UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MICROFIBER SENSOR APPLICATION FOR BCAA (PROTEIN) CONCENTRATION DETECTION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Engineering Technology (Telecommunications) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Microfiber Optic Sensor Application for BCAA (Protein) Concentration Detection" is the results of my own research except as cited in references.

Signature : ………………………

Name : ………………………

Date : ………………………

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree in Bachelor of Engineering Technology Electronic (Telecommunications) (Hons.). The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

ABSTRACT

Microfiber sensor is a variety of interesting wave guiding properties, including widely tailorable optical confinement, evanescent fields and waveguide dispersion. This research is focused on the development of a sensor due to its possibilities of realizing miniaturized fiber optic sensor with small footprint, high sensitivity, fast response, high flexibility and low optical power consumption. Here was a recent progress in microfiber sensors regarding their fabrication, wave guide properties and sensing application of BCAA (protein) concentration detections. In addition, a low-dimensional optical fiber with diameter close to or below the wavelength of light, optical micro/nanofiber (MNF) offers a number of favorable properties for optical sensing, which have been exploited in a variety of sensing applications, including physical, chemical, and biological sensors. Typically, microfiber sensors structures were including tapers, optical gratings, and circular cavities and functionally coated/doped were summarized. This project was developing to sensing concentration of BCAA for adequate amount required for human body. It sustained from dynamic exercise, so that a net loss of muscle protein will decrease the synthesis and increase breakdown in our body. The protein was used to restore a balanced after exercise with no hypertrophy occurs. In this paper, it's reviews the principle, application and theory of fiber optic, fiber optic sensor, microfiber sensor and BCAA (protein).

ABSTRAK

Penderia Microfiber ialah pelbagai jenis gelombang menarik membimbing harta termasuk dengan meluas tailorable pengurungan optic, medan fana dan penyerakanpandu delombang. Penyelidikan ini ditumpukan bagi pembangunan satu sensor disebabkan kemungkinannya menyedari bersaiz kecil, kepekaan tinggi, reaksi cepat, fleksibilit tinggi dan penggunaan kuasa optik yang rendah. Dimana microfiber adalah satu kemajuan baru bagi mengesan mengenai rekaan, ciri-ciri pandu gelombang dan dapat membaca kadar kepekatan BCAA(protein). Sebagai tambahan, satu gentian optik dengan dimensi yang rendah atau bermaksud garis pusat menghampiri atau di bawah jarak gelombang cahaya, oleh itu microfiber/ nanofiber menawarkan beberapa ciri-ciri untuk penderiaan optik yang telah dieksploitasi kan di pelbagai jenis aplikasi penderiaan termasuk fizikal, kimia, dan biologi. Lazimnya, struktur pengesan microfiber termasuklah meruncing, berkeriut optik, rongga bulat dan bersalut/ melalikan telah dirumuskan. Projek ini adalah untuk membangunkan sensor yang dapat mnguji kepekatan BCAA untuk nilai yang dikehendaki oleh badan manusia. Kecederaan yang berlaku adalah dari latihan yang dinamik dan akan mengurangkan kerosakan sintesis dan peningkatan dalam badan kita. Protein juga digunakn bagi memulihkan keseimbangan selepas senaman dengan tiada hipertrofi yang berlaku. Dalam kertas ini, ia mempunyai meninjau prinsip, permohonandan teori gentian optik, penderia gentian optik, penderia microfiber dan BCAA (protein).

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The development of optical fibre communication systems was arguably one of the greatest engineering achievements of the past century. Developments in fiber technology have revolutionised society, allowing first low-cost, high-quality voice communications and more recently the development of the internet.

Optical methods are some of the oldest and best established sensing techniques. The development and improvement of optical sensors are driven by the continuous demand for simple, rapid, sensitive, and in-situ monitoring techniques in a broad range of areas including medical, pharmaceutical, environmental, defense, bioprocessing, and food industries. By using optical fibers as transduction elements, fiber-optic physical, chemical, and biosensors have been very successful in the past decades. With the rapid development of micro/nanotechnology, as well as the increasing demands on miniaturized sensors with higher performances, fiber optical sensors with small size, high sensitivity, fast response, high selectivity, and low detection limits are the current trends of sensing systems.

The application of the fiber optic in our daily communication can be label as a new technology because in our country fiber optic uses not yet widely only have in a certain place such as city that full of people. The problem occurs due to require special skills because optical fibers cannot be joined together as easily as copper cable and requires additional training of personnel and expensive precision splicing and measurement equipment.

In tissue engineering application, smaller microfiber has many advantages, such as the bridging of large gaps between the cut ends of the transected tissue or being used as scaffolds for tissue regeneration. For this reason, we will apply to the practiced microfluidic technology to achieve this objective. In our study strategy, we discussed the geometric design for influence of the chitosan size and used the devices to generate the chitosan microfibers. Finally, the produced microfibers were used to culture the cells and demonstrate the study could apply to scaffold in tissue engineering.

1.2 Objective

1. To understand fiber optic communication.
2. To develop microfiber sensor application for BCAA concentration detection.
3. To analyse performance microfiber sensor on BCAA.

1.3 Problem Statement

Branched-chain amino acids are essential amino acids (specifically, valine, leucine and isoleucine). They are essential, meaning we must get them in our diet because our bodies do not produce them. The term 'branched-chain' just refers to the molecular structure. Amino Acids are the building blocks of protein (meat, dairy and legumes) and have various functions related to energy production during and after exercise so they are needed in adequate amounts, but not excessive. Because of that we want to build a new sensor using microfiber optic in BCAA concentration detection for measure rates BCAA that body needs.

