

# **Faculty of Electrical and Electronic Engineering Technology**



Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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# DEVELOPMENT OF SINGLE SIDE POLISHED PLASTIC OPTICAL FIBER INTENSITY-BASED SENSOR FOR HUMIDITY DETECTION

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A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours



# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

# DECLARATION

I declare that this project report entitled "DEVELOPMENT OF SINGLE SIDE POLISHED PLASTIC OPTICAL FIBER INTENSITY-BASED SENSOR FOR HUMIDITY DETECTION" 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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# 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 (Industrial Electronics) with Honours.

Signature : Supervisor Name TS. SITI HALMA BINTI JOHARI : Date 12 / 2 / 2023 ..... . . . . . . . . UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# DEDICATION

I dedicate my dissertation work to my family and my friends. A special feeling of gratitude to my loving parents, BAKAR BIN JAFFAR and SITI BINTI KARTIJAN whose words of encouragement and push for tenacity ring in my ears. My sisters NOOR BASYAH BINTI BAKAR, NOOR BAEYAH BINTI BAKAR and my brother MOHAMAD AMIR BIN BAKAR have never left my side and are very special. I also dedicate this dissertation to my friends FIRDAUS AMEEN and NURUL HASANAH who have supported me throughout the process. I will always appreciate all they have done.



#### ABSTRACT

The purpose of this investigation is to explain a straightforward and compact optical fiber that makes use of a tapered plastic optical fiber (POF) that has a design in the shape of a U. The optical fiber transmits data using a system that allows for the intensity of the light to be varied. POF is a type of optical fiber in which the core material is polymethyl methacrylate (PMMA), which allows light to pass through it. POF can also be used in sensing. POF is superior to silica fiber in a number of ways, including the fact that it can be stretched further before breaking, the fact that its component parts are simpler and cheaper, and the fact that it is also lighter. POF are a promising substrate for low-cost sensing because of their enormous core size, which allows evanescent waves to be coupled. This project's purpose is to develop a low-cost sensing device for humidity sensors. The POF was modified using chemical etching technique with a three cm tapering length was used to lower the waist diameter of POF at 400, 500, 600, and 700 um. A single side polished POF was tapered with sand paper until the waist diameter achieved. An experiment was conducted with the purpose of finding the optimal taper waist diameter and evaluating the sensing performance of the suggested structure. The experiment used two separate wavelengths, 470 nm (Blue) and 645 nm (Red). The POF was bending into a U-shape and increasing the decrease of tapered POF waist diameter will increase the number of total internal reflection (TIR) events, resulting in more evanescent wave (EW) contact with the environment, but will also increase light leakage. The data analysis that will be taken in this project is optimization number of layers, repeatability, stability and resolution. The best waist diameter with the best wavelengths will be taken for the proposed sensor.

Keywords: Plastic optical Fiber, Taper, U-Shaped, Evanescent wave

#### ABSTRAK

Laporan ini menjelaskan serat optik sederhana dan ringkas berdasarkan intensitas cahaya termodulasi yang memanfaatkan serat optik plastik meruncing (POF) dalam konstruksi bentuk-U. POF adalah jenis serat optik di mana bahan intinya adalah polymethyl methacrylate (PMMA), yang memungkinkan cahaya melewatinya. POF juga dapat digunakan dalam penginderaan. POF memiliki keunggulan dibandingkan serat silika karena dapat diregangkan lebih jauh tanpa putus, ia memiliki komponen yang lebih sederhana dan lebih murah, dan lebih ringan. POF adalah substrat yang menjanjikan untuk penginderaan berbiaya rendah karena ukuran intinya yang sangat besar, yang memungkinkan gelombang evanescent untuk digabungkan. Tujuan proyek ini adalah untuk mengembangkan perangkat penginderaan berbiaya rendah untuk sensor kelembaban. POF dimodifikasi menggunakan teknik etsa kimia dengan panjang lancip tiga cm digunakan untuk menurunkan diameter pinggang POF pada 400, 500, 600, dan 700 um. POF satu sisi yang dipoles meruncing dengan kertas pasir sampai diameter pinggang tercapai. Dua panjang gelombang berbeda 470 nm (Biru) dan 645 nm (Merah) digunakan dalam percobaan untuk mengoptimalkan diameter pinggang lancip dan menguji kinerja penginderaan dari struktur yang diusulkan. POF membungkuk menjadi bentuk-U dan meningkatkan penurunan diameter pinggang POF yang meruncing akan meningkatkan jumlah peristiwa refleksi internal total (TIR), menghasilkan lebih banyak kontak gelombang evanescent (EW) dengan lingkungan, tetapi juga akan meningkatkan kebocoran cahaya. Analisis data yang akan dilakukan dalam proyek ini adalah optimasi jumlah layer, repeatability, stability dan time response. Diameter pinggang terbaik dengan panjang gelombang terbaik akan diambil untuk sensor yang diusulkan.

Kata Kunci: Serat optik plastik, Lancip, Berbentuk U, Gelombang evanescent

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# LIST OF SYMBOLS

- um Micrometer
- nm Nanometer
- cm Centimetre
- °C Celcius
- % Percentages



# LIST OF ABBREVIATIONS

POF	- Plastic Optical Fiber
PMMA	- Polymethyl Methacrylate
TIR	- Total Internal Reflection
EW	- Evanescent Wave
EM	- Electromagnetic
RI	- Refractive Index
HEC/PVDF	- Hydroxyethylcellulose / Polyvinylidenefluoride
RH	- Relative Humidity
U-LMR	- U-Shaped Lossy Mode Resonance
FWHM	- Fullwidth at Half-Maximum
CMC	- Critical Micelle Concentration
Linac	Linear Accelerator
IDE	- Integrated Development Environment
LED	- Light-Emitting Diode
NodeMCU	- Node MicroController Unit
SoC	- System-on-a-Chip
Pws	UNINDenominator EKNIKAL MALAYSIA MELAKA

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# **CHAPTER 1**

#### INTRODUCTION

#### 1.1 Background

The term "plastic optical fiber," which is abbreviated as "POF," refers to an optical fiber that is constructed out of plastic. It is the polymethyl methacrylate (PMMA) core of the photonic optical fiber (POF) that makes it possible for the fiber to be utilized for the purpose of light transmission. In addition to that, POF can be utilized for sensing purposes. POF is superior to silica fiber because it can be stretched to greater lengths before breaking, its component parts are simpler and less expensive, and it weighs less than silica fiber. POF, or plastic optical fiber, is sometimes referred to as consumer optical fiber because, in comparison to glass optical fiber, it is both more affordable and less complicated. POF are an ideal substrate for low-cost sensing due to their large core size, which permits the coupling of evanescent waves. POF are simple to add into a textile. They are resistant to electromagnetic (EM) radiation and do not generate heat. Furthermore, the apparent transmission windows for POF span from 520 to 780 nm. In light of this fact, applications for POF are limited to short distances of a few hundred meters or less, in contrast to those for glass, which can extend for hundreds of kilometers [1].

