UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVISED SENSING PROPERTIES WITH ZINC OXIDE COATED FOR SINGLE MODE AND MULTIMODE FIBER OPTIC

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electronic Engineering Technology (Telecommunication) with Honours

by

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This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor Degree of Electronic Engineering Technology (Telecommunication) with Honours. The number of the supervisory is as follow:

……………………………………………..

(Madam Aminah Binti Ahmad)

ABSTRAK

Dua jenis fiber optik; mod tunggal gentian optik and mod rangkaian gentian optik pada asalnya telah dibalut menggunakan polimer akrilat. Polimer akrilat ini juga dinamakan sebagai polimer plastik. Di dalam projek ini, balutan polimer akrilat pada gentian optik akan dibuka dan digantikan dengan menggunakan zink oksida. Balutan kabel itu diubah untuk mengenalpasti kadar kuasa keluaran yang akan dihasilkan. Balutan yang dibuka dan bahagian yang sensitif akan disalut menggunakan zink oksida. Perubahan pada pengesan gentian optik akan direkod berdasarkan perbezaaan jenis gentian optik, kepekatan cecair zink oksida, kadar sumber cahaya, tindakbalas gentian optic berdasarkan tempoh masa, dan darjah gentian optik dilenturkan. Projek ini akan menganalisis bagaimana jenis balutan pada gentian optik mempengaruhi kadar kuasa keluaran dalam sistem penghantaran informasi. Kajian ini bukan sahaja mungkin akan memberi kebaikan kepada sistem penghantaran informasi malah akan menambahbaikan dalam sistem telekomunikasi.

ABSTRACT

In present, two type of fiber optic cables; single-mode and multimode originally coated with acrylate polymer. The acrylate polymer was known as plastic polymer. In this project, the acrylate polymer coating will be strip and being replaced using zinc oxide. The coating will be modify in order to determine the value of output power that will be produced. The cladding region will be removes by means of stripping technique, and the sensitive layer will be deposited using zinc oxide liquid wrapping method. The sensing reaction of fibers sensor will be recorded based on type of fiber optic being used, zinc oxide concentrations, the value of the light source being used, fibers performance based on time, and degrees of the fiber optic will be bends. This project is to analyze the fiber optic performance if the original fiber optic coating will be replaced. This analysis may be brings not only limited to the benefit of transmission system but also will give an improvement to the telecommunication system.

DEDICATION

Every hard work needs self-efforts as well as guidance of elders especially those who were very close to our heart. My humble effort I dedicate to my beloved parent along with my supervisor, lecturers and friends. Whose affection, encouragement and prays to me upon completing my final year project report.

Special dedication to my loving parent

SEGAI ANAK DUSING

ROSALIND DANIEL CHUAT

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter is covered some topics. There are the background of project's title, the objective of this project, problem statement faced, work scopes, project significant and finally project's conclusion.

1.1 Project Background

H.H. Hopkins has been reported that the fibers were first invented been made in glass, quartz, nylon, and polystyrene by the 1950s. At that time, glass was deemed to be the best material due to its tensile strength and transparency. Hopkins and Kapany were the inventors to demonstrate the use of fiber bundles to carry images. These fiber bundles were made of 25μm diameter glass cylinders in approximately meter lengths (H. H. Hopkins, 1920).

After the fiber optic gone through varies type of inventions, fiber optic presents a considerably lower attenuation than the common polymer fiber optics, which allows the transmission distance travel in a longer distance than before (Joseba Zubia, 2001). Since an increase in the carrier frequency provides a larger information capacity, the historical trend in telecommunications systems has been to employ progressively higher frequencies. Because of its high frequencies, the optical portion of the electromagnetic spectrum is currently being used for most of the communications links by employing optical fibers as transmission media (Joseba Zubia, 2001).

The optical and electronic properties of Zinc Oxide (ZnO) nanostructures are largely dependent on their composition, crystal quality, structural defects, dimensions and shape. Based on a research that has been done, Muzafar A. Kanjwala states the nanofibers are particularly interesting because of their long axial ratio, which has a distinct impact on the physical and chemical characteristics. Zinc oxide nanofibers were reported to have good properties; electro-spinning is the most widely used technique to produce a pristine zinc oxide or zinc oxide based nanofibers (Muzafar A. Kanjwala, 2012).

So this project will focusing on the most effective type of fiber optic; single mode and multimode, coated with zinc oxide. The effectiveness can be determine by the fibers output power.

1.2 Objective

Project objectives are to;

(i) To study fiber optic for telecommunication system.

(ii) To develop coated process for fiber optic.

(iii)To analyze performance of fiber optic coated with zinc oxide.

