a combination of inflating polymers [4]. To modify the cladding layer's refractive index and response time, the expanding polymer mixing ratio was established through experimental testing. These cladding polymers were dissolved in EtOH:H20 = 1:1 or DMSO:H20 = 1:1 solutions and then dip-coated onto a PMMA (n=1.49) plastic fibre core with a diameter of 1 mm. The sensor heads were trimmed to a length of 5–6 cm, and the cladding layer thickness was varied from 1 to 51 metres. The sensor head was linked to the regular POFs after polishing both ends, as illustrated in Figure 2.1," Head structure of a POF-type humidity sensor."

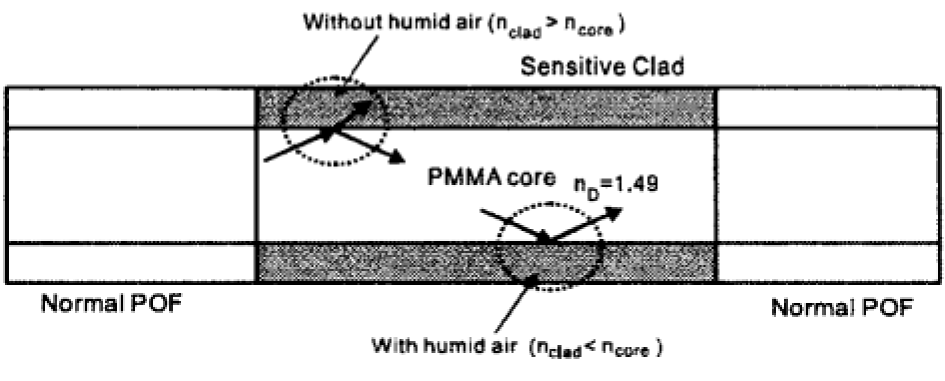

Figure 2. 1 Head structure of POF-type humidity sensor.

Researchers have looked at the POF-type simple optic humidity sensor, which is based on the POF structure changing from thermal sensors to being guided by the adaptation of water molecules. As a result, the provided sensors performed well throughout a wide humidity range. Furthermore, a connection to a respiratory condition monitor is now possible.

2.2.4 "Humidity and Isopropyl Alcohol Detection Sensor Based on Plastic Optical Fiber" by Lorant A. Szolga (2021).

The capabilities of plastic optical fiber for the detection of humidity and of isopropyl alcohol as a high-risk combustible chemical were examined in this journal. Optical fibre sensors have found success in a variety of industries where sensitivity and precision are critical. Electronic sensors are prohibited in combustible materials where electricity is a real threat. Optical fiber-based sensors are more than welcome in these circumstances. Glass optical fibers have already proven to be highly accurate in monitoring a variety of factors, ranging from mechanical (elongation, pressure) to temperature and humidity. The high cost of the interrogator and the specialist manpower required to instal and maintain these glass fiber sensors are disadvantages. A basic, low-cost system that runs with good precision and sensitivity is a useful solution in some instances. By constructing a proper testing environment, this research was able to demonstrate the operation of the plastic optical fiber in comparison to an electronic humidity sensor. Also, it was shown how sensitive an optical fiber-based sensor is to isopropyl alcohol vapours.

This journal study demonstrated the sensitivity of a plastic optical fibre as a humidity sensor if certain well-defined conditions were met, such as the use of an infrared LED and photodetector for transmitting and receiving light over the fiber; good connection and alignment of the fibre by polishing out the cladding; and at least 2 cm of the fiber's core exposed to the surrounding medium [5].

2.2.5 "Humidity Sensing using Plastic Optical Fibers" by C. M. Tay, K. M. Tan, S. C. Tjin, C. C. Chan, and H. Rahardjo (2004).

This journal shows how to measure relative humidity using plastic optical fibres (POFs) curved at the sensor area and coated with cobalt chloride (CoCl2) and gelatin as the overlay material. The sensitivity of the sensor is hugely affected by the fiber-core diameter and bending radius of the sensing site. Figure 2.2 depicts the experimental setup employed for relative-humidity sensing using POF.

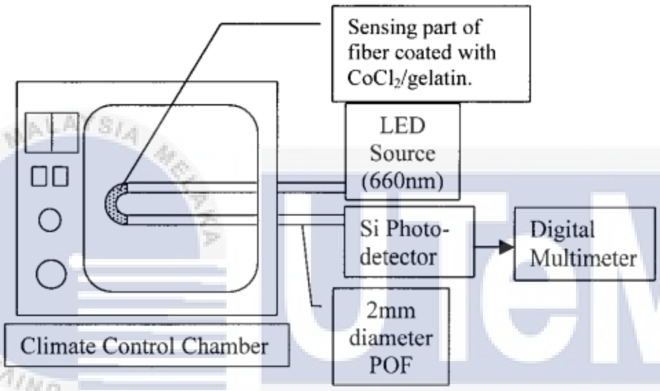

Figure 2. 2 Experimental setup for relative-humidity sensing using POF.

It was discovered that increasing the fibre diameter makes the evanescent wave stronger, enhancing the sensor's sensitivity [6]. The sensitivity of the sensor is also affected by the radius, with smaller radii resulting in greater evanescent wave penetration depths in the absorption film. This causes more light absorption and, as a result, a higher optical-intensity modulation. Some difficulties, such as light coupling into and out of the fibre and bending loss due to handling, must be handled before the sensor can be used efficiently.

2.2.6 "All Plastic Optical Fiber-based Respiration Monitoring Sensor" by Wern Kam, Waleed S. Mohammed, Gabriel Leen, Kieran O' Sullivan, Mary O'Keeffe, Sinead O'Keeffe and Elfed Lewis (2017).

The humidity change during intake and exhalation has been detected using a fluorescent plastic optical fibre as a humidity sensor in a breathing-condition monitor. A respiratory monitoring sensor made entirely of plastic optical fibres was developed in this study. The input and output plastic optical fibers (POF) are housed in 3-D printed sections with a flexible part in between to allow for movement changes in the chest or other site of attachment during respiration. The sensor is small and compact, and it can be worn near the lung and diaphragm in any section of the upper body.

To precisely measure the human respiration signal, an all-plastic, non-invasive optical fibre respiration monitoring sensor was created in this paper. The sensor is tiny enough to be worn on the body and detects the signal of various breathing patterns. For individuals (patients) in a sitting and lying posture, the sensor output was compared with a commercial device, and the results showed satisfactory agreement. For both normal breathing and chest breathing, the measurements of respiration rate recorded with the POF and a commercial sensor varied by up to 4% [7]. The sensor's all-plastic architecture permits it to be used in potentially hazardous electromagnetic environments, such as during MRI scans.

2.2.7 "Parallel Polished Plastic Optical Fiber-Based SPR Sensor for Simultaneous Measurement of RI and Temperature" by Lian Liu, Jie Zheng, Shijie Deng, Libo Yuan and Chuanxin Teng (2021).

A parallel polished plastic optical fiber (POF)-based surface plasmon resonance (SPR) sensor for simultaneous measurement of refractive index (RI) and temperature is proposed and