Optical fibers are currently widely available for use in a variety of applications, including those requiring sensors with a broad spectral range and serving as transmission media. A dielectric substance that is transparent is often used for an optical fiber's core, whereas a material with a lower refractive index is used for the cladding. The difference in index of refraction between the core and the cladding is what gives total internal reflection its name. TIR helps prevent contamination and reduces crosstalk between fibers because of this disparity. Core and cladding layers are typical components of optical fibers. The core transmits the signal and has a different index of refraction than the cladding. In order to safeguard the core, the optical signal is encased and transferred within it. POF has a significantly larger diameter than conventional optical fiber, resulting in slower data transmission speeds. This makes it perfect for short-distance transmission of signals with a large bandwidth. Plastic fiber, unlike glass,

can be easily cut and bent to fit into tight spaces, and its larger core enables it to continue functioning even when broken. POF is utilized for a range of applications, including industrial controls, automobiles, sensors, and short data lines.

#### **1.2 Problem Statement**

Some of the problems are coming from the experimental setup, which is complicated and expensive due to the present optical fiber sensor. The next issue involves fiber properties, which include the high cost of glass fiber compared to plastic fiber. Next, there's the sensor modification, which uses electrochemical sensors with a limited temperature range. Furthermore, straight structures allow for less evanescent wave penetration into the fiber's cladding region, resulting in less sensitivity to the external environment.

# 1.3 Project Objective AYSIA

The primary objective of this project is to design a systematic and effective approach for developing a Single Side Polished Plastic Optical Fiber Intensity-Based Sensor for Humidity Detection using a suitable methodology. The following are the specific objectives:

- a) To develop a device for humidity sensing applications.
- b) To optically characterize and optimize the polished fiber waist diameter.
- c) To validate experimentally the sensing application of the humidity sensor. UNIVERSITITEKNIKAL MALAYSIA MELAKA

# **1.4 Scope of Project**

The primary aim of this project is U shaped taper POF has 3 parameter which is taper waist diameter with only scope 400, 500, 600, and 700 um. The second of the parameter is taper length with only scope 3 cm. The third of the parameter is bend radius with only scope 3 cm. The light source parameter which is LED wavelengths with only scope 470 (Blue) and 645 (Red) nm. Sensing performance has 2 parameter which is sensor characteristic with only scope sensitivity, linearity, average standard deviation and resolution. The application parameter which is relative humidity with only scope 35% RH – 80% RH.

# **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Introduction

This chapter largely focuses on the researcher, the journal, the article knowledge and philosophy, previous analysis and comparisons between methods, preliminary analysis and comparisons between approaches. The plastic optical fiber intensity-based sensor for humidity sensing is discussed in this chapter. Sensors that detect changes in light intensity are known as optical sensors. This refers to the detection of the light emitted by the sensor.

# 2.2 Related Previous Study

# 2.2.1 Temperature Dependence of a Refractive Index Sensor Based on Side-Polished Macrobending Plastic Optical Fiber by Ning Jing, Chuanxin Teng, Fangda Yu, Guanjun Wang, and Jie Zheng (2016)

A RI sensor based on a side-polished macrobending plastic optical fiber was employed in this study to analyze the temperature dependence of the sensor. Figure 2.1 displays a concept for a side-polished macrobending POF sensing probe that was created by the authors. The probe was produced utilizing a commercial step-index multimode POF throughout the production process (Jiangxi Daishing POF Co., Ltd) (Jiangxi Daishing POF Co., Ltd). For the goal of characterizing and managing the sensor's temperature influence, we relied entirely on the sensor's pure temperature dependence. The thermo-optic coefficient of the sensor progressively lowers as the refractive index of the liquid being monitored gets higher, and it continues to do so until it touches 0 when the RI of the environment around it reaches a particular value. A temperature-insensitive device that has the potential to be employed in other sensing applications can be constructed by covering it with an appropriate RI material. Optical fiber RI sensors are resistant to electromagnetic interference, responsive, and compact, and they are compatible with communication networks that use optical fiber. A POF-based RI sensing probe with a side-polished macrobending structure was given as a fabrication method [2].



Figure 2.1: Schematic of the side-polished macrobending POF probe

# 2.2.2 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, Elfed Lewis (2017)

For a variety of reasons, including their tiny size, light weight, and resistance to external electromagnetic interference, respiration sensors are manufactured using fiber optics. Figure 2.2 depicts the configuration of a POF sensor for respiratory monitoring. Using a fluorescent plastic optical fiber as a humidity sensor, a breathing condition monitor was created to detect changes in relative humidity during inhalation and exhale. In this study, a totally plastic respiration monitoring sensor based on optical fibers was constructed. The input and output plastic optical fiber (POF) are wrapped in 3-D printed parts with a flexible component in between to facilitate movement of the chest or other connection location during respiration. When placed to the body, the sensor measures the respiratory signal from small bending or extension during breathing. The sensor is small and compact, and it can be put in any location of the upper body near the lung and diaphragm [3].



Figure 2. 2 : Configuration of a POF sensor for respiratory monitoring

# 2.2.3 A study of relative humidity fiber-optic sensors by Malathy Batumalay, Sulaiman Wadi Harun, Ninik Irawati, Harith Ahmad, Hamzah Arof (2015)

The level of humidity can be determined by measuring how the refractive index (RI) of a humidity sensor covered with agarose gel or hydroxyethycellulose / polyvinyfluoride (HEC/PVDF) shifts over time. The experimental setup for the relative humidity sensor utilizing tapered POF with and without HEC/PVDF composite is shown in Figure 2.3. The RI will fluctuate whenever the implanted agarose gel or HEC/PVDF layer takes in water molecules from the environment around it and then expands as a result of doing so. When a POF containing a nanostructure of ZnO is subjected to the humidity of the surrounding air, individual water molecules immediately begin to adsorb onto the surface of the ZnO. As a consequence of this, the effective RI of its covering, which is made up of thin ZnO nanostructures and air, shifts in response to changes in the relative humidity. The coating's refractive index (RI) has an effect on the fiber's capacity to control light and, as a result, the output light intensity of each of these sensors [4].



Figure 2. 3 : Using a tapered POF with sensitive coating materials, an experimental configuration for the suggested relative humidity sensor was created

# 2.2.4 Relative Humidity Measurement Using Tapered Plastic Fiber Coated with HEC/PVDF by M. Batumalay, S.W. Harun (2013)

A simple tapered plastic optical fiber (POF) sensor was constructed and evaluated as a humidity sensor by using a tapered plastic optical fiber (POF) probe coated with a polymer blend of hydroxyethylcellulose/polyvinylidenefluoride (HEC/PVDF). This polymer blend acts as the humidity sensitive cladding. Figure 2.4 depicts the experimental setup for the proposed sensor to detect changes in relative humidity using tapered POF with and without HEC/PVDF composite. This sensor would use tapered POF to do the detection. In order to detect variations in relative humidity, this work coated tapered POF with a polymer mixture consisting of HEC and PVDF. The optical parameters of the coated tapered fiber alter as a response to an external stimulus. The measurement is based on an intensity modulation method that examines the output voltage of transmitted light in order to determine whether or not it varies as a direct result of shifts in the relative humidity of the environment. The ability of the HEC/PVDF composite-coated sensor to swell in a humid environment increases its sensitivity by lowering its refractive index below that of the core and allowing more light to flow through the tapered fiber. This is achieved by lowering the sensor's refractive index below that of the core [5].



