Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF LIQUID CONCENTRATION SENSOR USING OPTICAL FIBER FOR MEDICAL INDUSTRY

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

2021

DEVELOPMENT OF LIQUID CONCENTRATION SENSOR USING OPTICAL FIBER FOR MEDICAL INDUSTRY

MUHAMMAD HAKIMI BIN ABDUL HAMID

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

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled "Development of Liquid Concentration Sensor Using Optical Fiber for Medical Industry" 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.

Signature :

Student Name : MUHAMMAD HAKIMI BIN ABDUL HAMID

Date : 10/1/2022

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 (Telecommunications) with Honours.

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Date : 11/01/2022

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Co-Supervisor :

Name (if any)

Date :

DEDICATION

I dedicated this project to God Almighty my creator, my strong pillar and wisdom. To my family, I owe a particular debt of gratitude to my parents, who always supporting me and continue to speak to me about encouragement and tenacity.

Next, I devoted the project to my supervisor that have been show his guidance throughout the process of this project. Last but not least, not to be forgotten to my fellow friends that always supporting in mental to finish this project.

ABSTRACT

Fiber optic are capable of transmitting massive volumes of data at very fast rates. As a result, this technique is frequently employed in internet connections. Fiber optic cables are small, lighter, more flexible, and transport more data than standard copper lines. In the disciplines of health and research, fiber optic are commonly used. Optical technology is a crucial aspect of endoscopy, which is a non-interrupt surgical approach. In such cases, a small, bright light is utilized to illuminate the operation region inside the body, allowing the number and size of incisions to be reduced. Microscopy and biomedical research both employ fiber optics. The imaging and lighting components of endoscopes are the most important and common uses of fiber optics in medicine. Other than that, the research lays out the fundamental theory, assesses the current state of the art, and predicts how fiber-optic sensors will be employed in household appliances in the future.

ABSTRAK

Fiber optik mampu menghantar jumlah data yang besar pada kadar yang sangat cepat. Akibatnya, teknik ini sering digunakan dalam kabel internet. Kabel fiber optik kecil, lebih ringan, lebih fleksibel, dan mengangkut lebih banyak data daripada garisan tembaga standard. Dalam disiplin kesihatan dan penyelidikan, kabel fiber optik biasanya digunakan. Komunikasi optik adalah aspek penting endoskopi, iaitu pembedahan yang tiada gangguan. Dalam kes sedemikian, cahaya kecil dan terang digunakan untuk menerangi kawasan operasi di dalam badan, membolehkan bilangan dan saiz luka dikurangkan. Penyelidikan mikroskopik dan bioperubatan kedua-dua menggunakan fiber optik. Komponen pengimejan dan pencahayaan endoskop adalah kegunaan fiber optik yang paling penting dan biasa dalam perubatan. Selain itu, penyelidik meletakkan teori asas, menilai keadaan semasa seni, dan meramalkan bagaimana sensor fiber optik akan digunakan dalam peralatan isi rumah pada masa akan datang.

ACKNOWLEDGEMENTS

The success and outcome of this project required a lot of guidance from Md Ashadi bin Md Johari and words of wisdom and patient throughout this project. Moreover, I am very grateful to have all the lecturers in Faculty of Electrical and Electronic Engineering Technology (FTKEE) who had delivered all the knowledge throughout my bachelor's degree enrolment which these knowledges are implemented into this project.

Next, I want to express my appreciation to FTKEE for providing me the proper platform and environment to learn as much knowledge related to electronic communication engineering. It will never be a regret that I enrolled in FTKEE to improve my skills and abilities in connected industries.

Lastly, I like to thanks to my beloved family because support through my mental health during study. Their compassionate action is most valued when I was in this awful time. Thanks to almighty Allah for giving me strength, ability and bless mi with infinite knowledge, experience, and confidence to finish my project.

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LIST OF ABBREVIATIONS

FOS	-	Fiber Optic Sensor
COD	-	Coefficient of determination
dB	-	Decibel
	-	
	-	
	-	
	-	
	-	

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CHAPTER 1

INTRODUCTION

1.1 Background

Fiber optics is the medium or for transmitting data as light pulses over a glass or plastic strand or fiber. Fiber optics is utilized for long-distance and high-performance data networking. Fiber optics is also commonly used in telecommunication services such as internet, television, and telephones. Fiber optics send data across a fiber optic cable in the form of light particles called photons. The refractive index of the glass fiber core and cladding differs, bending incoming light at a certain angle. When light signals pass through fiber optic cable, they bounce off the core and cladding in a series of zig-zag bounces, which is known as total internal reflection.

Optical fiber sensors, also known as fiber optic sensors, employ an optical fiber or sensing device. Temperature, pressure, vibrations, displacements, rotations, and chemical concentration are all sensed by these sensors. For sensitivity situations, severe vibration, excessive heat, moist, and unstable settings, fiber optic sensors are ideal. These sensors can readily fit into small spaces and be placed where flexible fibers are required. There is two type of fiber optic sensor which are intrinsic fiber-optic sensors and extrinsic fiber-optic sensor. For intrinsic fiber-optic sensors, its sensing takes place within the fiber itself. To transform an environmental action into a modification of the light beam flowing through it, the sensors rely on the optical fiber's qualities. For extrinsic fiber-optic sensors, the fiber might be used to carry information that points to a black box. It sends out a light signal based on the data it receives from the black box. The black box might be composed of mirrors, gas, or any other optical signal-generating apparatus. Rotation, vibration velocity, displacement, twisting, torque, and acceleration are all measured with these sensors.

In Fiber Optic, when light moving through an optically dense material meets a boundary at a steep angle (more than the critical angle for the barrier), it is totally reflected known as total internal reflection. In optical fibers, this phenomenon is employed to restrict light in the core. Light passes through the fiber core and bounces back and forth between the core and the cladding. In Fiber Optic, refraction occurs when the deviation of a light beam or energy wave from a straight path when crossing obliquely from one media (such as air) into another (such as glass) with a different velocity.

Glucose is a basic sugar that serves as the body's primary energy source. Natural glucose is the major sugar produced by the body and is detected in the blood. The body produces glucose from all three components of food which are protein, fats, and carbs, although carbs provide the most glucose. For living cells, glucose is the primary source of energy. Cells, on the other hand, cannot utilize glucose without the support of insulin.

This project is to observe the execution of the fiber optic sensor in different concentration of glucose. Besides, this project requires SMF28 optical cable, a laser source with wavelength of 1550nm, Optical Spectrum Analyzer (OSA) and five different Glucose concentration at 10%, 20%, 30%, 40% and 50%. The experiment will be repeat for three times for each solution and the results that will be obtained is the reading of loss at the peak of the spectrum from the OSA device. At the end of the project, one optical concentration sensor with high sensitivity is formed.

1.2 Problem Statement

Liquid sensor had been using in medical industry for such a long time ago. In general, liquid sensors are used to aid medical professionals in obtaining an accurate diagnostic of a patient's condition. In Malaysia, the number of patients suffer from diabetes are caused by glucose consumption and their daily food with high amount of sugar. In general, high blood sugar can cause damage to our blood vessel, nerves, and organ. It also can lead to the other serious condition. Therefore, lack of an accurate reading can cause of diabetes. On the other hand, optical fiber usually used in medical industry such as endoscope to produce an image of inside the body. So, throughout this project will be observed the performance fiber optic glucose sensor.

1.3 Project Objective

This project is based on three major objectives as mentioned as below:

a) To study the operation of the Fiber Optic in liquid.

b) To develop Fiber Optic Sensor in different concentration of Glucose.

c) To analyze the perfomance of the Fiber Optic Sensor in Glucose detection.

1.4 Scope of Project

The scope of this project is stated as below:

a) Optic Fiber SMF28 will be used in this experiment.

b) The part where the detection is measured must be the bare fiber (without cladding).

c) The light source used are in the same wavelength which is 1550nm.

d) The concentration of Glucose liquid is prepared.

e) Measure the glucose in different concentration

f) Measurement is taken from the spectrum reading from the Optical Spectrum Analyzer (OSA).

g) Repeat the step to produce more graph.

1.5 Report Overview

In chapter 2, will discussed about the literature review. Literature review is a finding an article about the title of the project. Literature review relevant to optical fiber are needed to study because fiber optic is used in this project. In this chapter, will study the type of fiber optic sensor which is single-mode optical fiber and multi-mode optical fiber. Literature review about the reflective and refractive also will be study in this chapter. Lastly, literature about various type of fiber optic sensor also will be investigated which is intrinsic optical fiber and extrinsic optical fiber.

In chapter 3, will provide information about the experiment's technique. This chapter explains the project's flowchart, which depicts the experiment's flow. This chapter will explain how fiber optic sensors are made. The procedure that required in this chapter is stripping procedure and splicing procedure. After that, it is necessary to know the characterization of fiber optic sensor before starting the experiment. Lastly, elaborating the procedure on how the testing will be conducted.

In chapter 4, will discussed about the preliminary result of the experiment. The result is collected from the sample previous work from another research. The result is showing the different concentration of sodium chloride which is 20%, 40%, 60%, 80% and 100%. The experiment also is tested on 1310nm wavelength.

In chapter 5, will conclude the entire chapter of bachelor's degree project 2. This chapter will conclude all the objective that has been achieved. From the experiment, the experiment has been succesfully for all concentration which are 10%,20%,30%,40% and 50%. From the experiment, the graph has been produced based on the data taken. All the result has been state in Chapter 4.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In today's modern society, energy efficiency is identified as key strategies to address growing issues in increasing fuel cost, market competition, tightening regulation, climate change and energy crisis due to depleting fossil fuel resources. Utilities and regulators are putting greater emphasis to find ways to reduce distribution TL as it represents key indicator of an energy efficient system. For strategic planning and development of energy efficient distribution network, it is important for utilities to develop effective methodology to correctly and efficiently evaluate the magnitude, location and sources of TL that occurs in the system. With comprehensive and accurate TL information, corrective and preventive solutions for TL reduction can be planned and executed correctly, and in a timely and effective manner.

2.2 Anatomy of Fiber Optic

Optical fiber is a type of data transmission technology that works by sending light pulses down a long fiber, that are generally made by glass or plastic. Metal wires are preferred for optical fiber communication transmission because signals move with less harm. Electromagnetic interference has no effect on optical fibers. The complete internal reflection of light is used in the fiber optical cable. Depending on the power and transmission distance requirements, the fibers are designed to aid in the propagation of light in connection with the optical fiber.

The total internal reflection principle guides the functioning of the optical fiber. Light rays have the ability to transmit large amounts of info. So, until we have along straight wire with no bends, we would not be able to take use of this benefit. The optical cables, on the other hand, are intended to bend all light rays inwards (using TIR) as shown in Figure 2.1. Light beams travel eternally, bouncing off fiber optic barriers and transmitting data from one end to the other. Although light signals degrade with time depending on the purity of the material utilized, the loss is significantly less than when employing metal wires.

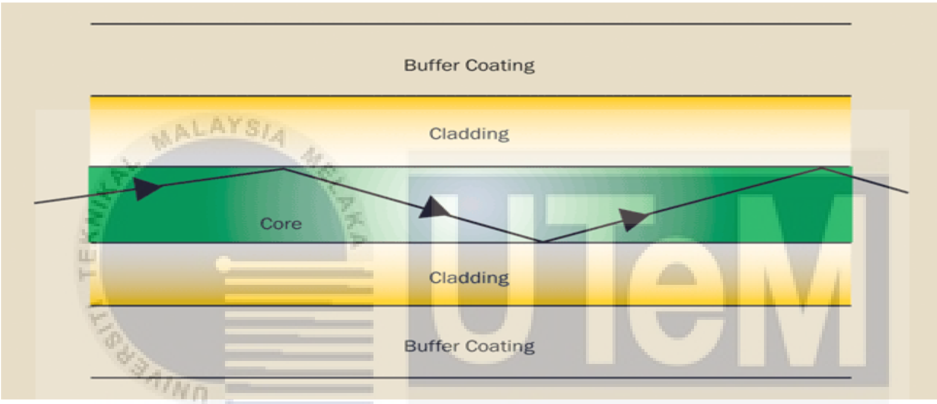


Figure 2.1 Total Internal Reaction (TIR) of fiber optic

2.2.1 Types of fiber optic

2.2.1.1 Single mode fiber optic

In By shaping a small section of single-mode[1] optical fiber into a closed ring to construct a low-loss cavity, a high finesse optical resonator may be created. Such a fiber ring can be closed in a low-loss way thanks to recent improvements in single-mode fiber directional couplers. Single-mode fiber is a form of optical fiber that is commonly utilized for long-distance transmission. It is one of two optical fiber kinds, with multi-mode fiber being the other. In Figure 2.2 show a single-mode fiber is a strand of glass that transmits just one mode or beam of light. There is just one transmission mode in single-mode fiber. It has a larger bandwidth capacity than multi-mode fiber. However, require a light source with a limited spectral breadth. Single-mode strands have evolved into more enigmatic shapes, such as coordinated clad, discouraged clad, and other unusual forms.

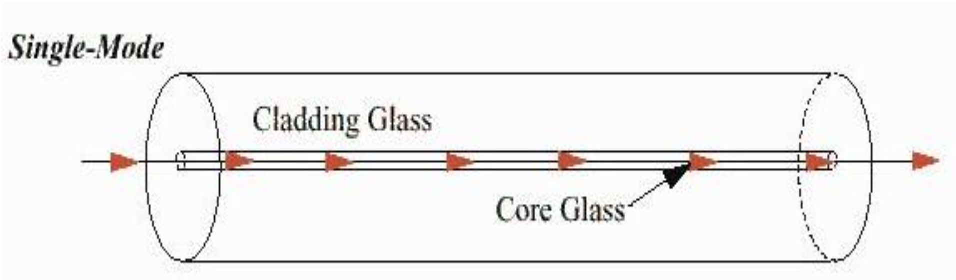


Figure 2.2 Single mode of fiber Optic.

2.2.1.2 Multimode fiber optic

The name multimode fiber comes from the fact that light travels through the core in several beams (or modes). This means that light can propagate in a variety of ray pathways through the fibers.[2] It has a core that is five to six times bigger in diameter than single mode, allowing it to capture more light. Core sizes range from 50 micrometers (m) to 1,000 micrometers (m) and are generally used to communicate across small distances, such as between residences or building. Data rates of 10 Mbit/s to 10 Gbit/s over connection lengths of up to 600 meters are typical for multimode connections, which are more than sufficient for most premises applications. Furthermore, a single point on a multimode fiber is subjected to mechanical vibrations. When multipoint vibrations are present, some challenges arise because we can only analyze the image at the fiber end, where all vibration points' influences interfere. [3]

The diagram below shows how the aggregate inward reflection standard relates to multimode step-file fiber. Because the center refraction index is higher than the cladding index, light that enters at a location other than the fundamental point is steered along the fiber.