1.3 Problem Statement

Fiber optic is being used to send large amount of data in telecommunication system. There are two types of fiber optic, single mode ray and multimode ray. In present, the fiber optic are coated with a layer of acrylate polymer and contained in a protective tube. This research is about to determine the effectiveness of replacing the present coated fiber optic material with zinc oxide in two types of fiber optic rays. The most effective types of fiber optic coated with zinc oxide will be determined by the value of the output power being produced.

1.4 Scope Project

The scope of this project is to determine the most effective types of fiber optic when being coated with the zinc oxide. The effectiveness of fiber optic works will be analyzed by the result of output power value. This project will contribute a benefits to the telecommunication guided transmission system as this project may be gives an improvement in the industry. Lastly, the scope project is able to achieve the objectives of this project.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

The characteristics and some information of the equipment and materials being used in the project are discussed in this chapter. The research topics that had been discussed in this chapter are the basic structure of fiber optic cable, polymer glass, refractive index, zinc oxide, light source and optical analyzer.

2.1 Fiber Optic

An idea to the development of using light for telecommunications goes back to 19th century. Alexander Graham Bell reported done an experiment that demonstrated a photophone back in 1881. The photophone is a device in which a voice or musical tone is encoded on a beam of light, and transmitted to a detector that converts the light to an acoustical signal (Bell, 1881). However, photophone comes with its disadvantage. The photophone is its requirement of unobstructed line-of-sight between transmitter and receiver (Bell, 1881).

Right after Bell's photophone report, Kuzyk reported that Lord Rayleigh considered a waveguide in year 1897. A waveguide which confines light inside a flexible structure, allows the light signal to be routed.The theory of waveguide was then developed in 1910 by Hondros and Debye and experimentally investigated by Schriever in 1920. By this time, it was understood that long and thin strands of fiber could be used to guide light through total internal reflection (Kuzyk, 2007).

An increasingly larger portion of the electromagnetic spectrum has been utilized for conveying information from one place to another since the invention of the telegraph by Samuel Morse in 1838 (Joseba Zubia, 2001). According to Joseba, the reason for the research is that, in electrical systems, data are usually transferred through the communications channel by superimposing the information signal onto a sinusoidally varying electromagnetic wave, which is known as the carrier. Since an increase in the carrier frequency provides a larger information capacity, the historical trend in telecommunications systems has been to employ progressively higher frequencies. At the destination, the information is removed from the carrier wave and processed as desired. Because of its high frequencies, the optical portion of the electromagnetic spectrum is currently being used for most of the communications links by employing optical fibers as transmission media. Although the first optical fibers that were used as a communications channel were made of glass, however plastic fiber optics have become increasingly popular since 1960s, owing to their growing utility (Zubia & Arrue, 2001).

Since the development of the graded-index plastic optical fibers by Professor Koike at Keio University (1990) and the later attainment of the low-attenuation perfluorinated fibers (1996), plastic optical fibers have received a lot of interest, which is expected to give rise to a great deal of applications in the next several years (Joseba Zubia, 2001). Its historical evolution is shown in Table 1. Joseba Zubia also states the graded-index plastic optical fibers were then being used universally in telecommunication cable system as it's just easy to handle and minimize the diameter of glass being used in fiber optic. So the fiber optic will less brittle when handling (Joseba Zubia, 2001).

Table 2.1 Historical Evolution of the Most Important Landmarks Related to Plastic Optical Fiber during the Past 30 Years.