Figure 2. 4 : Experimental configuration for the proposed relative humidity sensor with and without HEC/PVDF composite employing a tapered POF

# 2.2.5 Tapered Plastic Optical Fiber Coated With Al-Doped ZnO Nanostructures for Detecting Relative Humidity by Zuraidah Harith, Ninik Irawati, Hartini Ahmad Rafaie, Malathy Batumalay, Sulaiman Wadi Harun, Roslan Md Nor, and Harith Ahmad (2015)

The RH sensor is demonstrated using a tapered plastic optical fiber (POF) coated with Al-doped ZnO nanostructures. Figures 2.5(a) and (b) are micrographs of the untapered and tapered original POF, with cladding diameters of 1 mm and 0.45 mm, respectively (b). The tapering POF, which utilizes intensity modulation technology, was produced by an easy etching procedure. The fiber was then coated with Al-doped ZnO nanostructures by employing a sol–

gel immersion technique with different mol percents of Al nitrate as the dopant. Compared to other doping concentrations, the 1 mol percent Al nitrate concentration employed in the manufacturing process was more effective. The outcomes were then compared and investigated for both undoped ZnO and ZnO doped with 1% Al. The performance of 1 mol percent Al-doped ZnO was superior to that of undoped ZnO, with linearity and sensitivity of 97.5 percent and 0.0172 mV/percent, respectively, vs 93.3 percent and 0.0029 mV/percent, respectively. According to the findings, using tapered POF with Al-doped ZnO nanostructures boosts fiber sensitivity for detecting changes in RH [6].



Figure 2.5: (a) and (b) are microscopic views of the original untapered and tapered POFs, respectively, with cladding diameters of 1 mm and 0.45 mm

# 2.2.6 Investigation of a Macro-Bending Tapered Plastic Optical Fiber for Refractive Index Sensing by Chuanxin Teng, Ning Jing, Fangda Yu, and Jie Zheng (2016)

Presented and enhanced is a plastic optical fiber (POF) probe with a macro-bending tapered construction for refractive index (RI) measurement. Figure 2.6 illustrates the tapered, macro-bent POF probes. The macro-bending loss and evanescent wave introduced by the fiber's macro-bending tapering structure and controlled by the environmental RI serve as the operating basis. For the fabrication of a tapered POF and the building of a robust macro-bending structure for the probe, a heating and drawing operation and a thermal setting procedure were used. Created were probes with and without cladding. The sensing capabilities of the probe was enhanced by modifying the taper waist and curvature radius. Within the 1.33–1.41 RI range, the cladding-equipped probe's optimum sensitivity was 937 percent/RIU. By removing the cladding, the RI sensing range was widened to 1.33–1.45 and the sensitivity was reduced to around 800 percent /RIU, compared to those with cladding. Additionally, the

sensor's temperature sensitivity was studied. With its basic construction, small size, and visible wavelength intensity modulation, the POF probe offers a low-cost choice for RI sensing [7].



Figure 2. 6 : (a) The POF probe schematic with cladding. (b) The POF probe schematic without sheathing

# 2.2.7 Refractive Index Sensor Based on Spiral-Shaped Plastic Optical Fiber by Subhashish Tiwari, Manuj Kumar Singh, and Praveen C. Pandey (2017)

Utilizing a spiral-shaped plastic optical fiber, the refractive index of a solution of sucrose was determined (POF). Using standard data available at 20 °C, the sucrose solution concentration is converted to refractive index values and plotted against output voltages, as shown in Figure 2.7. The sensing approach is based on the interaction of evanescent waves between light traveling through the fiber and the surrounding medium. A variation in output voltage is detected when the concentration of the sucrose solution changes from 10% to 50%, demonstrating a correlation between the two values. Adjusting the sensitivity of the POF involves altering the pitch and tension of the spiral form. This spiral-shaped POF sensor has a low operating cost and gives sensing data in real time [8].



Figure 2. 7 : The POF's output voltage is shown versus the refractive index of sucrose solution

# 2.2.8 Design and Fabrication of Lossy Mode Resonance Based U-Shaped Fiber Optic Refractometer Utilizing Dual Sensing Phenomenon by Nidhi Paliwal, Nirmal Punjabi, Member, IEEE, Joseph John, Member, IEEE, and Soumyo Mukherji, Member, IEEE (2016)

This is the first exhaustive examination of the U-shaped lossy mode resonance (U-LMR) fiber optic refractometer based on dual sensing phenomena. Figure 2.8 is a diagram of a U-shaped fiber probe. A little portion of the cladding is taken from the center of the fiber, and the remaining segment is bent into a U-shaped probe. Figure 2.8's probe is not to scale due to the fact that the fiber core radius is always lower than the fiber bending radius. The purpose of this diagram is to depict the propagation of light through the U-shaped fiber core. Variations in wavelength shift, absorbance, and FWHM to evaluate the experimental sensitivity of the proposed U-LMR fiber optic refractometer. Using a U-shaped, ZnO-coated fiber optic probe with a 1.5 mm bend diameter, this publication revealed a sixfold increase in LMR sensitivity compared to a straight LMR probe. Our proposed U-shaped probe was demonstrated to be four times more sensitive than the uncoated U-shaped probe in terms of absorbance [9].



Figure 2. 8 : LMR-based U-shaped fiber optic sensing probe schematic not drawn to scale

# 2.2.9 Remote monitoring of water salinity by using side-polished fiber-optic U-shaped sensor by Dragan Z. Stupar, Jovan S. Bajić, Ana V. Joža, Bojan M. Dakić, Miloš P. Slankamenac, Miloš B. Živanov, Edvard Cibula (2012)

This work describes a remote water salinity monitoring system based on a simple and inexpensive U-shaped fiber-optic sensor that measures intensity. In Figure 2.9, a U-shaped sensor probe is displayed. The sensor system's U-shaped structure is side-polished to increase sensitivity and extend the measuring range. A multimode plastic optical fiber that monitors the refractive index is utilized as the sensor for detecting salinity. The salinity sensor suggested for use has a resolution of 0.001 and an uncertainty of 0.002. Additionally, wireless electronics based on ZigBee are deployed. The sensor can therefore conduct measurements wirelessly. The primary characteristics of this sensor are its simplicity, mobility, and light weight. Moreover, this sensor is electrically secure and resistant to electromagnetic interference [10].



Figure 2.9: a) Design of a side-polished fiber-optic U-shaped sensor with dimensions, b) Photograph of a side-polished fiber-optic U-shaped sensor that has been implemented

# 2.2.10 A simple U-shaped fiber optic probes for measurement of critical micelle concentration (CMC) in surfactant solutions by M. Ogita, C.D.Singh, Y. Shibata and T. Fujinami (2003)

Using the evanescent adsorption effect, this article offers a straightforward U-shaped optical fiber probe for measuring micelle concentration. An investigation was conducted into the fabrication and characterisation of a U-shaped fiber optic probe. Figure 2.10 depicts the experimental setup for measuring CMC using a U-shaped probe. The U-shaped is used to increase the evanescent field and, thus, the interaction with sample solutions containing sodium

dodecylbenzenesulfate. The effect of the probe's bending radius and launch parameters on the critical micelle concentration is investigated. It has been demonstrated that decreasing the radius of the U-bending shape increases the sensitivity of the sensor and improves the circumstances for detecting the critical micelle concentration point for a given sample solution concentration [11].



