Faculty of Electrical and Electronic Engineering Technology

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

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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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Tarikh: 26 / 1 / 2023

Tarikh: 12 / 2 / 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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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

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	-	Denominator

LIST OF APPENDICES

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

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.

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].

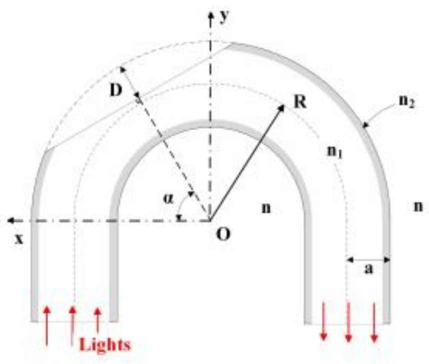

Figure 2. 1 : Schematic of the side-polished macrobending POF probe

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].

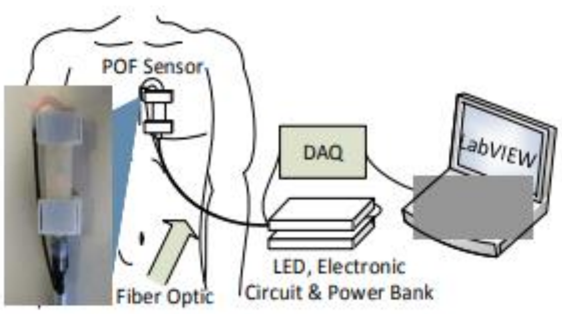

Figure 2. 2 : Configuration of a POF sensor for respiratory monitoring

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].

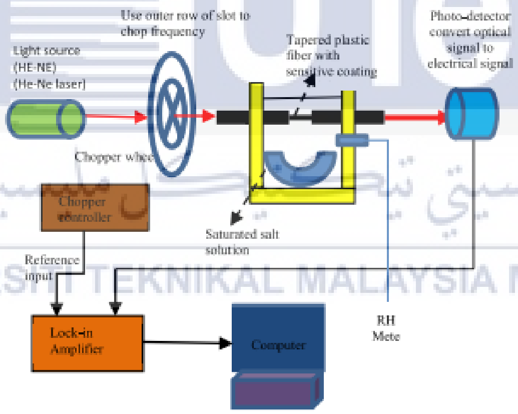

Figure 2. 3 : Using a tapered POF with sensitive coating materials, an experimental configuration for the suggested relative humidity sensor was created

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].

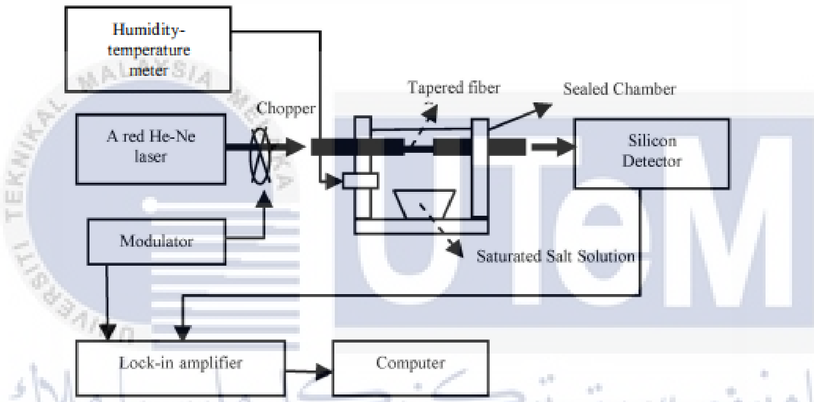

Figure 2. 4 : Experimental configuration for the proposed relative humidity sensor with and without HEC/PVDF composite employing a tapered POF

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–