Year	Organization	Landmark
1968	Dupont	First SI POF with PMMA core
1972	Toray	First SI POF with PS core
1981	NTT	Low attenuation PMMA SI POF (55 dB/km at 568 nm)
1982	Keio University	First GI POF (1070 dB/km at 670 nm)
	NTT	First SI POF with deuterated PMMA core (20 dB/km at 650 nm)
1983	Mitsubishi Rayon	PMMA "Eska" SI POF (110 dB/km at 570 nm)
1987	France	The French POF Club is established
1990	Keio University	First high speed transmission with a PMMA-core GI POF (300 MHz*Km at 670 nm)
1991	Hoechst Celanese	SI PMMA "Infolite" POF (130 dB/km at 650 nm)
1992	Keio University	GI deuterated PMMA POF (55 dB at 688 nm)
1993	Essex University	Transmission at 631 Mb/s over 100 m by means of a PMMA-core SI POF and an equalizer circuit
1994	USA/Japan	The high speed POF Network (HSPN) Consortium is created
	Keio University, IBM	The POF Consortium of Japan is created
	Keio University, NEC	Transmission at 1 Gb/s over 30 m by means of a GI POF and a VCSEL at 670 nm
	Asahi Chemical	Transmission at 2.5 Gb/s over 100 m by means of a GI POF at 650 nm; First multicore SI POF for high speed transmission
1995	Mitsubishi Rayon, NEC	Transmission at 156 Mb/s over 100 m by means of a low NA SI POF and a fast red LED
1996	Keio University, KAST	First perfluorinated (PF) GI POF (50 dB/km at 1300 nm)
		Theoretical estimation of the losses in a PF POF (0.3 dB/km at 1300 nm)
		Theoretical estimation of the transmission speed in a GI POF optical link (PMMA: 4 Gb/s over 100 m; PF: 10 Gb/s over 1 km)
1997	POF Consortium of Japan	Standardization at ATM LAN (156 Mb/s over 50 m of SI POF) in the ATM Forum.
		Standardization of the norm IEEE 1394 (156 Mb/s over 50 m of SI POF)
	Keio University, Fujitsu, Asahi Glass	Transmission at 2.5 Gb/s over 200 m by means of a PF-core GI POF at 1300 nm
1998	COBRA, Eindhoven University, Keio University, Asahi Glass, NEC	Transmission at 2.5 Gb/s over 300 m by means of a PF-core GI POF at 645 nm
	Matsushita	Transmission at 500 Mb/s over 50 m by means of a GI POF and a fast red-color LED (RC-LED; 650 nm)
1999	COBRA, Eindhoven University, Keio University, Asahi Glass	Transmission at 2.5 Gb/over 500 m by means of a PF-core GI POF at 840 and 1310 nm
	University of Ulm, Asahi Glass	Transmission at 7 Gb/s over 80 m by means of a PF-core GI POF at 950 nm
	Bell Laboratories, Asahi Glass	11 Gb/s data transmission through 100 m of perfluorinated GI POF at 830 nm and 1310 nm.
2000	Asahi Glass	GIPOF (Lucina) with an attenuation of 16 dB at 1300 nm and 569 MHz*km

** Note: SI, step-index; GI, graded-index; PMMA, polymethyl methacrylate; PS, polystyrene; PF, perfluorinated fiber.

2.1.1 Types Fiber Optic

Fiber optic is classified into two different types, which are single mode and multimode. It was classified separately based on the way in which the light travels through it. Three common types of fiber optic cable been used in telecommunication system includes;

2.1.1.1 Single mode

Figure 2.1 Single mode optical fiber propagation

Brooker reports the beam of light in single mode optical fiber are travelling along very narrow diameter of the core. A single mode fiber usually has a step-index core of diameter of 125µm (Brooker, 2003). A single mode optical fiber carries light only directly down the fiber in a transverse mode (Suzuki et al. 2008). As a single mode is designed to carry a single ray light beam, it's therefore batter at retaining the fidelity of each light pulse over longer distances than multi-mode optical fiber (Dai et al. 2015). So a single mode optical fiber can have a higher bandwidth than multi-mode fibers (Xiao et al. 2011).

2.1.1.2 Step-index multimode

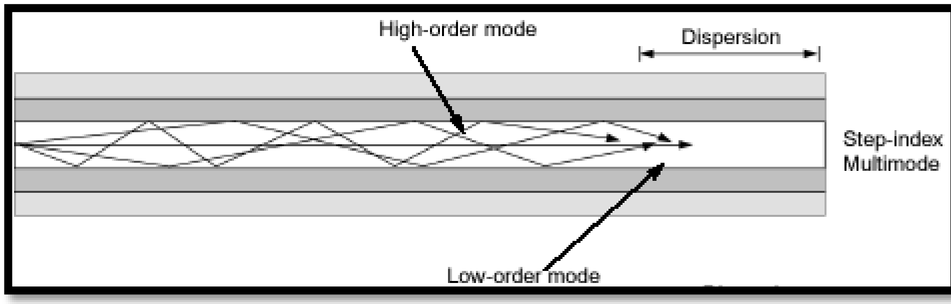

Figure 2.2 Step-index multimode optical fiber propagation

Based on the article in *Optics Demystified* reported by Gibilisco, the core in a step-index fiber has a uniform index of refraction and the cladding has a uniform lower index of refractive. The transition at the boundary of the optical fibers cable is abrupt. As shown in Figure 3, high-order mode ray enters the core parallel to the fiber axis and travels without striking the boundary unless there is a bend in the fiber optic cable (Gibilisco, 2009). If there is a bend, high-order mode ray veer off center and behaves like low-order mode ray, striking the boundary (Leon-Saval et al. 2005). Every time the low-order ray encounters the boundary, total internal reflection will occurs to keep the rays stay within the core (Leon-Saval et al. 2005).