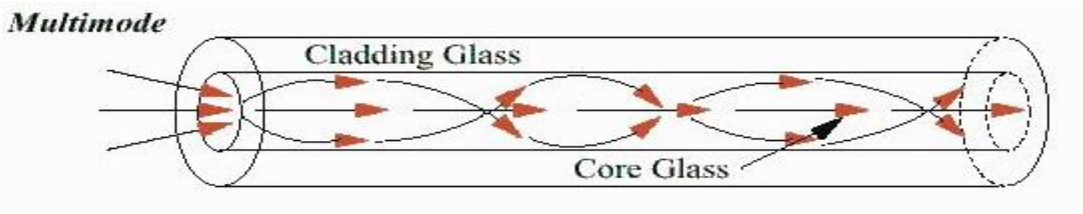


Figure 2.3 Multimode of fiber optic.

2.3 Difference between Single-mode and multi-mode

Single mode fiber is slightly smaller core than multimode fiber, making it more suitable for long distance applications. Single-mode systems are more costly in general. Multimode fiber has a thicker core than single mode fiber and is suggested for fiber lines of less than 400 meters (1300 feet). The distance and bandwidth capacities of multimode fiber are affected by its grade. In general, multimode systems are less costly.

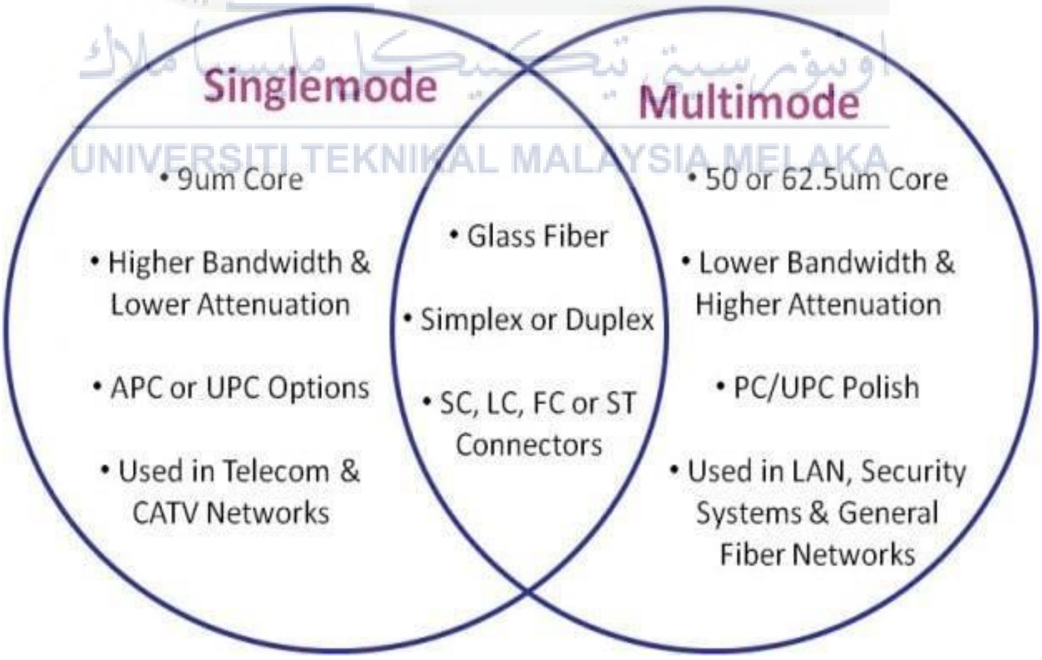


Figure 2.4 Different single-mode and multi-mode.

2.4 Reflective and Refractive

When a propagating wave approaches a medium barrier at an angle greater than a critical angle relative to the normal to the surface, total internal reflection occurs. If the refractive index on the other side of the boundary is lower than the critical angle and the incidence angle is bigger than the critical angle, the wave cannot pass through. Figure 2.5 shows the critical angle is the incidence angle above which the whole internal reflectance is seen. Other than that, refraction of light occurs when a light beam changes direction as it travels from one transparent material to another.[4]

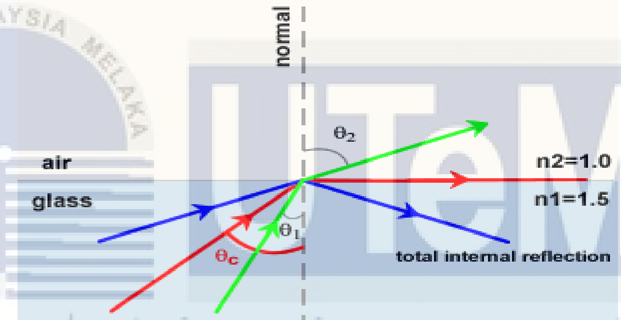


Figure 2.5 Total Internal Reflection.

The media's refractive index controls how much the light beam shifts in direction. Refraction is the bending of a wave when it enters a medium with a different speed. Refraction bends the light beam toward the normal to the boundary between the two media as it goes through a fast medium and into a slow medium. Willebrord Snell, a Dutch scientist, discovered the link between the varied angles of light as it travels through various transparent media in 1621. Snell's law states that as light flows from one clear substance to another, it bends according to the following formula:

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

Figure 2.6 Snell's Law formula.

Where:

n_1 is the refractive index of the medium through which light is being transmitted

θ_1 is the incident angle between the light beam and the normal (normal is 90° to the interface between two materials).

n_2 is the refractive index of the medium through which the light passes.

θ_2 is the angle of refraction between a light ray and the normal.

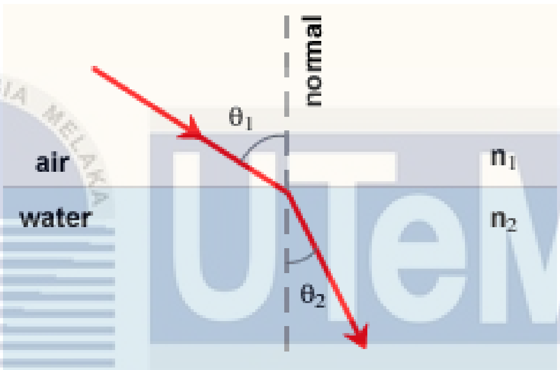


Figure 2.7 Refraction of light.

2.5 Glucose

Glucose is an aldose monosaccharide that is essential for photosynthesis and respiration in most organisms, as well as serving as a source of energy and metabolic fuel. Glucose, both as a monomer and as a component of more complex compounds such as polysaccharides and glucosides, plays a vital role in modern cuisine, particularly in terms of flavor and structure. Over the years, several various techniques to detect and measuring glucose have been created; this overview includes the most widely used and historically significant, such as copper iodometry, HPLC, GC, CZE, and enzyme-based systems like glucose meters. The strengths and disadvantages of each approach are evaluated, and contemporary applications in food chemistry are investigated.

2.5.1 How Glucose works on our body

In order for our body (muscles, brain, heart and liver) to function well, we need a good amount of energy.[5] The food we consume provides this energy. Our bodies combine the food we consume with fluids (acids and enzymes) in the stomach to digest it. The carbohydrate (sugars and starches) in the meal is converted into glucose, a different form sugar, when it digested in the stomach. Before being released into the circulation, glucose is absorbed by the stomach and small intestines. Once in the blood, glucose may be used for energy immediately or stored in our bodies for later use. Insulin, on the other hand, is required for our bodies to use or store glucose for energy. Without insulin, glucose stays in the bloodstream, causing blood sugar to increase. Figure below shows how glucose on the human body.

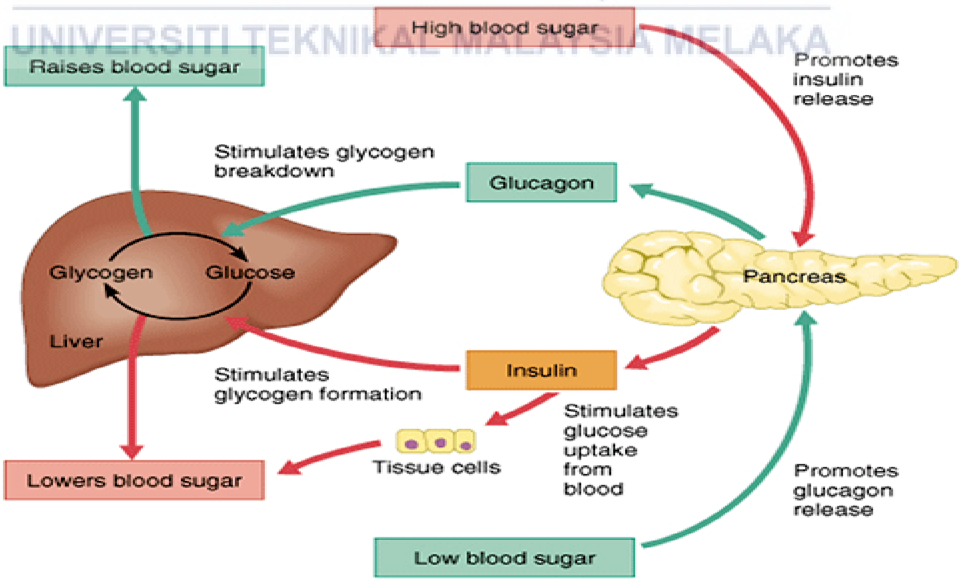


Figure 2.8 Glucose on human body.

2.6 Fiber Optic Sensor

When a fiber optic cable is used in telecommunications, the goal is to transport as little data as possible across the longest distance available. As light passes through the fibers, it is turned into a fiber-optical sensor, which can detect strength, pressure, temperature, magnetic fields, and other parameters. As a result, the characteristic that we use in sensing is light loss, which is necessary in telecommunications. Basically, fiber optic sensors are divided into two categories which is extrinsic and intrinsic. [6]

2.6.1 Intrinsic Fiber Optic Sensor

Sensors are incorporated in or part of the fiber optic system in this form. Consequently, the optical fiber undergoes minor changes. The intrinsic sensor [7] is the name for this kind of sensor. Fiber acts as a detecting element in this sensor type since it is instantly touched by measurand. The measurand's influence on the light to be transmitted occurs in the fiber itself. The light beam does not exit the optical cable in this case, rather is modified while remaining within it.

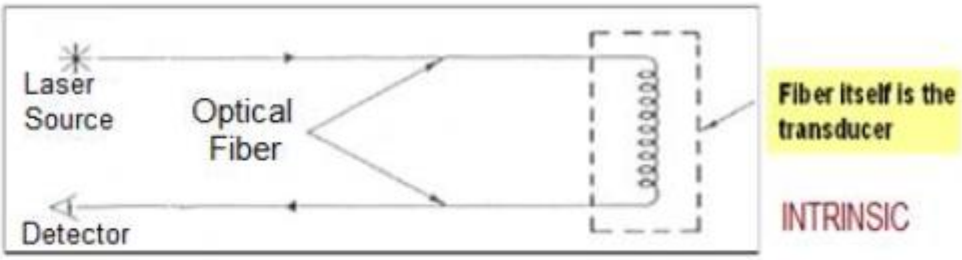


Figure 2.9 Intrinsic Fiber Optic.

2.6.2 Extrinsic Fiber Optic Sensor

Light exits the fiber and is obstructed or reflected before returning to the fiber optic system for extrinsic sensors. A barrier in the sensor may prevent light from going through a cut in one fiber into another. Transducers are located outside of the fiber optic systemin this configuration. As a result, fiber just records and transmit the amount detected. In this situation, fiber just transport light to and from the sensor device. The light is carried over the optical fiber from the source to the detector end, but the modulation takes place outside of it. A variety of extrinsic, low-cost switch-type devices based on on-off modulation of an optical signal have been created, with some of these being incorporated into commercial products.[8]

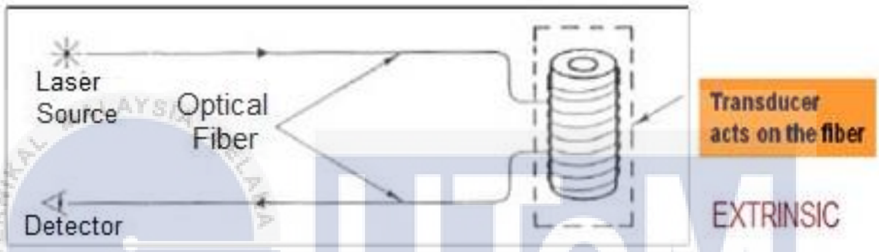


Figure 2.10 Extrinsic Fiber Optic.

2.7 Enzyme-Based Fiber Optic Sensor for Glucose detection

2.7.1 Introduction

Physical interferences are reduced since the signal is optical, there is no reference cell or electrode, and samples are analyzed at an inaccessible place. Fiber-optic sensors based on immobilized enzymes are newer than electrochemical sensors and seem to have various benefits. There have been reported fiber-optic probes based on fluorescence quenching and competitive substrate binding to glucose oxidase. Fiber-optic probes have been suggested for a variety of applications, including on-line pH, oxygen, and carbon dioxide measurement, blood electrolyte, and ammonia detection, among others.[9]

2.7.2 Experimental Apparatus

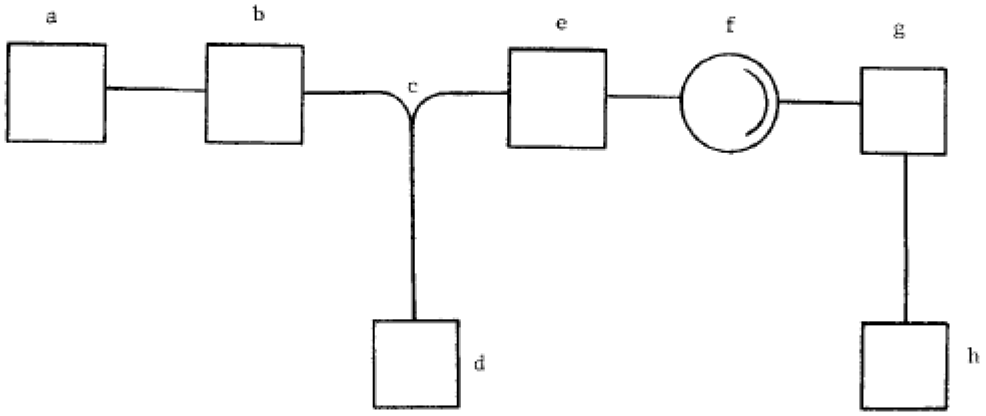


Figure 2.11 Block Diagram of apparatus

Block diagram above shows the apparatus that used in the experiment which are:

a) Light Sources
b) Monochromator
c) Bifurcated fiber optic bundle
d) Cell compartment
e) Monochromator
f) Photomultiplier tube
g) Photomultiplier readout
h) Strip chart recorder

A tungsten lamp is used as the light source, and it is coupled to the Beckman DU's excitation monochromator in the normal method. Monochromatic light with a wavelength of 425nm is focused onto the bundle's input arm and sent through the fiber to the cell. Scattered radiation is then directed through the bundle's opposite arm, which is focused on a second monochromator set to the same wavelength. This method filters out any stray radiation, resulting in a steady signal.