Figure 2. 10 : Setup for an experiment

# 2.2.11 A comparison of clinic based dosimeters based on silica optical fibre and plastic optical fibre for in-vivo dosimetry by Lingxia Chen, Sinead O'Keeffe, Peter Woulfe, Elfed Lewis (2017)

At the Galway Clinic, four sensors for clinical in-vivo dosimetry based on silica optical fibre and plastic optical fibre were developed and tested. Figure 2.11 depicts both theoritically and photographically the construction of the sensing parts of the four sensors. Using a clinical linear accelerator (Linac) as the radiation source, four sensors were irradiated with beam strengths of 6 MV and 15 MV at varying dose rates to provide first comparison data. According to experimental test results, sensors based on silica optical fibre are more sensitive to the incident radiation beam than sensors based on plastic optical fibre when exposed to identical irradiation conditions. A silica fiber-based sensor has five times the output intensity of a plastic optical fiber-based sensor [12].



Figure 2. 11 : Schematic diagram of sensor

# 2.2.12 Design and Characterization of a Plastic Optical Fiber Active Coupler by J. Zubia, U. Irusta, J. Arrue, and A. Aguirre (1998)

The first active coupler was built on the basis of plastic optical fiber technology. The physical structure of the POF active coupler resembles that of a contact coupler, with the exception of the replacement of the matching oil with a thin coating of LC. Figure 2.12 depicts more structural features. The device generated combines the features of switches and couplers, two of the most important devices made by this technology. The chosen solution relies on the construction of a passive contact coupler and the switching characteristics of a nonquadral nematic liquid crystal. As a coupler, the device exhibits experimental coupling of 4.5 dB and excess losses of less than 2.5 dB; as a switch, it possesses a dynamic range of 3 dB and switching durations of 2 milliseconds [13].



# 2.3 Summary of the Previous Study

Table 2.1 shows the summary of the previous study which is include the POF structure, sensing application, equipment and references.

POF Structure	Sensing application	Equipment	References
Macrobending POF	Humidity	OSA	[2]
U-Shaped	Humidity	OSA	[3]
Straight	Humidity	OSA	[4]
Straight	Humidity	OSA	[5]
Straight	Humidity	OSA	[6]
Macrobending	Humidity	OSA	[7]

Table 2.1	:	Summary	of	the	previous	study

Spiral-Shaped	Humidity	OSA	[8]
POF			
U-Shaped Fiber	Humidity	OSA	[9]
Probe			
U-shaped	Humidity	OSA	[10]
U-shaped	Humidity	OSA	[11]
Straight	Humidity	OSA	[12]
Straight	Humidity	OSA	[13]

# 2.4 Software Development

## 2.4.1 Arduino IDE

Figure 2.13 illustrates how the Arduino IDE creates and generates C language encoding software. Arduino IDE is an open-source programming environment created by Arduino.cc for authoring, compiling, and uploading code to the vast majority of Arduino Modules. The Arduino IDE is a software interface that is compatible with a wide variety of operating systems and windowed platforms. The IDE's principal purpose is to translate C language code into executable code that can be loaded into an Arduino microcontroller. This Arduino course is offered in Java, the language used to upload and link programs to the Arduino board. The programming language is defined or encoded, and a machine represents a set of commands capable of doing specified tasks. The programming language is a set of commands that may be used to conduct any function. It is written on a computer or as part of a device. Moreover, the pre-programmed programs can construct a custom program to execute particular algorithms [14].



Figure 2. 13 : Arduino Software

#### 2.4.2 Proteus 8 Professional

Proteus is a simulation, design, and sketching program for electrical circuits. Labcenter Electronics invented the product. 2.14 represents the Proteus 8 Professional software. It also supports 2D CAD drawing. From concept to completion is a justifiable phrase. The ISIS library has numerous components. It consists of sources, signal generators, measurement and analysis instruments such as oscilloscopes, voltmeters, and ammeters, probes for real-time monitoring of circuit parameters, switches, displays, loads such as motors and lamps, discrete components such as resistors, capacitors, inductors, and transformers, and digital and analog components. Integrated circuits, semiconductor switches, relays, microcontrollers, processors, and sensors, to name a few. ARES is capable of designing circuit boards with up to 14 inner layers using surface mount and through-hole packaging. It contains the footprints of discrete components including ICs, transistors, headers, and other discrete components. The PCB Designer is able to choose between automatic and manual routing. The ARES diagram is immediately transferable from the ISIS diagram [15].



Figure 2. 14 : Proteus 8 Professional

# 2.5 Hardware Development

#### 2.5.1 Plastic Optical Fiber

The components that make up plastic optical fiber are seen in figure 2.15. Even though many applications of optical fiber depend on their capability to transmit optical information with low losses, it is sometimes desired for the optical fiber to be strongly influenced by a physical quality of its environment. This is the case even though there are many applications of optical fiber that depend on their ability to transmit optical information. The application of

such a parameter as a sensor is made possible by this technological advancement. In this part, we will investigate a variety of light-powered sensors based on optical fiber. There are several convincing arguments that can be made in favor of utilizing POF as sensors. They share the same manageability and cost-effectiveness characteristics as all other multimode optical fibers. It is feasible to achieve great sensitivity with optical fiber despite the fact that it does not require a big surface area because of the inherent flexibility and compact size of optical fiber. In addition, it has been demonstrated that a POF is capable of detecting a wide variety of parameters, such as temperature, humidity, pressure, the presence of organic and inorganic chemicals, wind speed, and refractive index. These are only some of the factors that may be detected by a POF. Optical sensors based on POF, on the other hand, reduce the risk of electric sparks occurring in potentially explosive environments and can be read remotely [16].



2.5.2 Light Emitting Diode (LED)

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. Figure 2.16 illustrates the LED kind. Light is produced when electrons and holes collide within a semiconductor. The energy of photons controls the wavelength of emitted light and, consequently, its hue. Various semiconductor materials with differing bandgaps produce a spectrum of colors. The wavelength-specific color can be adjusted by modifying the composition of the light-emitting or active area [17].



Figure 2. 16 : Type of LED

# 2.5.3 NodeMCU

The low-cost System-on-Chip ESP8266 serves as the foundation for the open-source software and hardware development environment known as NodeMCU (SoC). An example of a NodeMCU type can be shown in Figure 2.17. As a result, it is an excellent choice for a wide range of Internet of Things projects. The NodeMCU Development board features WiFi connectivity, analog pins, digital pins, and digital pins, as well as serial communication protocols. Since NodeMCU is an interpreter for the Lua programming language, it can swiftly comprehend Lua script. [18].