2.1.1.3 Graded-index multimode

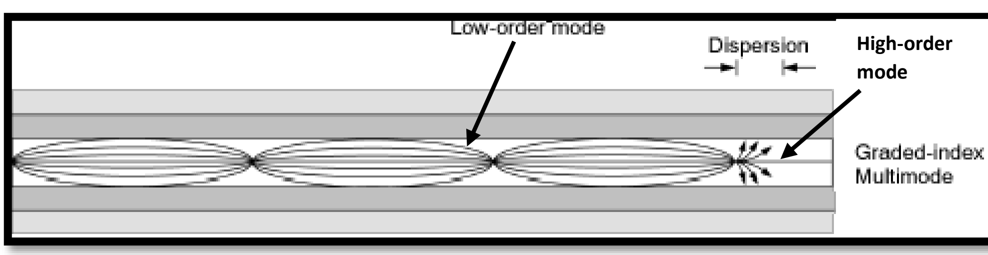

Figure 2.3 Graded-index multimode optical fiber propagation

Gibilisco was also briefed the other types of multimode. The core in a graded-index optical fiber has a highest refractive index along the central axis and steadily decreases outwards the light rays were travelling away from the center of the core. At the cable boundary, there is an abrupt drop in the refractive index. The high-order ray characteristics are same as in step-index multimode. Hence, the index of refraction will decreasing when a low-order mode ray moves away from the center of the core. If the low-order ray encounters an especially sharp bend in the fiber, the ray strikes the boundary between the core and the cladding, and total internal reflection will occurs (Gibilisco, 2009).

2.1.2 Fiber Optic Design

Fiber optic structure is has a central core, cladding and plastic coating (J. Laferriere & R. Taws, 2007). The central core is in a glass rod and surrounded by a cladding. While the external plastic coating is to protect and strengthen the fiber which also known as the buffer. Light guiding and propagation in fiber optic is based on total internal reflection of the light between the core and the cladding (J. Laferriere & R. Taws, 2007). Figure 2.4 illustrated the composition of fiber optic.

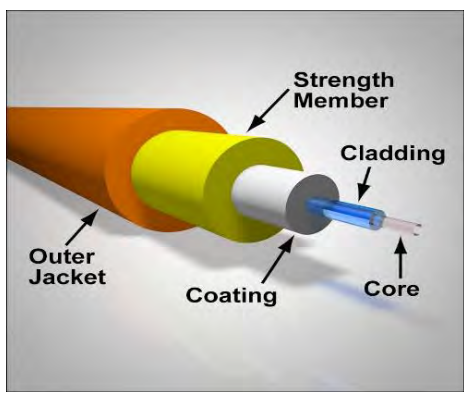

Figure 2.4 Fiber Optic Structure

2.1.3 Fiber Optic Transmission Principle

The injection of light into a fiber is at a small angle, α. The capability of the fiber optic cable to receive light through its core is determined by its numerical aperture (NA) (J. Laferriere & R. Taws, 2007).

$$NA = \sin\alpha_0 = \sqrt{n_1^2 - n_2^2}$$

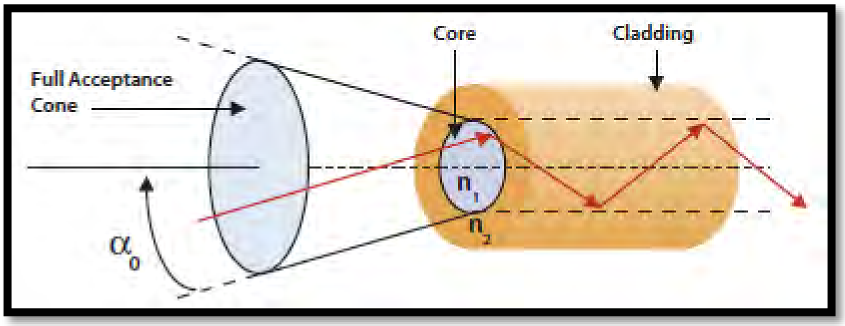

Figure 2.5 A Light Ray enters a Fiber

α_n is the maximum angle of acceptance (the limitation between reflection and refraction), while n_1 is the refractive index core and n_2 is the cladding refractive index respectively (J. Laferriere & R. Taws, 2007).

Based on the research by Massa, the fiber optic transmission are using wavelengths that are in the near-infrared portion of the spectrum, just above the visible, and thus undetectable to the unaided eye. There are ranges of wavelengths at which the fiber optic will operates best. Each range is known as an operating window. Each window is centred on the typical operational wavelength, as shown in Table 2.2.

Table 2.2 Fiber Optic Transmission Window

Window	Operating Wavelength
800 – 900 nm	850 nm
1250 – 1350 nm	1310 nm
1500 – 1600 nm	1550 nm