2.7.3 Experimental Procedure

The enzymatic solution was applied on a preactivated Immunodyne membrane 1 x 1.5 cm to immobilized glucose oxidase (Pall, New York). The enzymatic membrane was washed in 50 mL of 1 M KC1 for 1 hour with gentle and continuous stirring after 10 minutes. The membrane was then kept at 4°C in a buffer containing 0.2 M acetate and 0.2 M KC1, pH 5.5. The test solution in this investigation consisted of 0.2 mL peroxidase, 0.2 mL ABTS, and 4 mL buffer having a specified concentration of glucose. A magnetic stirrer was used to stir the contents of the cell at a steady pace. The enzymatic membrane is wrapped around the bundle's common end and secured with an O-ring.

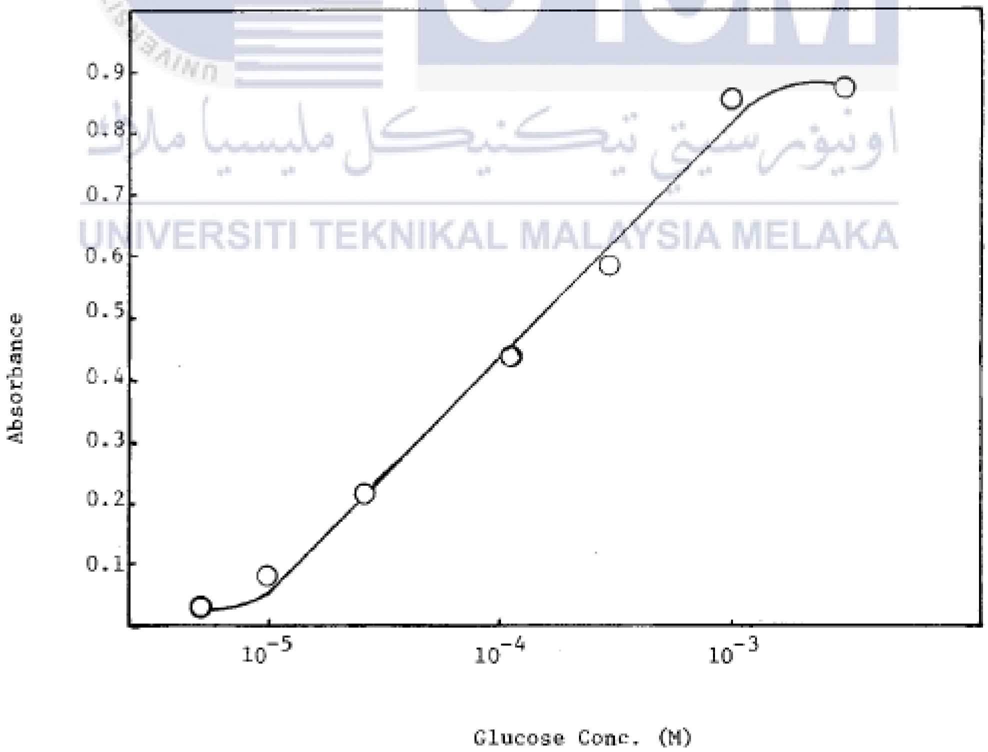


Figure 2.12 Standard calibration curve for glucose with the fiber optic probe

2.7.4 Discussion

The ability to determine glucose utilizing immobilized glucose oxidase on the tip of a fiber optic bundle is shown in this work. Simple apparatus, which is likely to be accessible in most labs, may be used to conduct the investigation. Immunodyne membranes make enzyme immobilization easier, and they are also quite dependable. With continued usage, however, the oxidized ABTS is permanently adsorbed on the membrane surface. This adsorption might be the fundamental cause of the gradual reduction in enzyme activity. This is minor challenge, however, due to the simple technique for immobilizing the enzyme.

2.8 Fabrication and characterization of a surface plasmon resonance-based fiber optic sensor using gel entrapment technique for the detection of low glucose concentration.

2.8.1 Introduction

Fabrication and characterization of a fiber optic sensor based on surface plasmon resonance (SPR) that uses a wavelength interrogation approach to assess low glucose concentrations (comparable to human blood) in aqueous fluid. The sensing probe is made by depositing silver and silicon films on the optical fiber core, then utilizing the gel entrapment technique to immobilize the enzyme (glucose oxidase). On increasing the content of glucose in samples, experimental findings on SPR spectra demonstrate a blue shift in the resonance wavelength.[10]

2.8.2 Experimental Setup

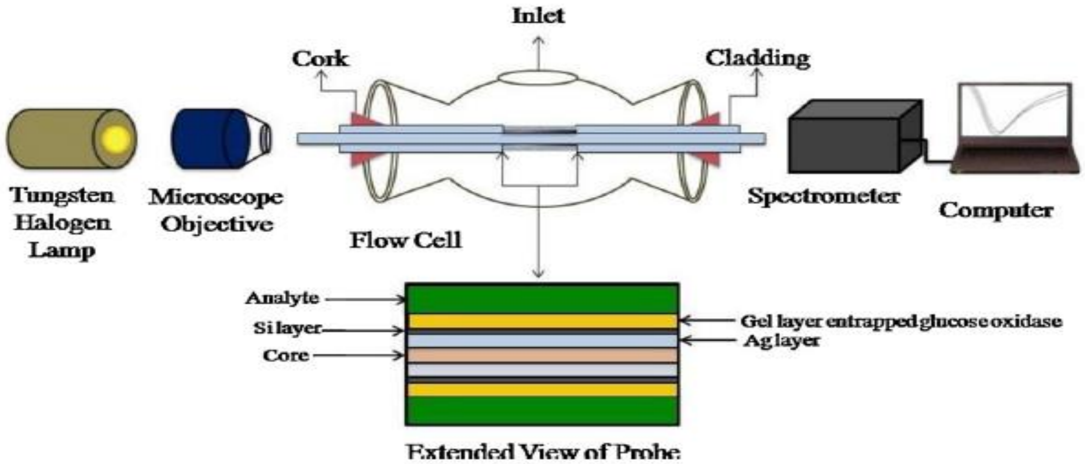


Figure 2.13 Schematic Diagram of the experimental setup.

Figure 2.13 show the setup for experimental of SPR-based fiber optic glucose sensor. The fiber optic probe was installed in a tiny flow cell to allow for the supply and removal of an aqueous glucose solution surrounding the sensing surface. Using glucose in buffer solution, aqueous samples of glucose with concentrations ranging from 0 to 260 mg/dL were generated. All the samples' refractive indices were determined using an Abbe refractometer with a 0.001 precision. Within the refractometer's precision, all the samples produced had the same refractive index. With the use of a microscope objective, unpolarized light from a temperature regulated and intensity stabilized tungsten–halogen lamp (Ava-Light-HAL) was focused onto the input face of the fiber. A spectrometer (AvaSpec-3648) and a personal computer interfaced with the spectrometer were used to record the spectrum of the transmitted power at the other end of the fiber. For each sample, the resonance wavelength was calculated from the spectrum.

2.8.3 Discussion of experiment

The surface plasmon resonance approach was used to fabricate and characterize a fiber optic glucose sensor. The enzymatic process involving glucose oxidase is used to detect glucose. Fiber core, silver, silicon, and enzyme are the four layers that make up the probe. The gel entrapment approach is used to cover the enzyme layer. Invulnerability to source intensify fluctuation/reduction, portability, cheap cost, online measurement, remote sensing, immunity to electromagnetic fields, and biocompatibility are all benefits of the current wavelength interrogation-based sensor. The sensor has a high sensitivity, a pH/glucose concentration working range that is within the physiological blood glucose range, and findings that are reusable and reproducible, making it suitable for practical applications.

2.9 Comparison of Literature Review

Table 2.1 Comparison table for Literature Review

No	Title	Author	Source	Finding
1	Stokes, L. F., Chodorow, M., & Shaw, H. J. (1982). All-single-mode fiber resonator. Optics Letters, 7(6), 288-290.	[1]	Single-mode optical fiber	Explain about the single mode fiber.
2	Fidanboylu, K. A., & Efendioglu, H. S. (2009, May). Fiber optic sensors and their applications. In 5th International Advanced Technologies Symposium (IATS'09) (Vol. 6, pp. 2-3).	[3]	Fiber optic sensor	Obtain the advantage and application for fiber optic sensor.

3	Takagi, R., Horisaki, R., & Tanida, J. (2017). Object recognition through a multi-mode fiber. Optical Review, 24(2), 117-120.	[8]	Multi-mode optical fiber	Development of multi-mode through object recognition.
4	Silva, S., Frazão, O., Santos, J. L., & Malcata, F. X. (2012). A reflective optical fiber refractometer based on multimode interference. Sensors and Actuators B: Chemical, 161(1), 88-92.	[7]	Refractive of multi-mode optical fiber	Study about the refractive index for multi-mode optical fiber.

5	Shan, M., Min, R., Zhong, Z., Wang, Y., & Zhang, Y. (2015). Differential reflective fiber-optic angular displacement sensor. Optics & Laser Technology, 68, 124-128.	[6]	Reflective of fiber optic sensor	Study the reflective of fiber optic sensor.
6	Tracey, P. M. (1991). Intrinsic fiber-optic sensors. IEEE Transactions on Industry Applications, 27(1), 96-98.	[9]	Type of fiber optic sensor	The use of intrinsic fiber optic sensors.

2.10 Summary of Literature Review

In this chapter, will discuss about the previous paper, article and journal that have been carried out. The method and techniques that have been explained to ensure the project succeed with functionality. This chapter also discuss about the fabrication and characterization of fiber optic. All the types of fiber optic are included in this chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, will discuss about fabrication of fiber optic sensor. Experiment setup for fiber optic sensor contain stripping, splicing procedure and characterization of fabrication for fiber optic sensor. In this chapter also will shows the flow of this project by showing the flowchart process.

3.2 Flowchart of project

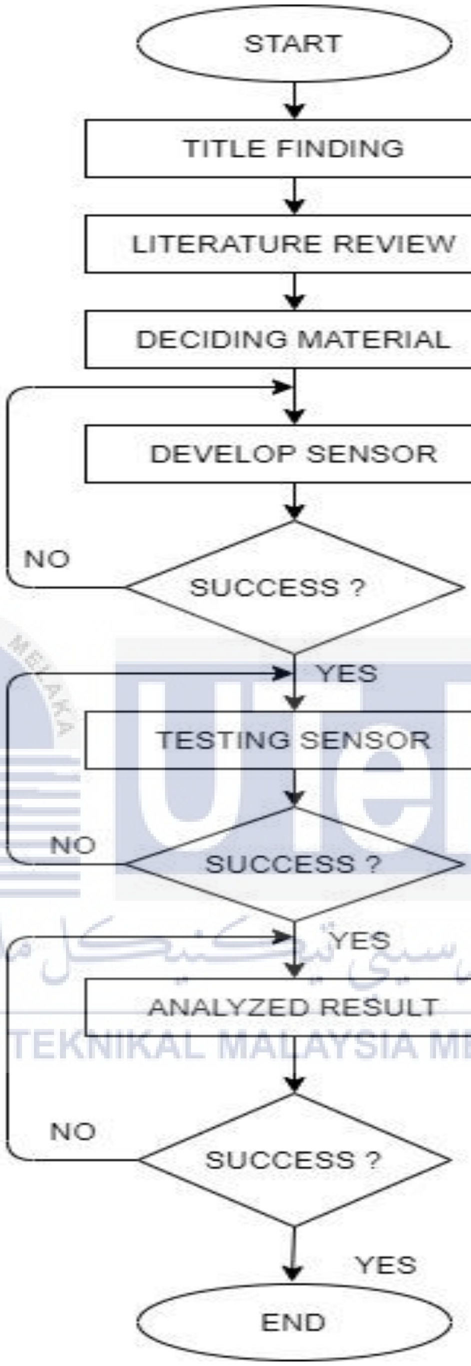


Figure 3.1 Flow chart process.

3.3 Flowchart for testing fiber optic sensor

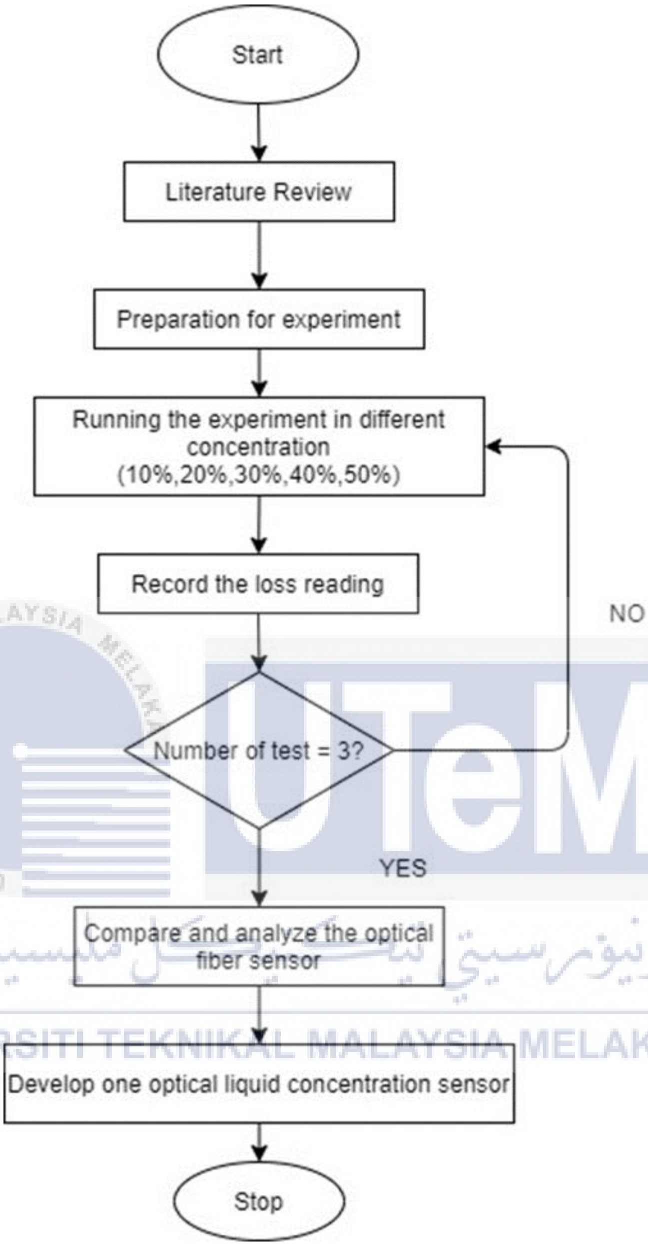


Figure 3.2 Flowchart of experiment.