# 2.5.4 Digital Temperature Humidity Meter

A relative humidity meter, also known as a humidity detector or humidity gauge, detects the relative humidity in the air using a humidity sensor. The type of digital temperature and humidity meter is depicted in Figure 2.18. Determining the environment's temperature and humidity is one of the most common physical measurements. For precise findings, it is imperative that the humidity meter be of high quality. In connection to the amount of water vapor in the atmosphere, the amount of water in the air is measured (moisture). Since Pws is a function of temperature, temperature has a substantial effect on relative humidity [19].



Figure 2. 18 : Type of Digital Temperature Humidity Meter

# 2.5.5 Amplifier circuit

An amplifier is an electrical circuit or device that boosts the signal strength of an input signal. Figure 2.19 illustrates the type of amplifier circuit. The term "amplifier" refers to a circuit that generates a signal with greater intensity than its input. However, amplifier circuits are categorized according to their circuit designs and modes of operation, thus they are not identical. Small signal amplifiers are commonly used in "Electronics" due to their ability to convert a small input signal, such as that from a sensor or photo-device, into a substantially larger output signal that can be used to drive a relay, lamp, or loudspeaker. In amplifiers, there are numerous electronic circuits, including Operational Amplifiers, Small Signal Amplifiers, Large Signal Amplifiers, and Power Amplifiers. Classification of an amplifier depends on the signal's size, whether it is large or little, its physical configuration, and how it processes the input signal, that is, the relationship between the input signal and load current [20].



Figure 2. 19 : Type of Amplifier Circuit

# 2.5.6 Phototransistor

A phototransistor is a semiconductor device with three layers and a light-sensitive base area. Figure 2.20 illustrates the phototransistor category. Then, the current is distributed

between the emitter and collector. A phototransistor resembles a photodiode with an amplifying transistor in its operation. When light touches the base terminal of a phototransistor, a small amount of current flows, which is subsequently amplified by a conventional transistor, resulting in a significant amount of current. The phototransistor consists of a semiconducting material. Once light reaches the semiconductor material, charge carriers, such as holes or electrons, can induce current to flow in the base region. This can be used to bias the transistor's base region. Light penetrates the base terminal of the transistor during reverse biasing and produces electron-hole pairs. The movement of electrons under the pressure of an electric field can generate current in the base area. Electrons from the emitter region can be used to inject this current [21].



Figure 2. 20 : Type of Phototransistor

#### 2.6 Summary

Due to the aforementioned numerous literature evaluations, a clearer understanding of the POF intensity-based sensor for humidity detection has emerged. A proper and advanced technological project has been explored as a result of the aforementioned literature reviews, allowing for the effective achievement of a goal. Based on the aforementioned literature reviews, the study indicated that the sensor's performance can be enhanced by modifying its manufacturing characteristics. The POF is an inexpensive system for measuring the refractive index. It has a straightforward design, a limited physical footprint, and an intensity modulation technique that uses visible-wavelength light. It is possible to improve the sensing performance by making adjustments to the radius of curvature, polished depth, and polished location (angle). Fiber optic sensors have a number of benefits over traditional sensors, including insensitivity to electromagnetic fields, minimum intrusion, ease of termination and connection, good fracture resistance, and light weight.

# **CHAPTER 3**

#### METHODOLOGY

#### 3.1 Introduction

The project overview, block diagram, flowchart, hardware, and application development will all be described in this chapter. To complete the current study's experimentation portion, the process of designing the research method is needed. As it provide a visual depiction, flow charts are an effective tool for developing project management methods. To produce a good project in the future project, then must have a wonderful flowchart. The findings of engineering research and studies published in bookable publications can be used to produce a highly desirable or specific project. The analysis technique will be carried out utilizing these desirable parameters and features, as well as the associated advantages and disadvantages, once the target parameter and aspects have been selected. If the previous stage has not been completed, enforcement actions will be utilized until the entire operation has been completed.

#### 3.2 Methodology

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In addition to their requirements, humidity sensors have evolved over time with regard to the materials used in their construction and their overall functioning principle. The rate of change in the electrical characteristics of a humidity-sensitive sensor element determines its functionality. Transmitted optical power is measured using optical absorption sensors as an indicator of humidity. In this instance, the evanescent wave, which consists of light with total internal reflection, interacts with the coating serving as the sensitive element. Plastic fibers, which are typically encased in silica, or side-polished fibers coated with various compounds such as zinc oxide, reduced graphene oxide, etc., are the most prevalent forms of fibers employed in this category of sensors. As the majority of these sensors are comprised of plastic fibers, the low production cost is a significant benefit. On both ends, optical power measurement is complex and extremely susceptible to noise and defects, such as light source change.

# 3.2.1 Experimental setup

The experiment setup for measuring humidity is depicted in Figure 3.1. It consists of a few pieces of equipment, including a laptop, a NodeMCU, an amplifier circuit phototransistor, an LED, a POF, a chamber, and a digital temperature humidity meter.



Figure 3.1 : Block diagram of the system

Figure 3.2 shows the measuring and cutting the jacket of POF. The taper length of POF is 3 cm and the total length of POF is 20 cm. Using ruler to measure the length of the POF in cm and using cutter to cut the jacket of POF which is the black colour and then the transparent colour is the cladding.





(V) (VI)

Figure 3. 2 : (I) until (VI) shows the measuring and cutting the jacket of POF

Figure 3.3 shows the process of taper waist diameter single side of POF using sand paper. Digital micrometer is to measure the taper waist diameter of POF which is 0.4 mm, 0.5 mm, 0.6 mm and 0.7 mm and after that label each POF with their own diameter.





(II)





(VI)



(VII)

Figure 3. 3 : (I) until (VII) shows the taper waist diameter of POF

Figure 3.4 shows the process of soldering on the PCB board using soldering iron. The jumper is use to connect the component connection.





Figure 3.5 shows the process of tight around connector LED and phototransistor using PVC tape and then label each with their own name which is red, blue and phototransistor.



Figure 3. 5 : Process of tight the connector of LED and Phototransistor

Figure 3.6 shows the setup of chamber from zero to complete chamber. This setup is using tape, soldering iron, and cordless drill. After that, install one by one all the component into the chamber.







(VII)

(VIII)





(X)





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(XV)

(XVI)



(XVII)

Figure 3. 6 : (I) until (XVII) shows the setup of Chamber

Figure 3.7 shows the complete of chamber and tested it using two wavelength which is red (645 nm) and blue (470 nm).



Figure 3. 7 : (I) until (IV) is the tested POF

Figure 3.8 shows the physical of silica gel before and after used. The silica gel can be recycle with heated in the microwave for 2 or 3 minutes.



# 3.2.2 Flowchart

Figure. 3.2 shows the flowchart of the system. The first thing that the user need to setup the experiment and fiber fabrication. The user need to set the humidity concentration value from 35% RH that is the minimum value until 90% RH that is the maximum value. Two distinct wavelengths such as Blue and Red were used to optimize the waist diameter of POF at 800, 700, 600 and 500 um. If the tapered POF was detect the humidity, the phototransistor sense and display the output. If the tapered POF cannot detect the humidity, it will turn to fiber fabrication and experiment setup. Next, the laptop will display the data analysis and validation of the output.



Figure 3. 9 : Flowchart of the system

#### **3.2.3** Fabrication of Tapered POF

Figure 3.3 depicts the digital micrometer measurement used to determine the thickness of a tapered plastic optical fiber.



