ANALYSIS OF THE BENDING EFFECT OF MULTIMODE FIBER (MMF) STRUCTURE TOWARD THE PERFORMANCE OF THE SINGLE MODE-MULTIMODE-SINGLE MODE (SMS) FIBER OPTIC SENSOR FOR LIQUID CONCENTRATION MEASUREMENT

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

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DEDICATION

This humble effort specially dedicated to express my gratitude to my beloved parents, family, lecturers especially my supervisor, and friends, for their support, guidance, and encouragement upon completing this research and thesis.

ABSTRACT

Fiber optic sensor is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. There are various types of sensors used based on electrical for liquid concentration measurement. Although most of the devices work well in practice, the sensors are costly and have a complicated configuration. However, fiber optic cable is immune to electromagnetic interference (EMI) or any short circuit and it safe to be used for flammable and non-flammable. In this project, fiber optic sensor (FOS) was designed and developed. The fibers are used for the lead-in and lead-out sections are single mode fiber (SMF) while the multimode fiber (MMF) represents the sensing-region and analyze with different size of diameter and a different number of loops. So, the diameter involves are 2.4 cm, 2.7 cm, and 3.3 cm and while the number of loops are 1 loop, 2 loop, and 3 loop. The length of the sensor used was 30 cm which is the bending part. The FOS is developed by using a fusion arc splicing technique. The etched sensors were tested in water, 1.0 mol sucrose solution and palm oil with the refractive index (RI) respectively. The bending effect of the sensor device experienced a redshift wavelength. The best sensitivity of the sensor achieved at 3 loop which is 9.7498 nm/RIU and with the size of diameter 3.3 cm which is 8.3557 nm/RIU. It can be

seen that the sensitivity of the sensor increase with the number of the loop and increased diameter.

ABSTRAK

Sensor fiber optik ialah satu kaedah penyebaran maklumat dari satu tempat ke satu tempat yang lain dengan menghantar informasi menggunakan cahaya melalui fiber optik. Terdapat pelbagai jenis sensor yang digunakan berdasarkan elektrik untuk pengukuran kepekatan cecair. Walaupun kebanyakan peranti berfungsi dengan baik dalam praktik, sensornya mahal dan mempunyai konfigurasi yang rumit. Walau bagaimanapun, kabel fiber optik adalah kebal terhadap gangguan elektromagnetik (EMI) atau mana-mana litar pintas dan ia selamat untuk digunakan terhadap bahan bakar dan bukan bahan bakar. Dalam projek ini, Single mode-Multimode-Single mode (SMS) dibengkokkan dengan saiz diameter yang berbeza iaitu 2.4 cm, 2.7 cm dan 3.3 cm dan bilangan gelung yang berbeza di kawasan yang terdedah telah direka bentuk. Fiber yang digunakan untuk port masuk dan port keluar ialah single mode fiber (SMF) manakala bahagian yang terdedah ialah multimode fiber (MMF) dan panjang sensor yang digunakan ialah 30 cm yang merupakan bahagian yang bengkok. Sumber isyarat optik memasuki MMF melalui port masuk SMF. Sensor fiber optik (FOS) di buat dengan menggunakan teknik penyambungan. Sensor yang di etched diuji di dalam air, 1.0 mol larutan sukrosa dan minyak kelapa sawit dengan indeks biasnya (RI). Kesan peranti sensor yang dibengkokkan mengalami panjang gelombang redshift. Sensitiviti sensor yang terbaik dicapai dengan menggunakan tiga gelung iaitu 9.7498 nm/RIU dan dengan menggunakan saiz diameter 3.3 cm iaitu 8.3557 nm/RIU. Ia dapat dilihat bahawa sensitiviti sensor meningkat dengan bilangan gelung dan diameter meningkat.

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LIST OF SYMBOLS AND ABBREVIATIONS

EMI	:	Electromagnetic interference
FBG	:	Fiber-Bragg Grating
FOS	:	Fiber optic sensor
HF	:	Hydrofluoric acid
LED	:	Light-emitting diode
MMF	:	Multimode fiber
MZI	:	Mach-Zehnder Interferometer
OSA	:	Optical Spectrum Analyzer
POF	:	Plastic Optical Fiber
RI	:	Refractive index
SMF	:	Single mode fiber
SMS	:	Single mode-Multimode-Single mode
STC	:	Standard telephones and cables
SYABAS	:	Selangor Water Supply Company Sdn. Bhd.
TIR	:	Total Internal Reflection

CHAPTER 1

INTRODUCTION

This chapter explained the introduction of the project background, problem statements, and objectives of this project. In this chapter, these will be briefly explained. In addition, the scope of work also includes in this section.

1.1 Introduction

In recent years, optical fibers are not just used as telecommunication system as a data transmission medium and it is also widely used in a variety of applications such as transmitting transmit voice, data signals through small flexible threads of glass or plastic, military, medical environment to the broadcasting industry, television and images. Fiber optic cables are long, thin strands of very pure glass about the size of a human hair. They are arranged in bundles called optical cables and used to transmit signals over long distances. Optical fiber does not conduct electricity and also immune to electromagnetic interference. Therefore, it is suitable for highly inflammable material or high voltage electricity.

According to[1], the applications of optical fibers can be divided into two classes which are the used of fibers as the information transmission lines among industrial instruments and sensors and the other one are the use of the fiber itself as a sensor. Recent advances in fiber optic technology have significantly changed the telecommunications industry. The ability to carry gigabits of information at the speed of light increased the research potential in optical fibers. Simultaneous enhancements and cost reductions in optoelectronics components led to the similar emergence of new product areas[2].