This is the step to develop and testing the fiber optic in different concentration of glucose as mentioned in Figure 3.2. Begin with literature review which is to find the article to make a reference about this project. After that, make some preparation for experiment and provide glucose in this experiment. Next, running the experiment in different concentration which are 10%,20%,30%,40% and 50%. Besides, this project requires SMF28 optical cable under test, a laser source with wavelength of 1550nm, optical spectrum analyzer (OSA). The experiment will be done for three times for each solution and the results that will be obtained is the reading of loss at the peak of the spectrum from the OSA device.

3.4 Stripping procedure

The process of stripping an optical fiber's protective polymer covering in preparation for fusion splicing is known as stripping. Splicing begins with the preparation of both fiber ends for fusion, which requires the removal or stripping of all protective covering from both fiber ends. A small number of specialized business that also make fiber recoating machines provide fiber optical stripping and preparation equipment for fusion splicing. Fiber optical stripping is done using special stripping and preparation apparatus that use hot sulfuric acid or a controlled flow of hot air to remove the coating.

3.5 Splicing procedure

The technique of connect two or more fibers together is known as fiber optic splicing. To minimize network outages, we need to make sure fibers are correctly spliced whether constructing a new fiber optic network or extending an existing one. Splicing fibers is a typical technique for repairing fiber optic cables that have been accidently damaged or fusing two fibers together to generate a longer fiber for a longer cable length. There are two methods of splicing fibers which are mechanical splicing and fusion splicing.

3.5.1 Mechanical Splicing

Mechanical splicing of fibre optic cables is an alternative splicing method as mention in Figure 3.3 that does not need the use of a fusion splicer. A mechanical splice is a connection between two or more optical fibres that is aligned and kept in place by an assembly that uses index matching fluid to keep the fibre in place. Mechanical splicing links two optical fibres permanently using a small mechanical splice, roughly 6cm long and 1cm in diameter. This properly aligns two bare strands before mechanically securing them. The splice is securely fastened with a snap-type cover, an adhesive cover, or both. The fibres aren't permanently linked; they're only kept together tightly enough to allow light to flow through. Fiber mechanical splicing, on the other hand, introduces more reflection than fusion splicing. Mechanical splices for fibre optic cable are tiny, simple to use, and ideal for either fast repairs or long-term installations. Mechanical splices for single mode and multimode fibre optic cables are available.

Figure 3.3 Mechanical Splicer tool.

3.5.2 Fusion Splicing

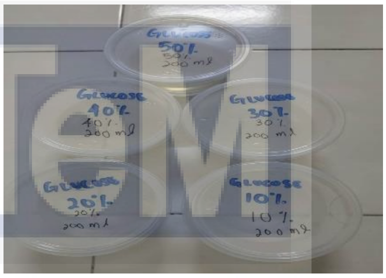
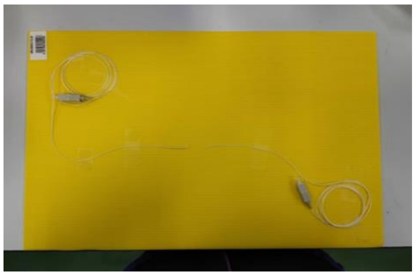
Fusion splicing is more costly than mechanical splicing, but it lasts longer. The fusion technique reduces attenuation by fusing the fibre cores together with minimal attenuation. In the fusion splicing procedure, specialised fusion splicer equipment is utilised to precisely align the two fibre ends, and then the glass ends are “fused” or “welded” together using an electric arc or another type of heat. This results in a clear, non-reflective, and continuous connection between the fibres, allowing for extremely low light loss. Other than that, Fusion splicing also the most used splicing technique since it has the lowest insertion loss and almost no back reflection. Fusion splicing is the most secure way to link two strands. Fusion splicing is carried out using a machine known as a fusion splicer (fusion splicing machines) show in Figure 3.4. This course will concentrate on fusion splicers.

Figure 3.4 Fusion Splicing Tool.

3.6 Equipment that uses in the experiment

All the equipment below are used for experiment.

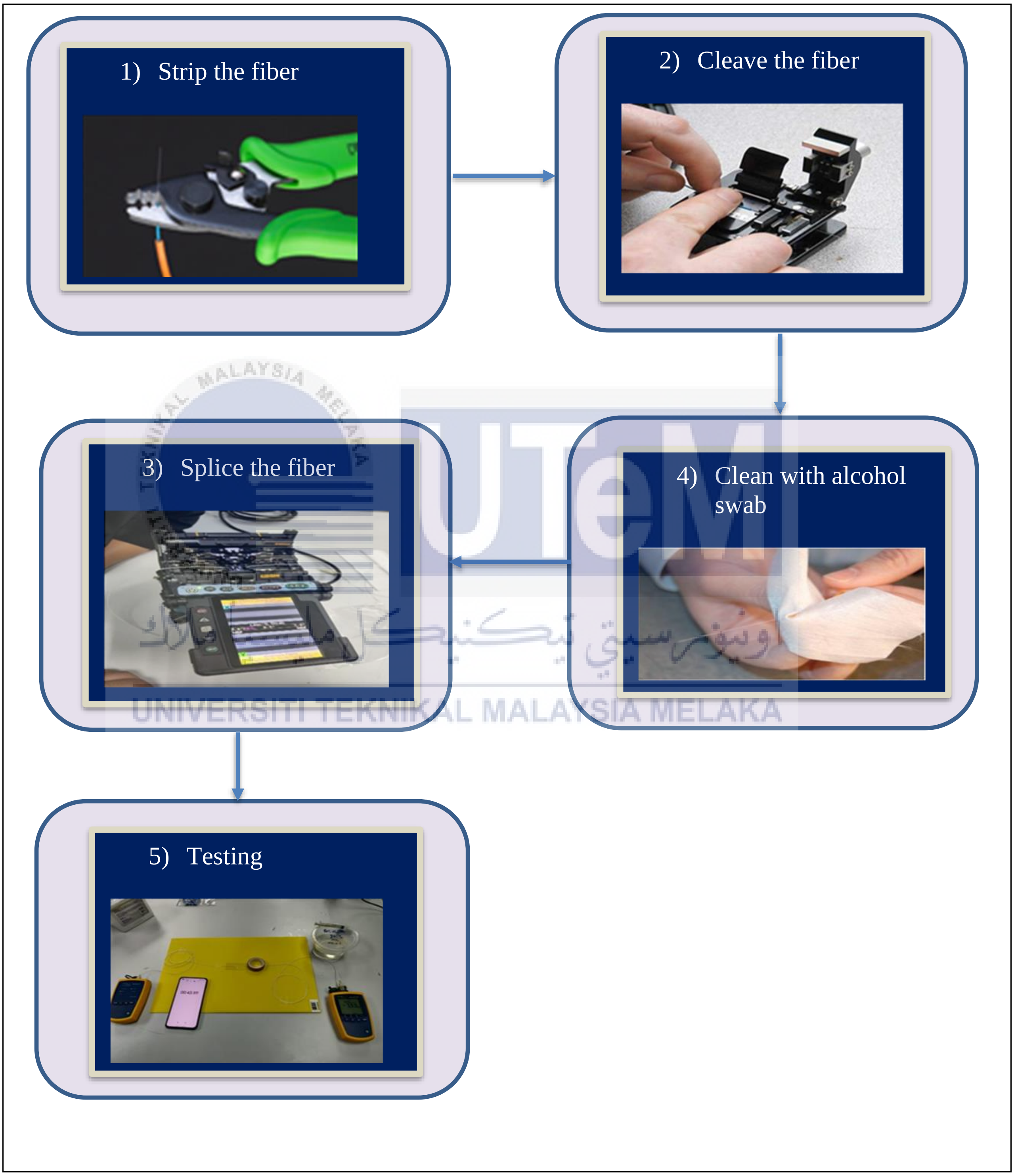
Table 3.1 Equipment use in the lab experiment.

a) Optical power meter 	b) Optical power level 
c) Splicer machine 	d) Glucose (granulated sugar) 
e) Cutter 	f) Cleaver 
g) Alcohol swab 	h) Pigtail 

3.7 Process of experiment

Below are the step of splicing and testing the experiment.

Table 3.2 Process of the experiment.



3.8 Characterization

Fiber characterization is the process of doing a series of tests on an installed connection to determine its overall quality and capacity to serve a given application or set of applications. The characterization of a fiber tells how well it will function. This is critical because, as data rates rise and systems grow more sophisticated, a variety of variables may degrade system performance. Fiber characterization is a set of tests performed on a fiber optic cable to verify the fiber quality, installation procedures, and performance for a certain transmission rate.

3.8.1 Optical Return Loss (ORL)

The total light reflected back to the transmitter by the fiber and its components, such as connector pairs and mechanical splices, will be measured by ORL. Optical Return Loss (ORL) is a measurement of light that does not reach the fiber's opposite end. Aside from that, Optical Return Loss (ORL) is a dB measurement that measures total fibre plant efficiency. Following that, all connection pairs and mechanical splices are included in the reflected events. The better the reflections in the fibre under test, the greater the Optical Return Loss (ORL).

3.8.2 Power Meter and Light Source

In a typical fibre optic technician's toolset, the power meter is the standard tester. It's a lifesaver when it comes to installation and repair. The basic purpose of the power metre is to show the incident power on the photodiode. Only an optical power metre is used to measure the optical power sent and received. Optical loss requires the use of an optical light source to be measured. Connect the light source to one end of the fibre and the power metre to the other. A wavelength of light is sent down the fibre by the light source. The power meter at the opposite end of the wire reads that light and calculates the amount of signal loss. The most accurate technique to give end-to-end loss values on an optical span, including fibre attenuation and the beginning and end connections of the fibre under test, is to use a power meter and light source as mentioned in Figure 3.5.

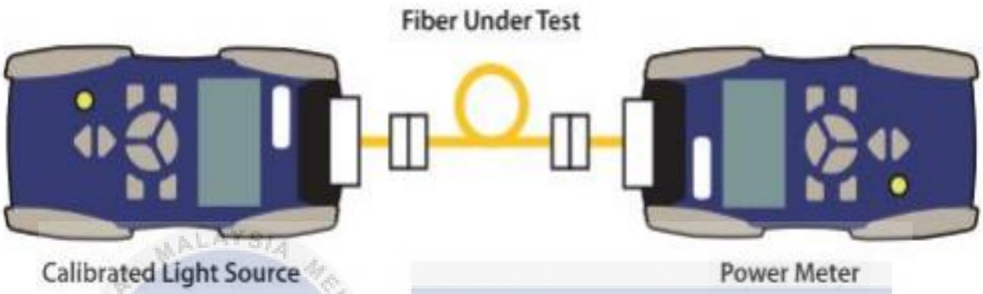


Figure 3.5 Power meter and light source tool.

3.8.3 Polerized Mode Dispersion (PMD)

The outcome of light passing through a fibre via multiple routes is polarization mode dispersion (PMD). Each route will be somewhat varied in length, resulting in various arrival times for each light component. PMD is the cause of the disparity in arrival timings. In picoseconds, this "differential delay" is measured. Polarized light is made up of light waves that move in various planes at various speeds.

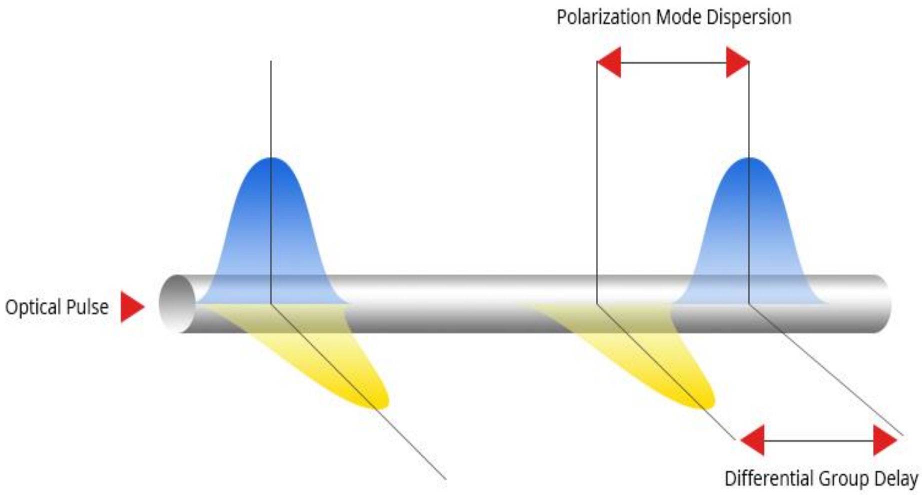


Figure 3.6 Polarized Mode Dispersion Method

3.8.4 Chromatic Dispersion

Different wavelengths of the non-zero spectral move at different speeds, resulting in chromatic dispersion. The variation in arrival time of each wavelength creates pulse spreading or (chromatic) dispersion since transmitters are made up of numerous wavelengths that move at various speeds.

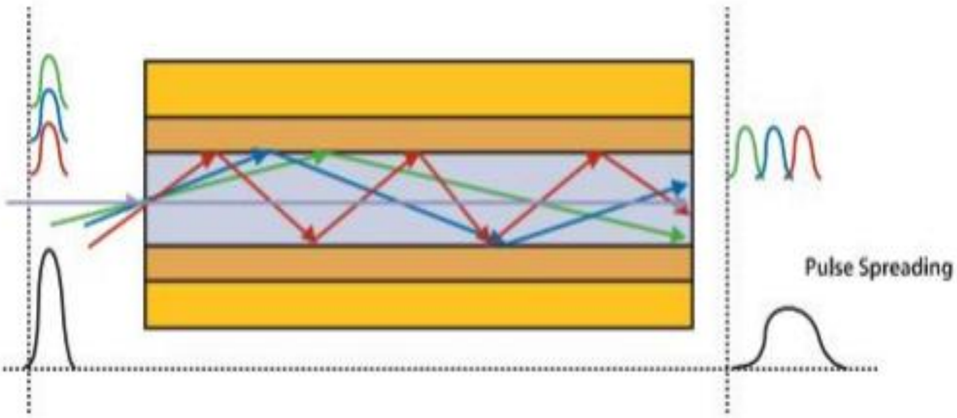


Figure 3.7 Chromatic Dispersion Method

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter will presents about the results and analysis on the development of liquid (glucose) concentration sensor using optical fiber. The experiment had been tested in 5 different glucose concentration which are 10%, 20%, 30%, 40% and 50%. In this experiment is tested in same wavelength on glucose concentration at 1550nm. This experiment also are tested in three times for each concentration.

4.2 Results and Analysis

4.2.1 10% of glucose concentration tested in 1550nm wavelength

Table 4.1 below shows the optical fiber test on 10% concentration of glucose using 1550nm wavelength. This table contain of time taken duration for 30 minutes and the results was taken every 3 minutes until the time reach 30 minutes for 1550nm wavelength. The results were taken for three times.

Table 4.1 10% Glucose concentration table for three time taken.