Figure 3. 10 : Digital Micrometer measurement

Figure 3.4 depicts the waist diameter of POF that tapers. The POF is made up of multiple components, including a jacket or buffer, cladding, and core. A buffer protects the fiber from moisture and physical damage by covering it. Before termination or splicing, the fiber buffer is eliminated. The cladding encases the core and decreases the index of refraction, allowing the optical fiber to operate. The majority of optical fiber cores are made of glass, although some are made of plastic. In the field of fiber optics, light that has traveled all the way to the end of the fiber is reflected back through the core at the point where the core meets the cladding. In the absence of cladding, the vast majority of light energy would be scattered as it traveled through the core of the fiber before being absorbed by its outer jacket.



Figure 3. 11 : Example of tapered POF with waist diameter

# 3.3 Summary

In conclusion, this project can be completed if all phases are finished and all requirements, including software and hardware, are met. To meet the project's objectives, any obstacles that develop throughout its implementation must be addressed. As stated in the next chapter, data will be collected and analysed.

# **CHAPTER 4**

# **RESULTS AND DISCUSSIONS**

# 4.1 Introduction

This chapter will describe the findings of a number of various research that have been conducted. The purpose is to present an overview of the findings as well as a discussion of the data gathered during the project's first phase. This entails running tests and analyzing data to ensure that it is correct and operates well. In addition, it covers a chunk of the project's development as well as the prototype's final outcome.

# 4.2 Result and Analysis

4.2.1 Repeatability Test

Red Wavelength (645 nm)

Table 4.1 shows the repeatability of 400 um red wavelength. This table shows run 1, run 2, run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

Table 4.1: Table of 400 um red wavelength

400um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	3.02	3.01	3.01	3.01	0.005774
40	2.96	2.96	2.95	2.96	0.005774
45	2.91	2.92	2.9	2.91	0.01
50	2.88	2.87	2.85	2.87	0.015275
55	2.83	2.83	2.81	2.82	0.011547
60	2.8	2.79	2.78	2.79	0.01
65	2.79	2.78	2.77	2.78	0.01
70	2.79	2.78	2.77	2.78	0.01
75	2.79	2.78	2.77	2.78	0.01
80	2.79	2.78	2.77	2.78	0.01
ΔV	0.23	0.23	0.24	0.23	0.009837

Figure 4.1 shows the repeatability test 400 um (Red) which is run 1, run 2 and run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 3.0V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 2.7V.



Table 4.2 shows the repeatability of 500 um red wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

500um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	3.15	3.15	3.16	3.15	0.005774
40	3	3.01	3.1	3.04	0.055076
45	2.94	2.95	2.97	2.95	0.015275
50	2.82	2.89	2.9	2.87	0.043589
55	2.79	2.8	2.84	2.81	0.026458
60	2.71	2.75	2.75	2.74	0.023094
65	2.7	2.71	2.7	2.70	0.005774
70	2.7	2.71	2.7	2.70	0.005774
75	2.7	2.71	2.7	2.70	0.005774
80	2.7	2.71	2.7	2.70	0.005774
ΔV	0.45	0.44	0.46	0.45	0.019236

Figure 4.2 shows the repeatability test 500 um (Red) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 3.1V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 2.7V.



Table 4.3 shows the repeatability of 600 um red wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

Table 4.	3 :	Table	of	600	um	red	wave	length
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600um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	3.25	3.29	3.28	3.27	0.020817
40	3.22	3.24	3.25	3.24	0.015275
45	3.2	3.23	3.24	3.22	0.020817
50	3.19	3.2	3.22	3.20	0.015275
55	3.19	3.18	3.18	3.18	0.005774
60	3.18	3.18	3.17	3.18	0.005774
65	3.17	3.17	3.16	3.17	0.005774
70	3.17	3.17	3.16	3.17	0.005774
75	3.17	3.17	3.16	3.17	0.005774
80	3.17	3.17	3.16	3.17	0.005774
ΔV	0.08	0.12	0.12	0.106667	0.010682

Figure 4.3 shows the repeatability test 600 um (Red) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 3.2V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 3.1V.



Table 4.4 shows the repeatability of 700 um red wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

Table 4.	4: Table	of 700 un	n red wave	elength
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700um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	3.5	3.55	3.55	3.53	0.028868
40	3.48	3.54	3.53	3.52	0.032146
45	3.46	3.52	3.51	3.50	0.032146
50	3.44	3.5	3.49	3.48	0.032146
55	3.42	3.47	3.46	3.45	0.026458
60	3.4	3.45	3.43	3.43	0.025166
65	3.38	3.42	3.42	3.41	0.023094
70	3.38	3.42	3.42	3.41	0.023094
75	3.38	3.42	3.42	3.41	0.023094
80	3.38	3.42	3.42	3.41	0.023094
ΔV	0.12	0.13	0.13	0.126667	0.02693

Figure 4.4 shows the repeatability test 700 um (Red) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 3.5V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 3.3V - 3.4V.



Blue Wavelength (470 nm)

Table 4.5 shows the repeatability of 400 um blue wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

400um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	1.14	1.13	1.14	1.14	0.005774
40	1.1	1.11	1.12	1.11	0.01
45	1.08	1.1	1.1	1.09	0.011547
50	1.08	1.09	1.09	1.09	0.005774
55	1.06	1.08	1.08	1.07	0.011547
ALA60	1.06	1.07	1.07	1.07	0.005774
65	1.06	1.07	1.07	1.07	0.005774
70	1.06	1.07	1.07	1.07	0.005774
75	1.06	1.07	1.07	1.07	0.005774
80	1.06	1.07	1.07	1.07	0.005774
ΔV	0.08	0.06	0.07	0.07	0.0 <mark>0</mark> 7351

Table 4. 5 : Table of 400 um blue wavelength

Figure 4.5 shows the repeatability test 400 um (Blue) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 1.1V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 1.0V.



Figure 4. 5 : Graph repeatability test 400 um (Blue)

Table 4.6 shows the repeatability of 500 um blue wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

500um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	1.3	1.31	1.33	1.31	0.015275
40	1.28	1.29	1.31	1.29	0.015275
45	1.27	1.26	1.3	1.28	0.020817
50	1.26	1.25	1.29	1.27	0.020817
55	1.25	1.24	1.27	1.25	0.015275
60	1.24	1.23	1.25	1.24	0.01
65	1.23	1.23	1.22	1.23	0.005774
70	1.23	1.23	1.22	1.23	0.005774
75	1.23	1.23	1.22	1.23	0.005774
80	1.23	1.23	1.22	1.23	0.005774
ΔV	0.07	0.08	0.11	0.09	0.012055

Table 4. 6 : Table of 500 um blue wavelength

Figure 4.6 shows the repeatability test 500 um (Blue) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 1.3V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 1.2V.