Fiber optic sensor (FOS) have been used to monitor a wide range of environmental parameters such as the concentration of chemical species, mechanical strain, temperature, humidity, acceleration, rotations, pressure, vibrations, displacements and several other environmental factors[2]. FOS requires a light source to be transmitted through the cable to the output display.

An optical fiber is divided into three parts which are the core, the cladding, and the coating or plastic buffer. The core is a central tube of a very thin size that made up of optically transparent dielectric medium and carries the light from the transmitter to the receiver. The core diameter can vary from about 5µm to 100µm[3]. Besides, the cladding is an outer optical material surrounding the core having a reflecting index lower than the core. It helps to keep the light within the core throughout the phenomena of total internal reflection while the plastic buffer is a plastic coating that protects the fiber made of silicon rubber. The typical diameter of fiber after the coating is 250 to 300µm[3]. Figure 1.1 shows the basic structure of optical fiber[2].

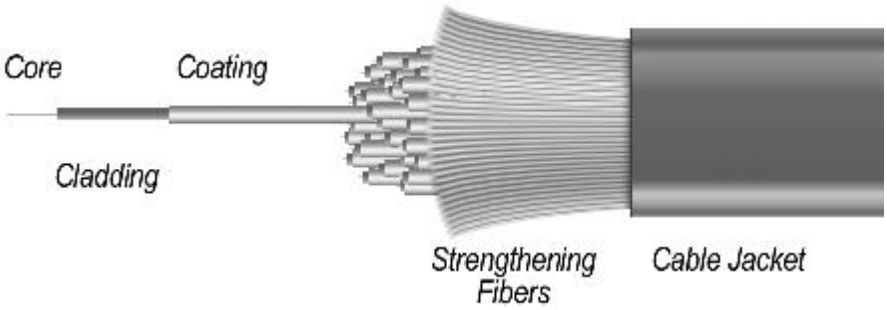

Figure 1.1: Basic structure of the optical fiber[2]

In this project, FOS will be employed for liquid concentration measurement by using a Mach-Zehnder Interferometer (MZI) structure. The Single Mode-Multimode-Single Mode (SMS) are bending with varied sizes of the diameter of the sensing region is design and fabricate. The propagating characteristics of this SMS based structure as a sensor demonstrate that the transmission power is associated with the initial wavelength, a different number of loops and different size of diameters. The sensor device will be tested in air, water, 1.0 mol sucrose solution and palm oil. The readings for each solution will be repeating five times in order to obtain standard deviation error. The bending effect of the sensor device will be experienced by a wavelength shift and it is also being observed the sensitivity of FOS.

Since the signal is transmitted over optical fiber, the wavelength supplied by the optical light source must readable by optical output measurement devices such as Optical Spectrum Analyzer (OSA) and Optical Multimeter. Fiber optic can transmit over longer distances and at a higher bandwidth than wire cables which are currently using now.

The commercialization potential of this project is for the water companies in Malaysia such as Selangor Water Supply Compay Sdn Bhd (SYABAS), SAJ Holding Sdn Bhd and Air Kelantan Sdn Bhd for liquid concentration measurement.

Furthermore, there is also commercialization potential for any research labs that are doing research for liquid concentration and suitable to be used in food and chemicals industry.

This project is environmentally friendly because it does not release any chemical or any hazardous gas. Moreover, the FOS also uses less power compared to the conventional electronic sensor. The safety aspect of this project is safe because there is no large amount of power needed to operate. Thus, it does not have any harm potential to people. This project also is using standard communication fiber optics which is single mode (SMF) and multimode (MMF) optical fiber. So, it is a low-cost project.

1.2 Problem Statement

There are various types of sensors used based on electrical for liquid concentration measurement. Although most of the devices work well in practice, the sensors are costly and have a complicated configuration. However, fiber optic cable is immune to electromagnetic interference (EMI) or any short circuit and it safe to be used for flammable and non-flammable. Furthermore, silica fiber base material that does not run electricity in contrast to other devices those have the potential to cause a short circuit. In addition, energy consumption is also one of the problems. It uses more power supply to operate their experiment. Besides, bending effect will be enhanced sensitivity. So, it will be varied the bending radius and increase the evanescent wave. In order to continuously monitor liquid concentration especially in chemical industries, a liquid concentration measurement based on fiber optic is a solution. Furthermore, the cost can be reduced by using the standard communication optical fibers. Thus, the optical fiber is a better choice to replace the electronic sensor.

1.3 Objectives

To provide a solution for the mentioned problems above, this study is carried out to achieve the following objectives:

i. To design and fabricate the single mode-multimode-single mode fiber optic (SMS) by using splicing technique.
ii. To analyze the bending effect of the multimode fiber optic sensor (FOS).
iii. To determine the sensitivity of the sensor for liquid concentration measurement based on bending effect.

1.4 Scope of works

The scope of work on this project is to analyze the effect of bending of multimode fiber optic sensor for liquid concentration measurement. The FOS is developing by using a fusion arc splicing technique[4]. The sensor device is fabricated by using commercial splicer Fujikura FSM-18R and a high-quality cleaver Fujikura CT-30 is employed in order to obtain flat and clean end faces uncoated fiber. The fiber will be cleaned with alcohol before it is spliced. This project will be used a standard SMF-28. Both SMF-28 and MMF are spliced by a multimode auto mode.

The lead-in of the sensor is connecting to the optical light source with 1310 nm and 1550 nm operating wavelength with -6.50 dBm powers while the lead-out of the sensor device is connecting to an optical spectrum analyzer (OSA) Anritsu MS9740A with a 0.050 nm resolution and optical multimeter OMM-6810B. The length of the etched sensor is 30 cm. The sensor device will be tested in water, 1.0 mol sucrose solution and palm oil. The bending size of diameter used are 2.4 cm, 2.7 cm and 3.3 cm and there will be bending with 3 loops and the effect of the sensor