	Power Meter(dBm)		
Time/min	**1st cycle**	**2nd cycle**	**3rd cycle**
0	-7.28	-7.3	-7.27
3	-7.28	-7.3	-7.26
6	-7.29	-7.29	-7.26
9	-7.29	-7.29	-7.26
12	-7.29	-7.3	-7.26
15	-7.23	-7.3	-7.26
18	-7.27	-7.29	-7.27
21	-7.28	-7.29	-7.26
24	-7.29	-7.28	-7.26
27	-7.28	-7.28	-7.26
30	-7.28	-7.28	-7.26

Figure 4.1 below shows 1550nm wavelength test on 10% glucose concentration for 1st cycle. From the result, from first 0 minute to 3 minutes the graph is remain constant then its decrease in 3 minutes to 6 minutes from -7.28 dBm to -7.29 dBm. The graph remains constant from 6th minutes 12th minutes. Next, the graph is increase from 12th minutes to 15th minutes from 07.28 dBm to -7.23 dBm. After that, the graph is decrease from 15th minutes to 24th minutes from -7.23 dB to -7.29 dBm. Lastly, from 24th minutes the graph is increase then remain constant from -7.29 Db to -7.28 dBm.

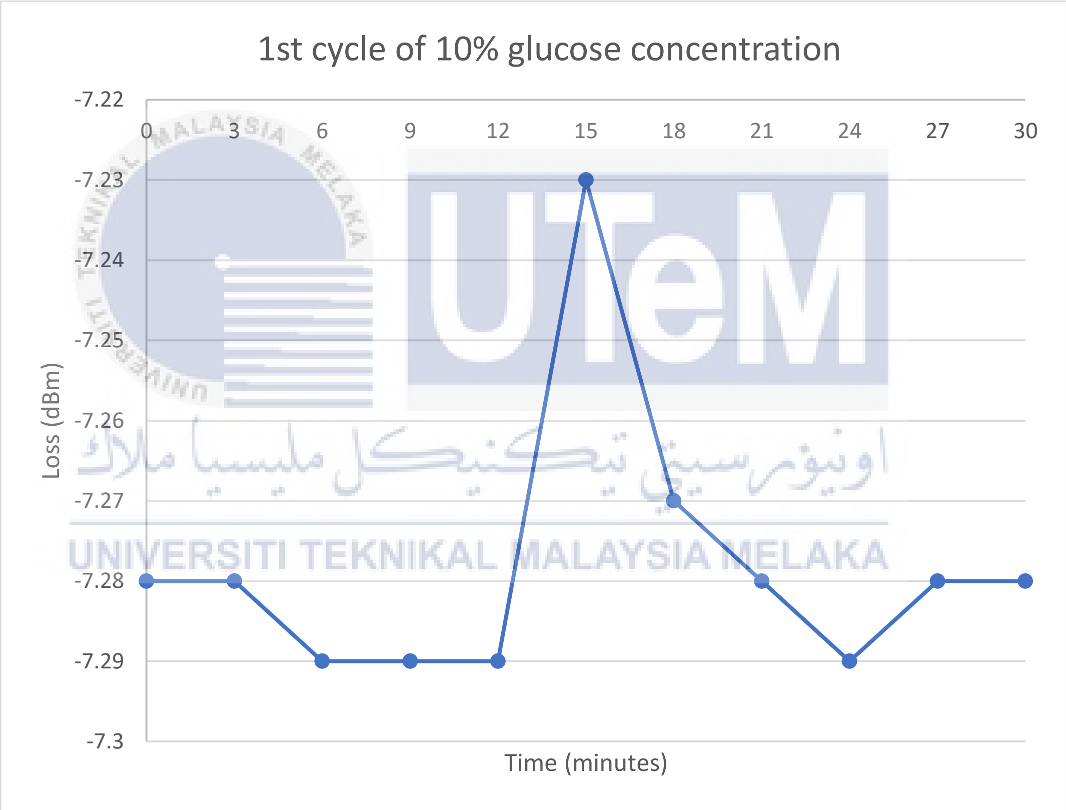


Figure 4.1 1st cycle for wavelength 1550nm test on 10% glucose concentration for 30 minutes.

Figure 4.2 below shows 1550nm wavelength test on 10% glucose concentration for 2nd cycle. As the results shows in the first 0 minute to 3 minutes the graph is constant. From 3rd minutes to 6th minutes the graph is increase from -7.3 dBm to -7.29 dBm. Then the graph is remains constant and its decrease from 9th minutes to 12th minutes from -7.29 dB -7.3 dBm. After that, the pattern of graph is increase from 15th minutes to 24th minutes from -7.3 dB to -7.28 dBm. Lastly, the graph is remains constant from 24th minutes to 30th minutes.

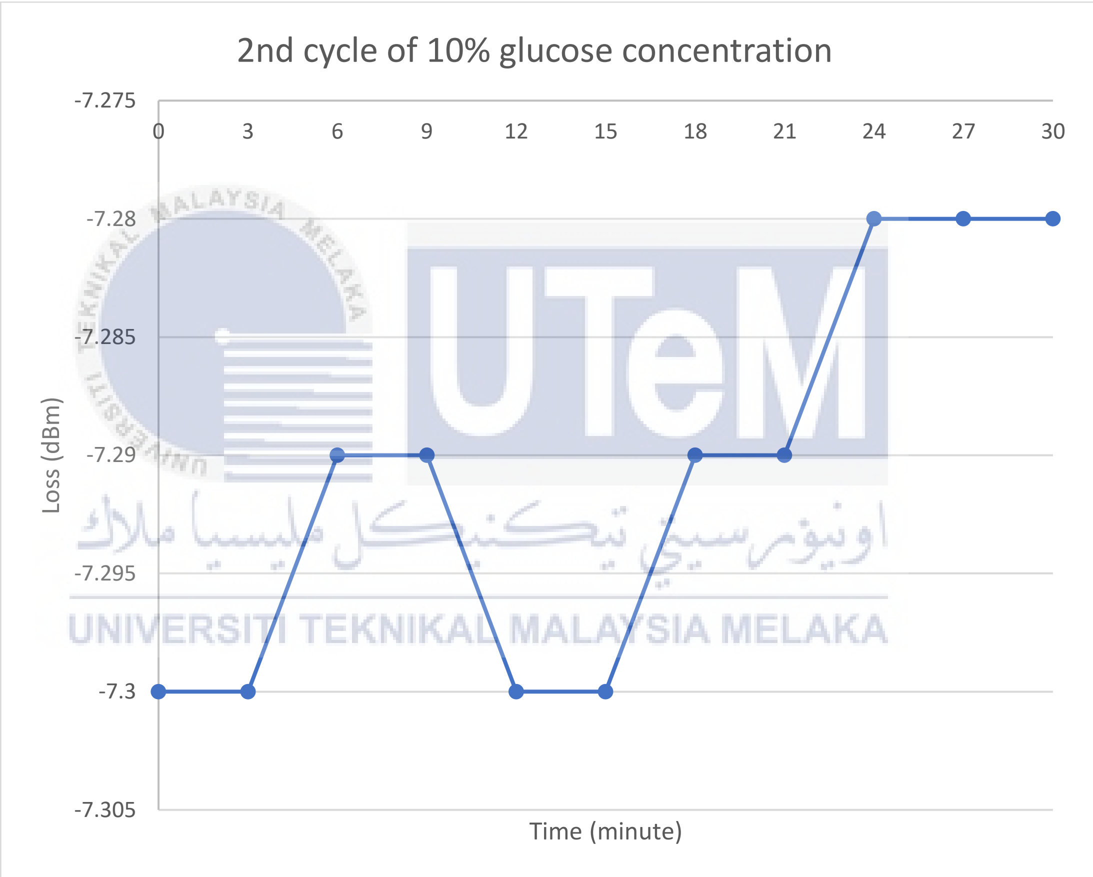


Figure 4.2 2nd cycle for wavelength 1550nm test on 10% glucose concentration for 30 minutes.

In this Figure 4.3 below shows 1550nm wavelength test on 10% glucose concentration for 3rd cycle. As the results in first 0 minutes to 3 minutes the graph is increase from -7.27 dB to -7.26 dBm. After that, the graph is remains constant from 3rd minutes to 15th minutes for -7.26 dBm. Next, from 15th minutes to 18th minutes the graph is decrease from -7.26 dB -7.27 dBm. Lastly, the graph is increase from 18th minutes to 21st and remains constant until 30th minutes for -7.26 dBm.

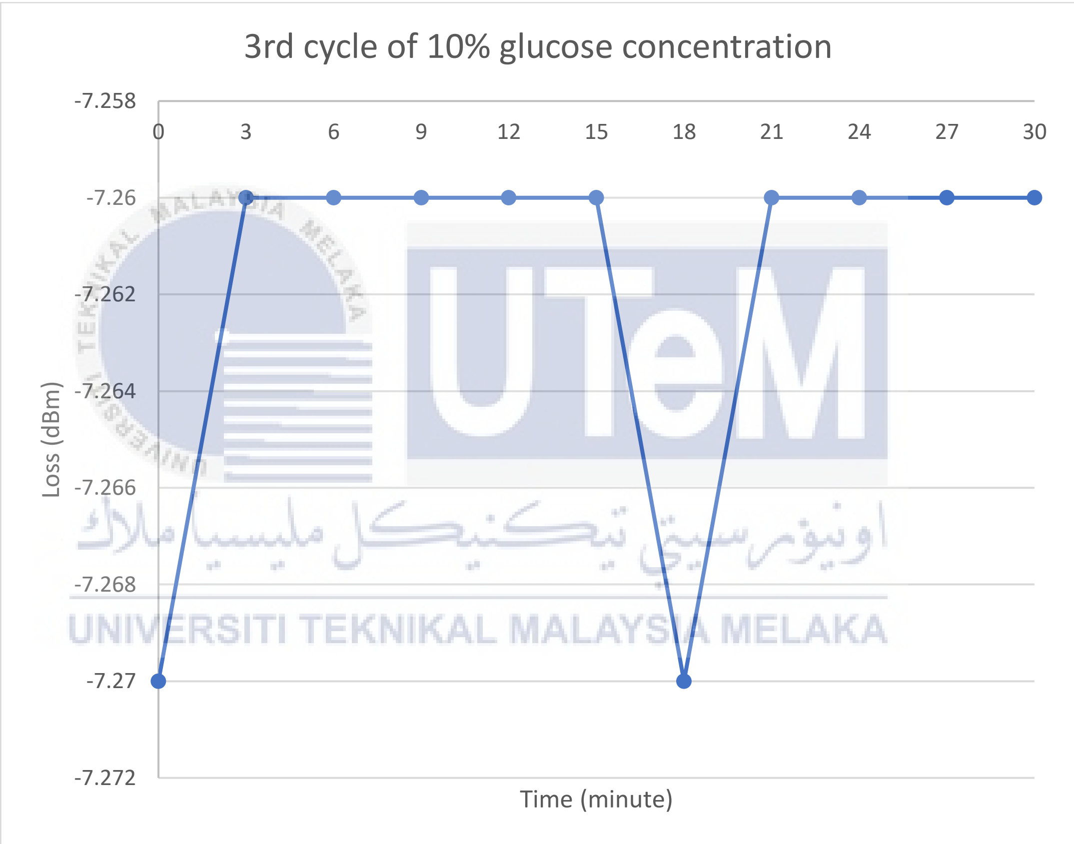


Figure 4.3 3rd cycle for wavelength 1550nm test on 10% glucose concentration for 30 minutes.

4.2.2 20% of glucose concentration tested in 1550nm wavelength

Table 4.2 below shows the optical fiber test on 20% concentration of glucose using 1550nm wavelength. This table contain of time taken duration for 30 minutes and the results was taken every 3 minutes until the time reach 30 minutes for 1550nm wavelength. The results were taken for three times.

Table 4.2 20% Glucose concentration table for three time taken.

	Power Meter (dBm)		
Time/min	**1st cycle**	**2nd cycle**	**3rd cycle**
0	-7.32	-7.31	-7.3
3	-7.31	-7.31	-7.3
6	-7.31	-7.31	-7.32
9	-7.31	-7.31	-7.33
12	-7.3	-7.3	-7.33
15	-7.28	-7.3	-7.33
18	-7.29	-7.3	-7.32
21	-7.29	-7.3	-7.32
24	-7.28	-7.29	-7.31
27	-7.27	-7.29	-7.3
30	-7.26	-7.28	-7.29

Figure 4.4 below shows 1550nm wavelength test on 20% glucose concentration for 1st cycle. From 0 minutes until 15th minutes the graph is increase from -7.32 dBm to -7.28 dBm. Next, the graph is decrease to -7.29 dB from 15th minutes to 18th minutes. After that, the graph is constant from 18th minutes to 21st minutes for -7.29 dBm. Lastly, the graph is increase from 21st minutes to 30th minutes from -7.29 dB to -7.26 dBm.

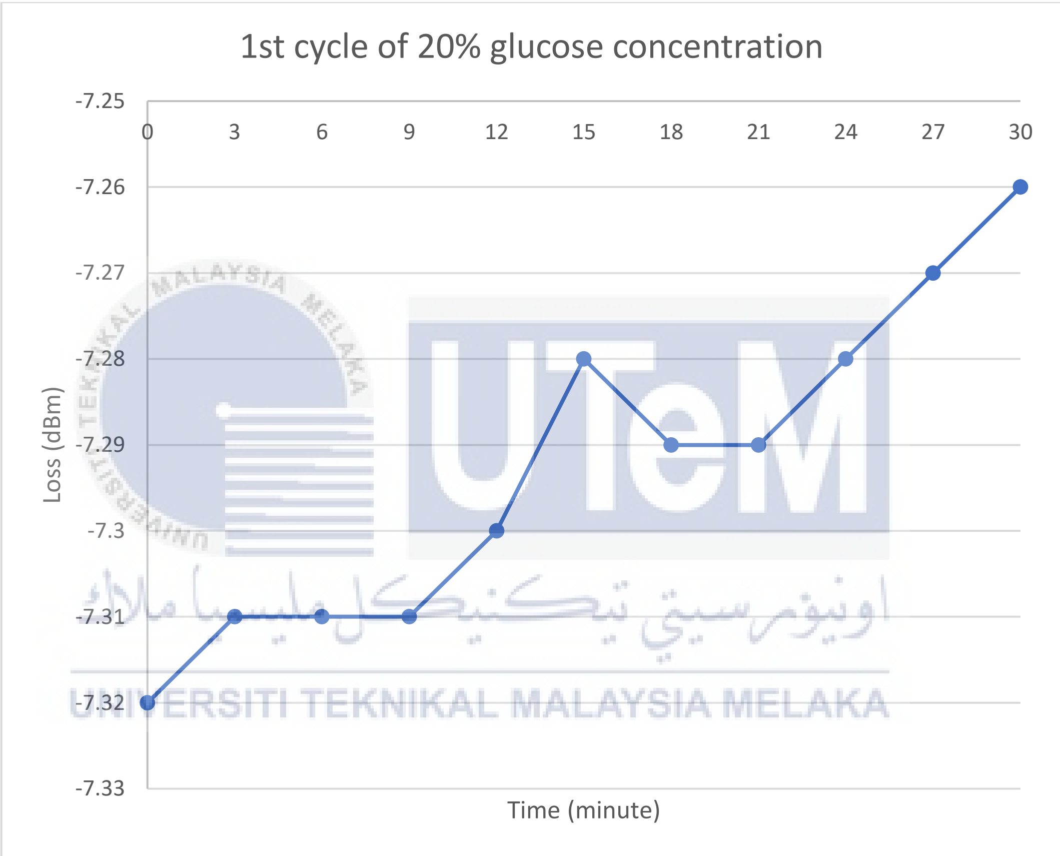


Figure 4.4 1st cycle for wavelength 1550nm test on 20% glucose concentration for 30 minutes.