Figure 4. 6 : Graph repeatability test 500 um (Blue)

Table 4.7 shows the repeatability of 600 um blue wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

600um					
	Forward(3	5 to 80)			
Humidity	Run 1	Run 2	Run 3	Average	stdev
35	1.48	1.5	1.53	1.50	0.025166
40	1.47	1.49	1.52	1.49	0.025166
45	1.46	1.48	1.51	1.48	0.025166
50	1.45	1.47	1.5	1.47	0.025166
55	1.45	1.46	1.49	1.47	0.020817
60	1.44	1.45	1.46	1.45	0.01
65	1.43	1.44	1.45	1.44	0.01
70	1.43	1.44	1.45	1.44	0.01
75	1.43	1.44	1.45	1.44	0.01
80	1.43	1.44	1.45	1.44	0.01
ΔV	0.05	0.06	0.08	0.06	0.017148

Table 4.7: Table of 600 um blue wavelength

Figure 4.7 shows the repeatability test 600 um (Blue) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 1.4V - 1.5V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 1.4V.



Figure 4.7: Graph repeatability test 600 um (Blue)

Table 4.8 shows the repeatability of 700 um blue wavelength. This table shows Run 1, Run 2, Run3, average and standard deviation. From run 1, run 2, and run 3 show the descending voltage value if humidity value more higher. This shows the data taking from tested POF is stable because the data no fluctuations.

700um					
	Forward(3	5 to 80)			
<b>Humidity</b>	Run 1	Run 2	Run 3	Average	stdev
35	1.73	1.76	1.71	1.73	0.025166
40	1.72	1.75	1.71	1.73	0.020817
45	1.71	1.71	1.7	1.71	0.005774
50	1.69	1.69	1.69	1.69	2.72E-16
55	1.67	1.67	1.68	1.67	0.005774
60	1.66	1.66	1.67	1.66	0.005774
65	1.65	1.64	1.66	1.65	0.01
70	1.65	1.64	1.66	1.65	0.01
75	1.65	1.64	1.66	1.65	0.01
80	1.65	1.64	1.66	1.65	0.01
ΔV	0.08	0.12	0.05	0.08	0.01033

Table 4.8: Table of 700 um blue wavelength

Figure 4.8 shows the repeatability test 700 um (Blue) which is Run 1, Run 2 and Run 3. This graph is relative humidity (%) versus the output voltage (V). From this graph, when the value of relative humidity (%) is ascending, the value of output voltage is descending. The value of relative humidity (%) at 35% is around 1.7V and then the value of voltage keep descending until 65%, then the voltage maintain until the 80% which is around 1.6V.



Figure 4.8 : Graph repeatability test 700 um (Blue)

# 4.2.2 Trendline Graph

Table 4.9 shows the average of 400 um, 500 um, 600 um, and 700 um with each wavelength. From this table, 500 um for both wavelength show high sensitive compare than others because the voltage value for both is higher which is for red wavelength is 0.45V and for blue wavelength is 0.086V. However, fiber 500 tested at wavelength 645 nm give better sensitivity compare to wavelength 470 nm.

	Red Wavelength (645 nm)				Blue Wavelength (470 nm)			
Humidity	400 um	500 um	600 um	700 um	400 um	500 um	600 um	700 um
35	3.013333	3.153333	3.273333	3.533333	1.136667	1.313333	1.503333	1.733333
40	2.956667	3.036667	3.236667	3.516667	1.11	1.293333	1.493333	1.726667
45	2.91	2.953333	3.223333	3.496667	1.093333	1.276667	1.483333	1.706667
50	2.866667	2.87	3.203333	3.476667	1.086667	1.266667	1.473333	1.69
55	2.823333	2.81	3.183333	3.45	1.073333	1.253333	1.466667	1.673333
60	2.79	2.736667	3.176667	3.426667	1.066667	1.24	1.45	1.663333
65	2.78	2.703333	3.166667	3.406667	1.066667	1.226667	1.44	1.65
70	2.78	2.703333	3.166667	3.406667	1.066667	1.226667	1.44	1.65
75	2.78	2.703333	3.166667	3.406667	1.066667	1.226667	1.44	1.65
80	2.78	2.703333	3.166667	3.406667	1.066667	1.226667	1.44	1.65
ΔV	0.233333	0.45	0.106667	0.126667	0.07	0.086667	0.063333	0.083333
	2	1	4	3	3	1	4	2

Table 4.9: Table of average red wavelength (645 nm) and blue wavelength (470 nm)

Figure 4.9 shows the trendline graph of Red Wavelength (645 nm) which is 400 um, 500 um, 600 um and 700 um. From this graph, the 500 um is very sensitive compare than others. The value of gradient which is y = mx+c for 500 um is -0.0099 higher than others value.



Figure 4.9: Trendline graph of red wavelength (645 nm)

Figure 4.9 shows the trendline graph of Blue Wavelength (470 nm) which is 400 um, 500 um, 600 um and 700 um. From this graph, the 500 um is very sensitive compare than others. The value of gradient which is y = mx+c for 500 um is -0.002 higher than others value.



Figure 4. 10 : Trendline graph of blue wavelength (470 nm)

Table 4.10 shows the data analysis of red wavelength (645 nm) and blue wavelength (470 nm). From this table, 500 um for both wavelength provide the higher sensitivity which is the red wavelength (645 nm) is 0.0099 V/%RH and the blue wavelength (470 nm) is 0.002 V/%RH.

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Fable 4. 10 : Data analysis of wavelength red (645 nm) and blue (470)	nm	)
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		Wavelength									
			Red = 6	645 nm		Blue = 470 nm					
Waist Diameter (um)		400 µm	500 μm	600 µm	700 μm	400 µm	500 µm	600 µm	700 µm		
Sensitivity	(V/%RH)	0.0052	0.0099	0.0022	0.0031	0.0014	0.002	0.0015	0.0021		
Linearity (9	%)	91.8477	92.83318	91.41663	95.67654	86.89074	95.02105	95.94269	94.76814		
Resolution	ı (%RH)	1.891717	1.94302	4.855675	8.687216	5.250609	6.027654	11.43207	4.919204		

## 4.2.3 Hysteresis Graph

Table 4.11 shows the voltage value for red wavelength 500 um which is forward and reverse voltage value. This data taking one cycle complete which is from 35% until 80% and then from 80% until 35% relative humidity.

	Red 500 ur	n		
	Humidity	Forward	Reverse	
	35	3.15	3.15	
	40	3.01	3.11	
	45	2.95	3.05	
	50	2.89	3	
	55	2.8	2.99	
	60	2.75	2.94	
	65	2.71	2.89	
MALAYSI	70	2.71	2.83	
S	75	2.71	2.8	
1 Alexandre	80	2.71	2.78	
<u> </u>	ΔV	0.44	0.37	

Table 4. 11 : Table of 500 um (red) forward and reverse

Figure 4.11 shows the hysteresis graph forward and reverse for red wavelength. From this graph we decide to take the relative humidity at 65% and after that the forward value subtract the reverse value and we got the voltage value is -0.18.



Figure 4. 11 : Hysteresis graph forward and reverse for red wavelength

Table 4.12 shows the voltage value for blue wavelength 500 um which is forward and reverse voltage value. This data taking one cycle complete which is from 35% until 80% and then from 80% until 35% relative humidity.