Figure 4.5 below shows 1550nm wavelength test on 20% glucose concentration for 2nd cycle. From the graph, starting from 0 minutes until 9th minutes the graph is remain constant for -7.31 dBm. Starting from 9th minutes until 30th minutes the graph is increase from -7.31 dB to -7.28 dBm.

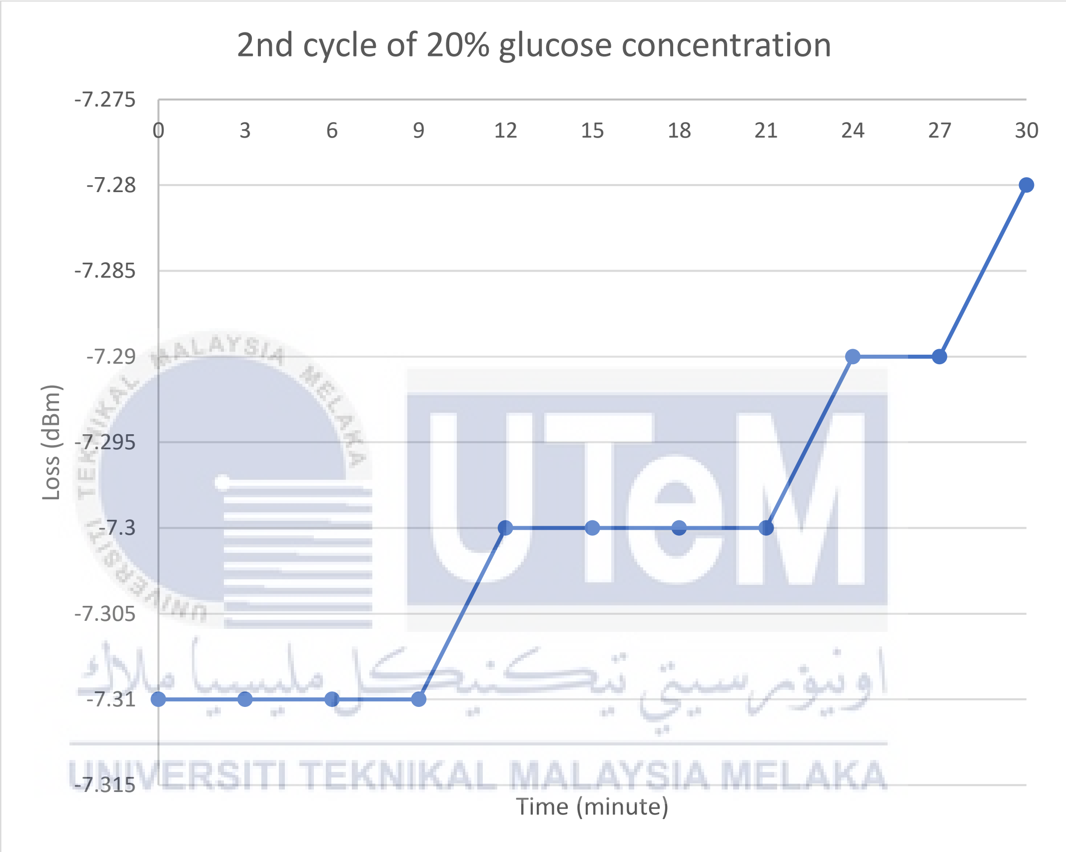


Figure 4.5 2nd cycle for wavelength 1550nm test on 20% glucose concentration for 30 minutes.

Figure 4.6 below shows 1550nm wavelength test on 20% glucose concentration for 3rd cycle. As the result shows from first 0 minutes until 3 minutes the graph is constant on -7.3 dBm. Next, from 3rd minutes until 9th minutes the graph shows the pattern is decrease from -7.3 dB to -7.33 dBm. After that, from 9th minutes until 15th minutes the graph is constant on -7.33 dBm. Lastly, is increase from 15th minutes until 30th minutes from -7.33 dB to -7.29 dBm.

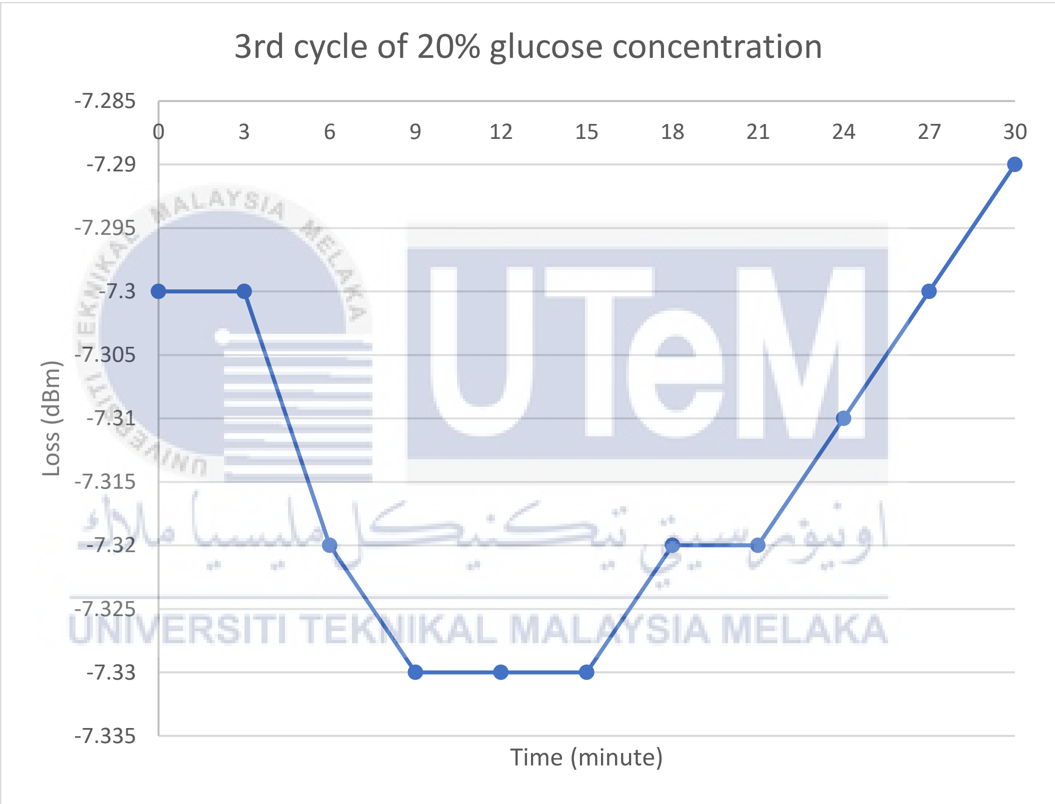


Figure 4.6 3rd cycle for wavelength 1550nm test on 20% glucose concentration for 30 minutes.

4.2.3 30% of glucose concentration tested in 1550nm wavelength

Table 4.3 below shows the optical fiber test on 30% concentration of glucose using 1550nm wavelength. This table contain of time taken duration for 30 minutes and the results was taken every 3 minutes until the time reach 30 minutes for 1550nm wavelength. The results were taken for three times.

Table 4.3 30% Glucose concentration table for three time taken.

	Power Meter (dBm)		
Time/min	**1st cycle**	**2nd cycle**	**3rd cycle**
0	-7.31	-7.31	-7.29
3	-7.3	-7.31	-7.28
6	-7.36	-7.3	-7.28
9	-7.36	-7.31	-7.27
12	-7.37	-7.32	-7.26
15	-7.36	-7.31	-7.26
18	-7.33	-7.3	-7.26
21	-7.32	-7.3	-7.26
24	-7.32	-7.29	-7.26
27	-7.32	-7.29	-7.27
30	-7.32	-7.28	-7.27

Figure 4.7 below shows 1550nm wavelength test on 30% glucose concentration for 1st cycle. From the graph, for the first 3 minutes the graph is increasing from -7.31 dBm to -7.3 dBm then the graph is decreasing 3rd minutes until 12th minutes from -7.3 dBm to -7.37 dBm. After that, the graph is increase from 12th minutes until 21st minutes from -7.37 dBm to -7.32 dBm. Lastly, the graph is remains constant until 30rd minutes for –7.32 dBm.

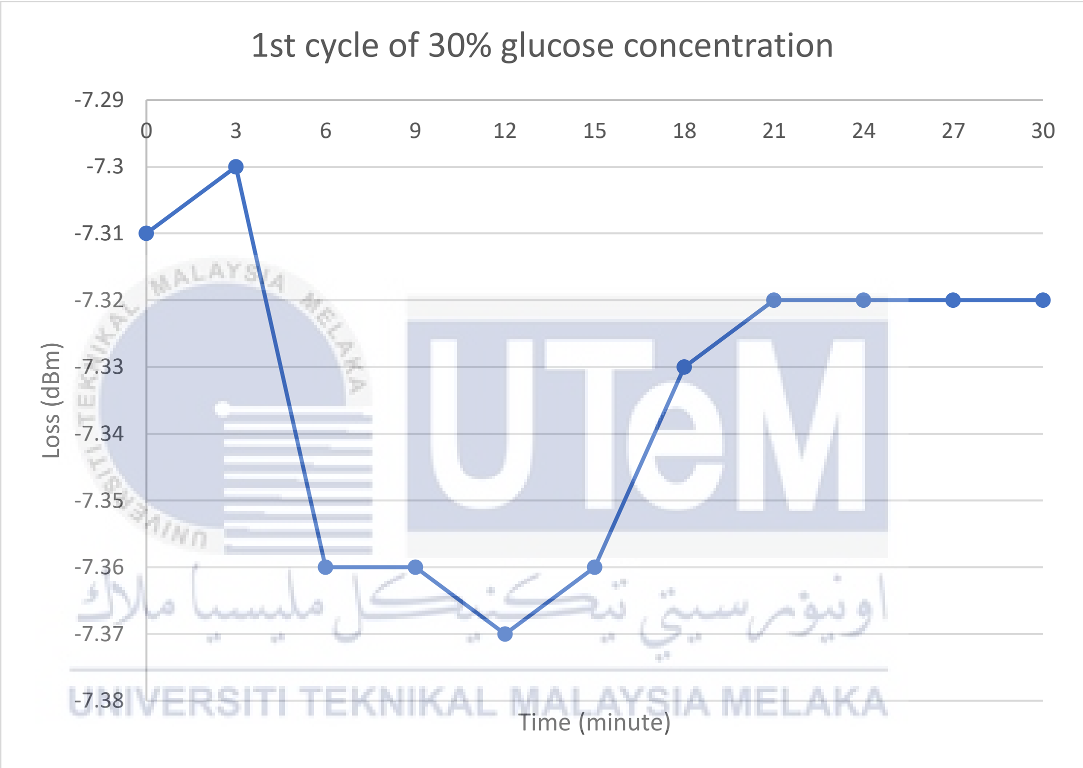


Figure 4.7 1st cycle for wavelength 1550nm test on 30% glucose concentration for 30 minutes.

Figure 4.8 below shows 1550nm wavelength test on 30% glucose concentration for 2nd cycle. As the results, for the first 3 minutes the graph is constant and its rise from 3rd minutes until 6th minutes from -7.31 dBm to -7.3 dBm. After 6th minutes the graph drop continuously until 12th minutes from -7.3 dBm to -7.32 dBm. Lastly, the graph increasing from 12th minutes until 30th minutes from -7.32 dBm to -7.28 dBm.

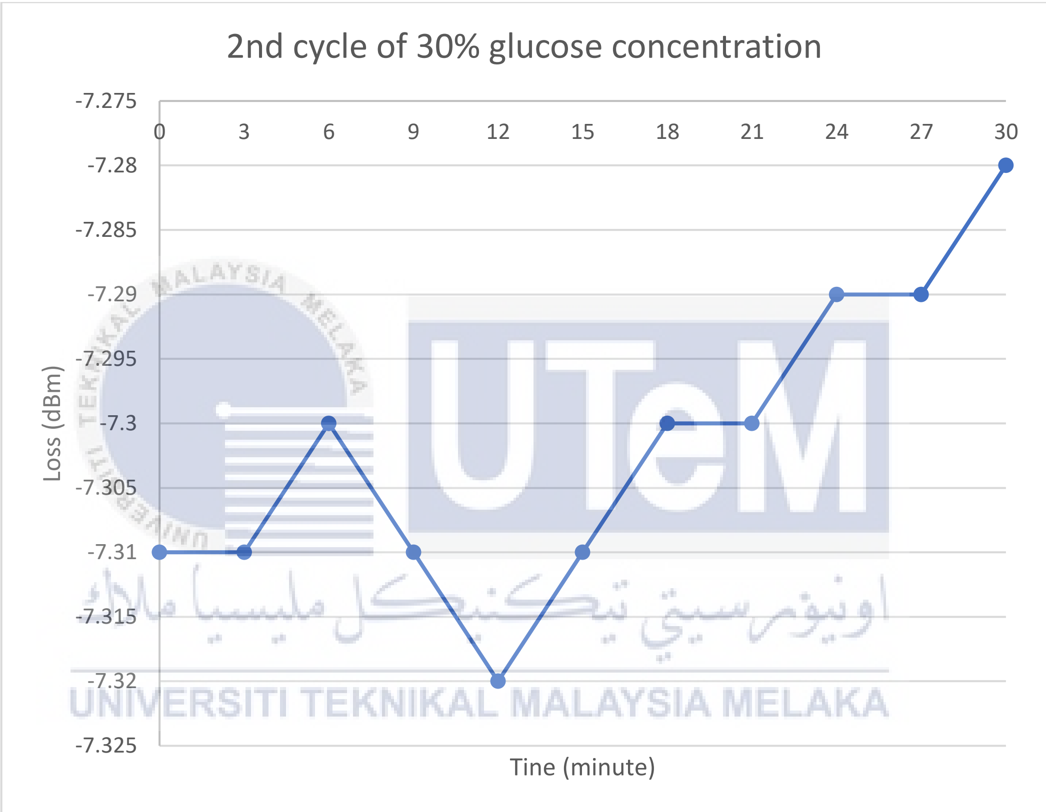


Figure 4.8 2nd cycle for wavelength 1550nm test on 30% glucose concentration for 30 minutes.

Figure 4.9 below shows 1550nm wavelength test on 30% glucose concentration for 3rd cycle. From the graph, for the first 3 minutes the pattern of the graph is rising from - 7.29 dBm to -7.28 dBm. Then the graph continues maintain until 6th minutes and start rising until 12th minutes from -7.28 dBm to -7.26 dBm. After that, the pattern of the graph is constant from 12th minutes until 24th minutes for -7.26 dBm. Lastly, the graph is decrease and keep constant until 30th minutes for -7.27 dBm.

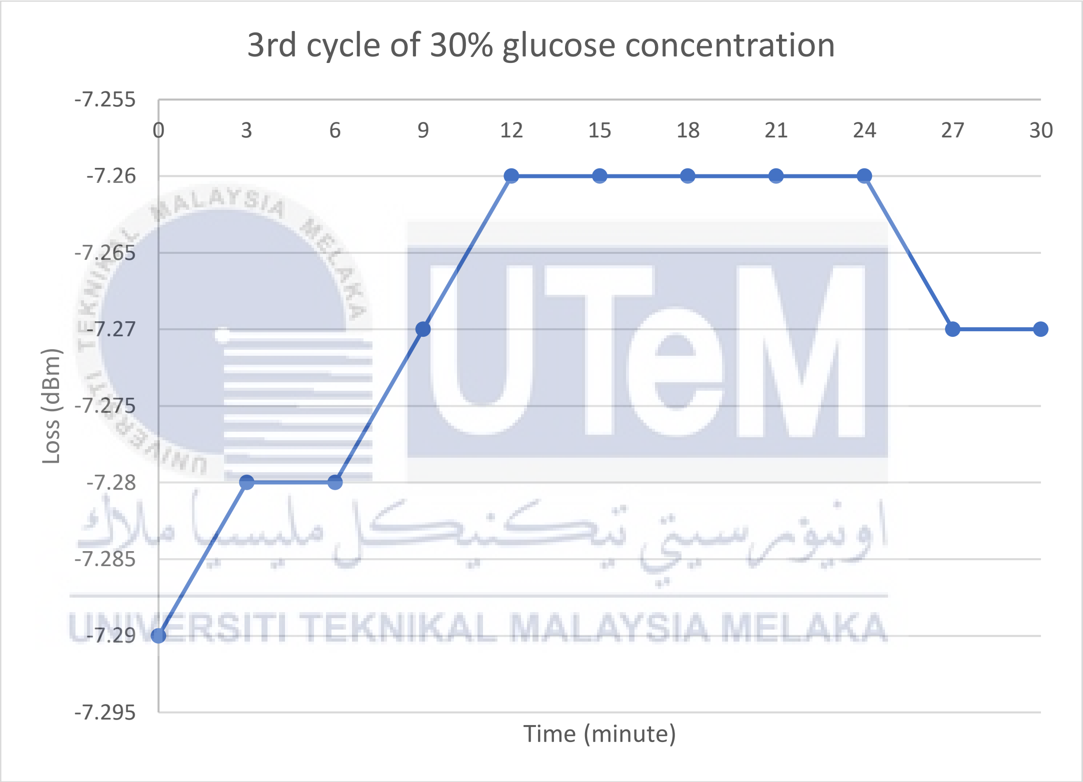


Figure 4.9 3rd cycle for wavelength 1550nm test on 30% glucose concentration for 30 minutes.

4.2.4 40% of glucose concentration tested in 1550nm wavelength

Table 4.4 below shows the optical fiber test on 40% concentration of glucose using 1550nm wavelength. This table contain of time taken duration for 30 minutes and the results was taken every 3 minutes until the time reach 30 minutes for 1550nm wavelength. The results were taken for three times.

Table 4.4 40% Glucose concentration table for three time taken.

	Power Meter (dBm)		
Time/min	**1st cycle**	**2nd cycle**	**3rd cycle**
0	-7.28	-7.27	-7.3
3	-7.27	-7.27	-7.31
6	-7.26	-7.28	-7.31
9	-7.26	-7.28	-7.3
12	-7.26	-7.27	-7.3
15	-7.26	-7.26	-7.31
18	-7.27	-7.25	-7.32
21	-7.26	-7.25	-7.31
24	-7.25	-7.24	-7.3
27	-7.25	-7.23	-7.29
30	-7.24	-7.23	-7.28

Figure 4.10 below shows 1550nm wavelength test on 40% glucose concentration for 1st cycle. From the graph, for the 6 minutes shows the graph is increase from -7.28 dBm to -7.26 dBm. Then the graph remains constant from 6th minutes until 15th minutes for -7.26 dBm. After 15th minutes until 18th the graph is starting decrease into -7.27 dBm. Lastly, the pattern of the graph is rise from 18th minutes until 30th minutes into -7.24 dBm.

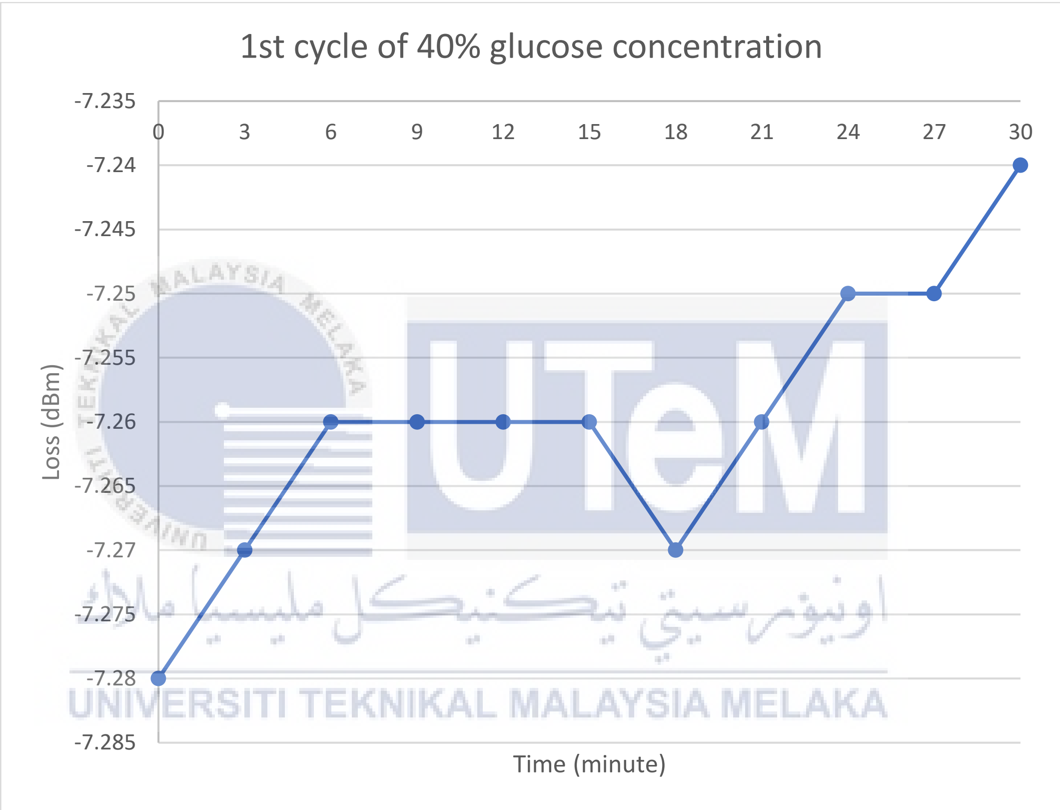


Figure 4.10 1st cycle for wavelength 1550nm test on 40% glucose concentration for 30 minutes.

Figure 4.11 below shows 1550nm wavelength test on 40% glucose concentration for 2nd cycle. As the results show, the graph is start from -7.27 dBm and constant until the first 3 minutes. Then the graph is decrease from 3rd minutes until 6th minutes into -7.28 dBm. After that, the graph is remains constant for the next three minutes. Next, the graph start rises from 12th minutes until 18th minutes into -7.25 dBm and remain constant until 21st minutes. Lastly, the graph is rise again until 27th minutes and remain constant into -7.23 dBm.

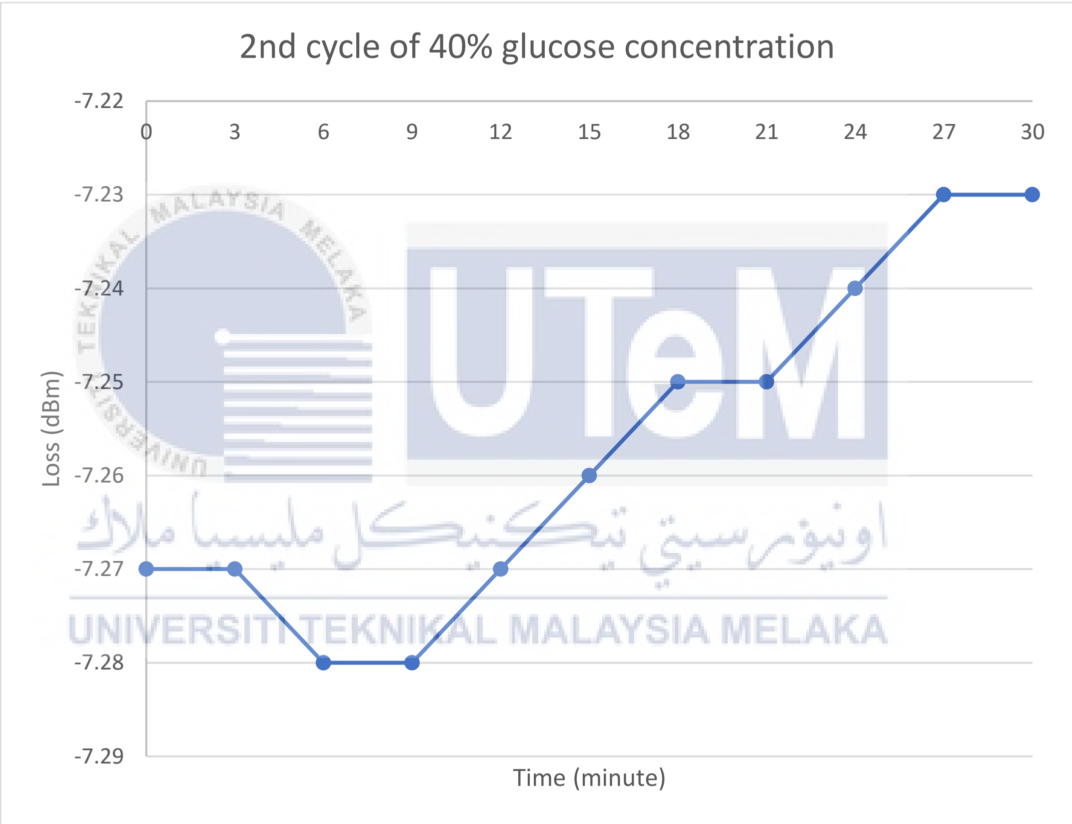


Figure 4.11 2nd cycle for wavelength 1550nm test on 40% glucose concentration for 30 minutes.

Figure 4.12 below shows 1550nm wavelength test on 40% glucose concentration for 3rd cycle. From the graph below, the graph is decrease from -7.3 dBm into -7.31 dBm for the first three minutes. After that, the graph is remains constant until 6th minutes. Next, the graph is increase until 9th minutes into -7.3 dBm and constant until 12th minutes. From 12th minutes until 18th minutes the graph is drop until 7.32 dBm. Lastly, the graph is rise until the 30th minutes into -7.28 dBm.

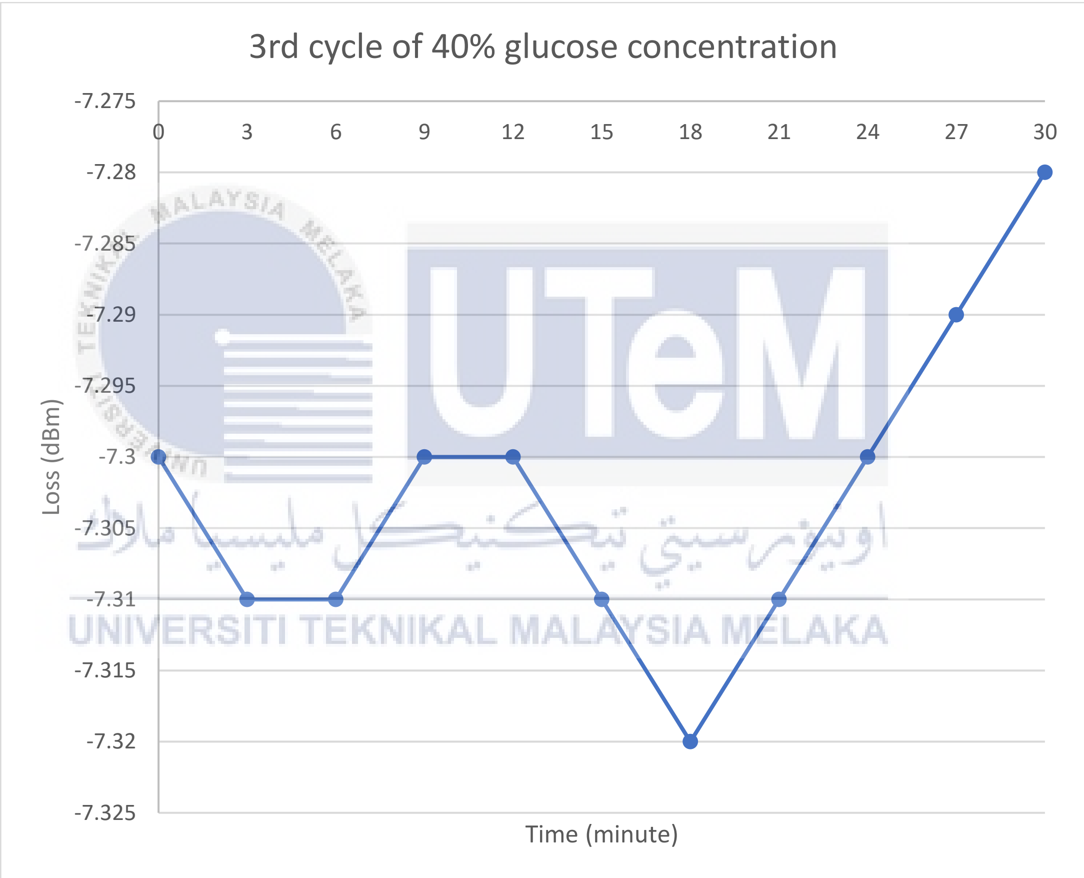


Figure 4.12 3rd cycle for wavelength 1550nm test on 40% glucose concentration for 30 minutes.

4.2.5 40% of glucose concentration tested in 1550nm wavelength

Table 4.5 below shows the optical fiber test on 50% concentration of glucose using 1550nm wavelength. This table contain of time taken duration for 30 minutes and the results was taken every 3 minutes until the time reach 30 minutes for 1550nm wavelength. The results were taken for three times.