	Blue 500 u					
	Humidity	Forward	Reverse			
	35	1.31	1.32			
	40	1.29	1.3			
	45	1.26	1.3			
	50	1.25	1.29			
	55	1.24	1.28			
	60	1.23	1.28			
	65	1.23	1.27			
	70	1.23	1.26			
	75	1.23	1.26			
	80	1.23	1.25			
≈/,	ΔV	0.08	0.07			

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Table 4. 12 : Table of 500 um (blue) forward and reverse

Figure 4.12 shows the hysteresis graph forward and reverse for blue wavelength. From this graph we decide to take the relative humidity at 65% and after that the forward value subtract the reverse value and we got the voltage value is -0.04. From this voltage value we can conclude that the blue wavelength is good because the voltage value is less than the red wavelength voltage value.



Figure 4. 12 : Hysteresis graph forward and reverse for blue wavelength

# 4.3 Summary

In conclusion, the data and analysis demonstrate that the most sensitive sensor is a plastic optical fiber with a diameter of 500um. Reason being, it produces the largest voltage variations compared to other plastic optical fiber diameter sizes. Additionally, 500um achieves the lowest value of standard deviation, demonstrating the sensor's consistency and precision.



## **CHAPTER 5**

#### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The potential for a deeper knowledge of the POF intensity-based sensor for humidity sensing has been apparent as a result of the aforementioned diverse literature reviews. A proper and advanced technological project has been explored as a result of the aforementioned literature reviews, allowing for the effective achievement of a goal. Based on the aforementioned literature reviews, the study indicated that the sensor's performance can be enhanced by modifying its manufacturing characteristics. The POF is a low-cost system for sensing the refractive index of a material. It has a simple structure, a small size, and the ability to modulate its intensity at visible wavelengths. Improving the sensing performance can be accomplished by adjusting the radius of curvature, the polished depth, and the polished position (angle). Traditional sensors don't have fiber optic sensors' insensitivity to electromagnetic fields, light weight, minimal intrusion, ease of termination and connection, and enough fracture resistance are only few of the benefits that come with using fiber optic sensors rather than traditional ones. This project can be concluded if all phases are concluded and all prerequisites, including software and hardware, are satisfied. To achieve the project's goals, any barriers that arise throughout its implementation must be overcome.

## 5.2 Future Works

A gas sensor is a device that can detect and quantify specific gases in the air. The sensor works by converting a potential difference created when gas molecules come into contact with solid sensors into an electrical signal. The sensing materials' reaction to the gases determines the sensor's sensitivity and selectivity. Optical fiber sensors have been proposed as a viable option due to their many advantages over other sensing technologies. These advantages include their resistance to electromagnetic interferences, their ability to operate without electricity, the possibility of multiplexation, and their suitability for use in both remote locations and extreme weather. A fiber optic gas sensing system consists of a light source, a signal input optical fiber, a signal output optical fiber, and a detector; other components, such as an optical modulator and a demodulator, are available as add-ons.



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#### APPENDICES

#### **APPENDIX A : CODING**

```
#include <Wire.h>
 1
 2
     #include <Adafruit_GFX.h>
 3
     #include <Adafruit SSD1306.h>
     #include <Fonts/FreeSerif9pt7b.h>
 Δ
 5
 6
     #define SCREEN_WIDTH 128 // OLED display width, in pixels
     #define SCREEN HEIGHT 64 // OLED display height, in pixels
 7
 8
 9
     // Declaration for an SSD1306 display connected to I2C (SDA, SCL pins)
10
     Adafruit SSD1306 display(SCREEN WIDTH, SCREEN HEIGHT, &Wire, -1);
11
     int ledPin = 3;
12
13
     //int buttonPin = 15;
     boolean ledOn = false;
14
     int buttonState:
15
     int customDelay = 200;
16
     int analogPin = 0;//Photoresistor Pin
17
18
19
     void setup() {
      Serial.begin(115200);
20
       //Serial.setDebugOutput(true);
21
       //pinMode(buttonPin, INPUT PULLUP);
22
       pinMode(ledPin, OUTPUT);
23
24
25
       if(!display.begin(SSD1306 SWITCHCAPVCC, 0x3C)) { // Address 0x3D for 128x64
                                                                 ودروت
         Serial.println(F("SSD1306 allocation failed"));
26
27
         //for(;;);
28
       delay(2000); RSITI TEKNIKAL MALAYSIA MELAKA
29
       display.setFont(&FreeSerif9pt7b);
30
       display.clearDisplay();
31
32
       display.setTextSize(1.5);
33
34
       display.setTextColor(WHITE);
       display.setCursor(0, 20);
35
36
       // Display static text
       display.println("Hello!");
37
       display.display();
38
       delay(1000);
39
40
41
```

```
void loop() {
42
       digitalWrite(ledPin, HIGH);
43
       display.clearDisplay();
44
       //buttonState = digitalRead(buttonPin);
45
       display.setCursor(30, 40);
46
47
      // display.println("LED:");
      // display.setCursor(70, 40);
48
      // display.println("OFF");
49
        //if (buttonState == 1 && !ledOn) {
50
51
           //digitalWrite(ledPin,HIGH);
           //display.setCursor(70, 40);
52
           //display.println("ON ");
53
           //ledOn = !ledOn;;
54
           //delay(customDelay); // Prevent rapid fire
55
          // } else if (buttonState == 1 && ledOn) {
56
             11
                   digitalWrite(ledPin,LOW);
57
58
              11
                   display.setCursor(70, 40);
               // display.println("OFF");
59
               // ledOn = !ledOn;;
60
               // delay(customDelay); // Prevent rapid fire
61
               11 }
62
       int lightLevel = analogRead(analogPin);
63
64
       float voltage = lightLevel (5.0 / 1024.0);
65
       Serial#println(voltage);
       //Serial.println(lightLevel);
66
67
       display.setCursor(40, 20);
       display.println("v:");
68
       display.setCursor(60,20);
69
       display.println(voltage);
70
71
       display.display();
72
       delay(150);
73
            UNIVERSITI TEKNIKAL MALAYSIA MELAKA
74
```

# **APPENDIX B : GANTT CHART**

14	13	12	11	10	9	8	7	6	S	4	3	2	<u> </u>	No.
PRESENTATION	REPORT SUBMISSION VIA ePSM	SUBMIT LOGBOOK AND DRAFT REPORT	COMPLETION OF REPORT	UPDATE DATA TO REPORT	UPDATE EXPERIMENTAL SETUP	COLLECT DATA	RUN PROJECT	FIXING ANY PROJECT ERROR	FEEDBACK CHECK BASED ON TESTING	PROJECT TESTING	CIRCUIT IMPROVEMENT	FABRICATION OF POF	PROJECT BRIEFING	Tasks
		4	MAL	AYSIA	20									W
		Kult			Part				P					W2
		I I									N	/		W3
		00	PAINO											W4
		de.	101	have	ا ما	<	ais		ر ت			igl		W5
						251112	- ** - A 1 - 1		- Q	2.4		12.6		W6
		UN	VER	SIT	IE	NIP	AL	MAL	ATS	IA IV	IEL/	INA		W
														W8
					Mi	dТ	erm	Br	eak					
														W9
														W10
														W11
														W12
														W13
														W14