Table 4.5 50% Glucose concentration table for three time taken.

	Power Meter (dBm)		
Time/min	**1st cycle**	**2nd cycle**	**3rd cycle**
0	-7.32	-7.3	-7.33
3	-7.29	-7.3	-7.3
6	-7.28	-7.31	-7.3
9	-7.28	-7.3	-7.3
12	-7.27	-7.28	-7.28
15	-7.26	-7.27	-7.27
18	-7.25	-7.27	-7.26
21	-7.26	-7.26	-7.26
24	-7.28	-7.25	-7.24
27	-7.27	-7.24	-7.23
30	-7.27	-7.24	-7.22

Figure 4.13 below shows 1550nm wavelength test on 50% glucose concentration for 1st cycle. From the results, the graph is rise from -7.32 dBm to -7.28 dBm until the first 6 minutes. Next, the graph shows it remains constant for the next three minutes. After that, from 9th minutes until 18th minutes the graph is linearly increase from -7.28 dBm to -7.25 dBm. Next, from 18th minutes until 24th minutes the graph is decrease from -7.25 dBm to -7.28 dBm. Lastly, the graph is increase and remains constant until 30th minutes.

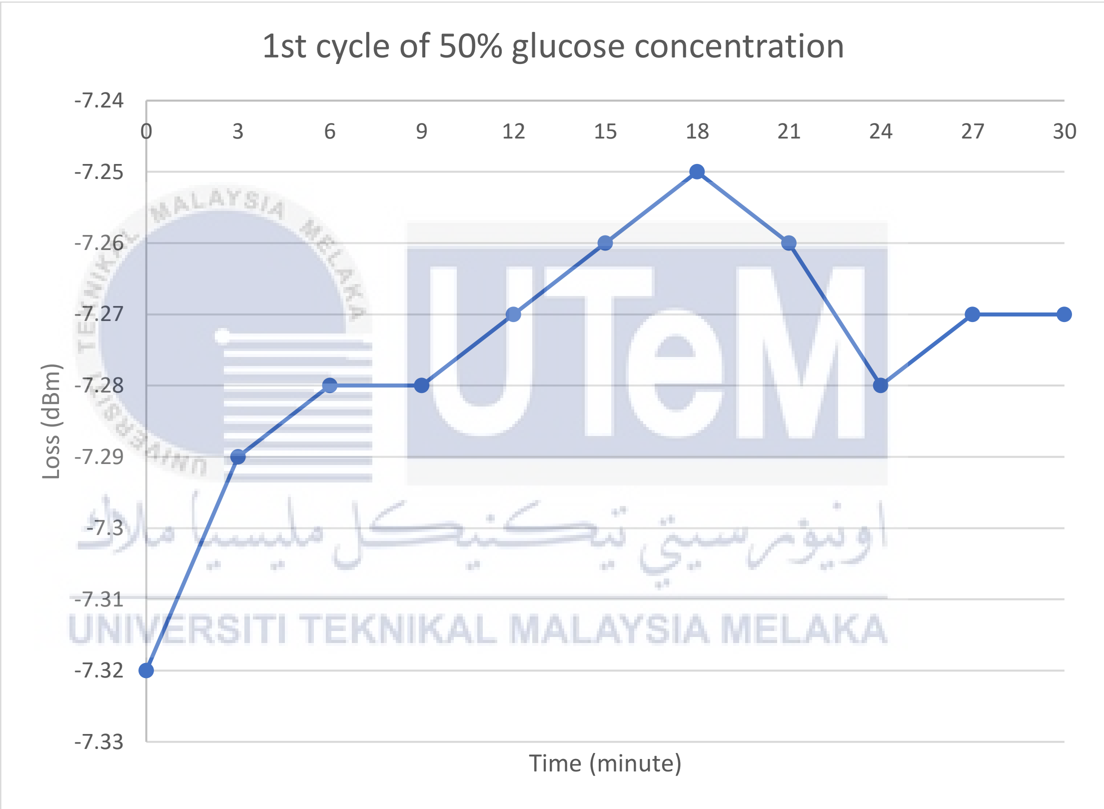


Figure 4.13 1st cycle for wavelength 1550nm test on 50% glucose concentration for 30 minutes.

Figure 4.14 below shows 1550nm wavelength test on 50% glucose concentration for 2nd cycle. The results show, the graph is decrease from start until the first 6 minutes from -7.3 dBm to -7.31 dBm. From 6th minutes until 30th minutes, the graph is linearly increase to -7.24 dBm.

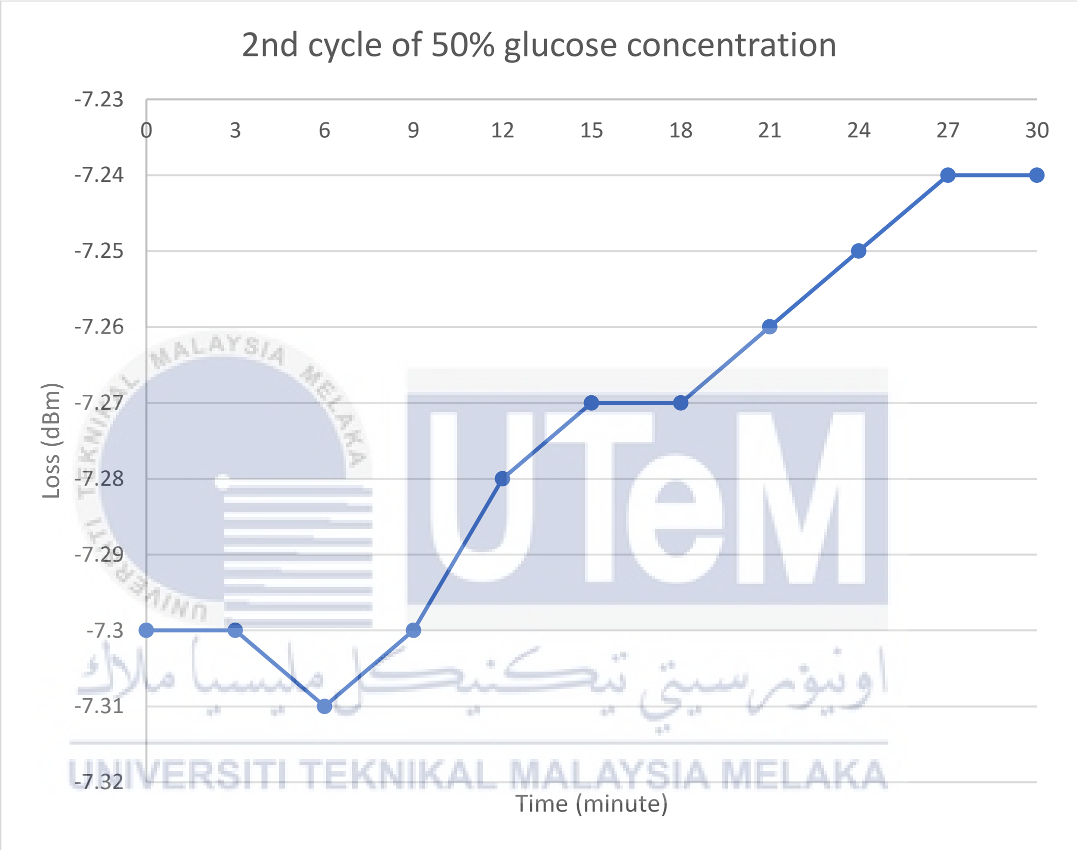


Figure 4.14 2nd cycle for wavelength 1550nm test on 50% glucose concentration for 30 minutes.

Figure 4.15 below shows 1550nm wavelength test on 50% glucose concentration for 3rd cycle. As the result show, the graph is increase for the three minutes from -7.33 dBm to -7.3 dBm. After that, the graph is remains constant for the next three minutes and linearly increase until 30th minutes to -7.22 dBm.

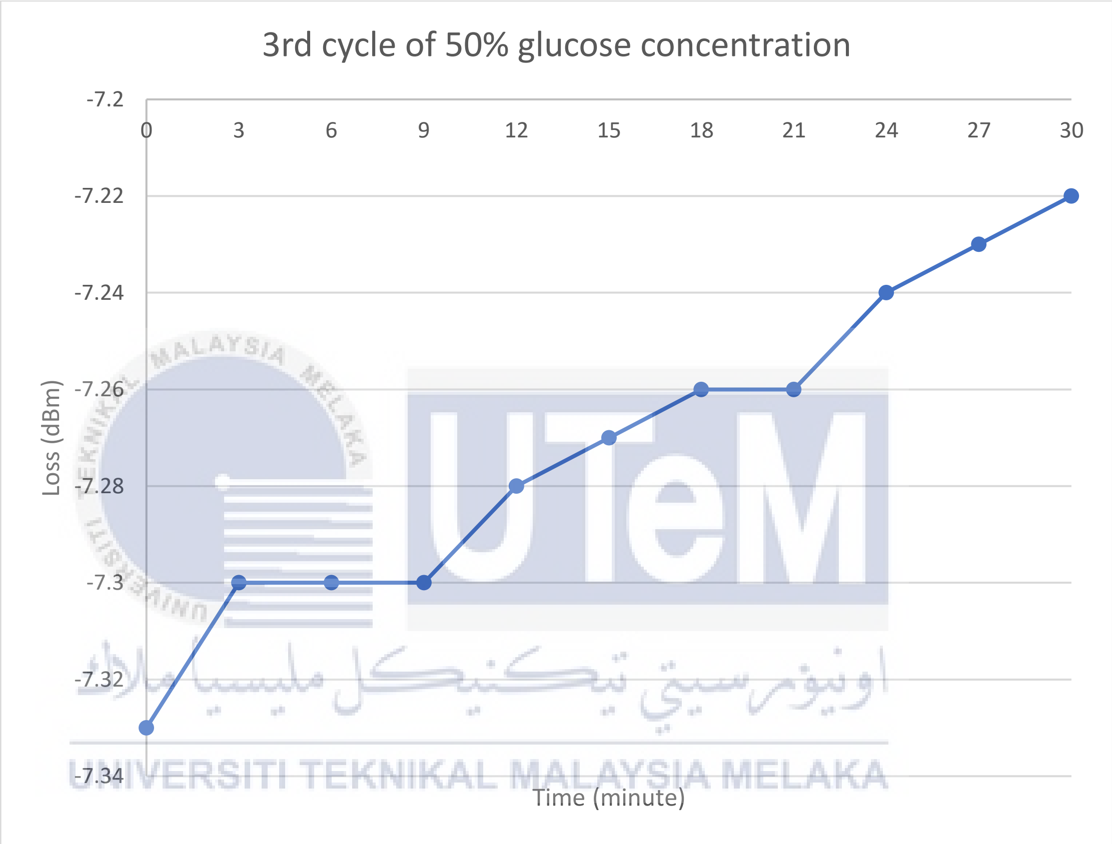


Figure 4.15 3rd cycle for wavelength 1550nm test on 50% glucose concentration for 30 minutes.

4.3 Summary for the best glucose concentration based on the sensitivity

Table 4.6 The best concentration based on the sensitivity.

Concentration	**10%**	**20%**	**30%**	**40%**	**50%**
Linear range (minutes)	0 ~ 30	0 ~ 30	0 ~ 30	0 ~ 30	0 ~ 30
Correlation R	0.3148	0.97	0.999	0.7023	0.9231
COD (%)	56%	98.49%	99%	83.80%	96.08%
Sensitivity	0.0082	0.0150	0.0325	0.0214	0.0018

The term correlation R refers to the accuracy data collected during a lab experiment. Because the data was identified using a precise reference, the correlation must be near to 1.0 that is high accuracy. From the table 4.6 above shows the less accurate data is 0.3148 and the most accurate data is 0.999. Next, is the coefficient of determination (COD) is to identify the molecule reaction to the glucose concentration. From the table 4.6, the highest molecule reaction is 99% and the lowest is 56%. After that is sensitivity, which is the sensitivity of fiber optic sensor (FOS) againts the parameter that use in lab experiment. The nearest value of 1.0 is the best sensitive of fiber optic sensor (FOS) to detect molecule. The nearest to 1.0 is 0.0325 which is for 30% of glucose concentration and the less sensitivity is 0.0018 which is 50% of glucose concentration. Based on the results above, the best reading is 30% of glucose concentration among all where it has the highest percentage. On the other hand, fiber optic would provide best performance when detecting concentrations of 30%. Fiber optics would be at their most sensitive at this concentration and could detect molecules up to 99% of the time.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

At the end of this project writing, this thesis present about the project of development of liquid concentration sensor using optical fiber for medical industry. In this project, a fiber optic sensor is a sensor that uses optical fiber as the sensing element. Based on the project title, fiber optic sensor is used to sense the liquid concentration using fiber optic cable. This project is to observe the execution of the fiber optic sensor in different concentration of glucose. This project is based on three major objective that to be achieved in this experiment which is the first objective is to study the operation of the fiber optic in liquid. The process of this experiment is the fiber optic sensor is immersed in the glucose concentration within 30 minutes and the data was taken every 3 minutes. Then, the second objective is to develop fiber optic sensor in different glucose concentration. This experiment has been tested in 5 different concentration which are 10%,20%,30%,40% and 50% with wavelength of 1550nm. From the experiment, one optical concentration sensor with high sensitivity is formed. The last objective of this project is to analyze the performance of the fiber optic sensor in glucose detection.

5.2 Future Works

For future improvements, accuracy of the glucose concentration estimation results could be enhanced as follows:

i) Development or modified by adding the type of fiber optic sensor.

ii) Decrease time spent recovery from surgeries.

iii) Develop to try another type of sugar which are Fructose (fruit sugar), Sucrose (table sugar) and Lactose (dairy sugar). Current glucose (granulated sugar).

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APPENDICES

A. PERANCANGAN PROJEK
PROJECT PLANNING (GANTT CHART)

Senaraikan aktiviti-aktiviti yang berkaitan bagi projek yang dicadangkan dan nyatakan jangka masa yang diperlukan bagi setiap aktiviti.
List all the relevant activities of the proposed project and mark the period of time that is needed for each of the activities.

	SEM I																			**SEM BREAK**					**SEM II**															
Aktiviti Projek *Project Activities*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Finding articles, books, and journal as reference for Literature Review	x	x	x	x	x																																			
Study about fiber optics and types of fiber optic sensor.			x	x	x	x																																		
Study the procedure of stripping and splicing.						x	x	x	x																															
Finding research about glucose concentration in fiber optic sensor.										x		x	x	x	x	x																								
Start the process of stripping and splicing of fiber optic.											**SEMINAR PSM I**														x	x												**SEMINAR PSM II**		
Run the experiment in 5 different concentrations and wavelength																											x	x	x	x	x	x	x							
Collect data of experiment																											x	x	x	x	x	x	x							
Troubleshooting any problems occur																															x	x	x	x	x					
Final checking for the project																																			x	x	x			