1.4 Scope of Project

The working scope of this project is to study and develop microfiber sensor application for BCAA concentration detection in communication system. The scope listed to ensure the project is conducted within its intended boundary and heading in the right direction to achieve its objective. Scopes of these projects were to study fiber optic, fiber optic sensor, microfiber optic, microfiber optic sensor, BCAA research and fabrication. The main focus for this project can be classified as:

1. The basic of fiber optic communication system
2. The implementation of microfiber sensor for BCAA
3. The system of microfiber optic communication application

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Literature reviews are all about carried out the information for whole project in order to completing this project. The sources that been used was from previous projects done by scientist and other such as books, journal and article where we obtained from SciVerse Science Direct. This chapter is to introduce about the projects that build in communication system fiber optic, fiber optic sensor and microfiber.

2.2 Fiber Optic

An optical fiber or optical fibre is a flexible, transparent fiber made of extruded glass (silica) or plastic, slightly thicker than a human hair. It can function as a waveguide, or "light pipe", to transmit light between the two ends of the fiber **[Thyagarajan,K. 2007].** The field of applied science and engineering concerned with the design and application of optical fibers is known as fiber optics.

Optical fibers are widely used in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths data rates than wire cables. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by total internal reflection. This causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).

Joining lengths of optical fiber is more complex than joining electrical wire or cable. The ends of the fibers must be carefully cleaved, and then carefully spliced together with the cores perfectly aligned. A mechanical splice holds the ends of the fibers together mechanically, while fusion splicing uses heat to fuse the ends of the fibers together. Special optical fiber connectors for temporary or semi-permanent connections are also available.

Optical fiber can be used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fiber with little attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters.

The per-channel light signals propagating in the fiber have been modulated at rates as high as 111 gigabits per second (Gbit/s) by NTT, although 10 or 40 Gbit/s is typical in deployed systems. In June 2013, researchers demonstrated transmission of 400 Gbit/s over a single channel using 4-mode orbital angular momentum multiplexing **[Bozinovic,N. 2013].**

Each fiber can carry many independent channels, each using a different wavelength of light (wavelength-division multiplexing (WDM)). The net data rate data rate without overhead bytes per fiber is the per-channel data rate reduced by the FEC overhead, multiplied by the number of channels usually up to eighty in commercial dense WDM systems as of 2008. As of 2011 the record for bandwidth on a single core was 101 Tbit/s (370 channels at 273 Gbit/s each). The record for a multi-core fiber as of January 2013 was 1.05 petabits per second. In 2009, Bell Labs broke the 100 (petabit per second)×kilometer barrier (15.5 Tbit/s over a single 7000 km fiber).

For short distance application, such as a network in an office building, fiber-optic cabling can save space in cable ducts. This is because a single fiber can carry much more data than electrical cables such as standard category 5 Ethernet cabling, which typically runs at 100 Mbit/s or 1 Gbit/s speeds. Fiber is also immune to electrical interference; there is no cross-talk between signals in different cables, and no pickup of environmental noise. Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment in high voltage environments, such as power generation facilities, or metal communication structures prone to lightning strikes. They can also be used in environments where explosive fumes are present, without danger of ignition. Wiretapping in this case, fiber tapping is more difficult compared to electrical connections, and there are concentric dual-core fibers that are said to be tap-proof.

Fibers are often also used for short-distance connections between devices. For example, most high-definition televisions offer a digital audio optical connection. This allows the streaming of audio over light, using the TOSLINK protocol.

2.3 Fiber Optic Sensor

A fiber optic sensor is a sensor that uses optical fiber either as the sensing element ("intrinsic sensors"), or as a means of relaying signals from a remote sensor to the electronics that process the signals ("extrinsic sensors"). Fibers have many uses in remote sensing. Depending on the application, fiber may be used because of its small size, or because no electrical power is needed at the remote location, or because many sensors can be multiplexed along the length of a fiber by using light wavelength shift for each sensor, or by sensing the time delay as light passes along the fiber through each sensor. Time delay can be determined using a device such as an optical time-domain reflectometer and wavelength shift can be calculated using an instrument implementing optical frequency domain reflectometry.

Fiber optic sensors are also immune to electromagnetic interference, and do not conduct electricity so they can be used in places where there is high voltage electricity or flammable material such as jet fuel. Fiber optic sensors can be designed to withstand high temperatures as well.

2.3.1 Intrinsic sensors

Optical fibers can be used as sensors to measure strain, temperature, pressure and other quantities by modifying a fiber so that the quantity to be measured modulates the intensity, phase, polarization, wavelength or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of intrinsic fiber optic sensors is that they can, if required, provide distributed sensing over very large distances.

Temperature can be measured by using a fiber that has evanescent loss that varies with temperature, or by analyzing the Raman scattering of the optical fiber. Electrical voltage can be sensed by nonlinear optical effects in specially-doped fiber, which alter the polarization of light as a function of voltage or electric field. Angle measurement sensors can be based on the Sagnac effect.

Special fibers like long-period fiber grating (LPG) optical fibers can be used for direction recognition. Photonics Research Group of Aston University in UK has some publications on vectorial bend sensor applications.

Optical fibers are used as hydrophones for seismic and sonar applications. Hydrophone systems with more than one hundred sensors per fiber cable have been developed. Hydrophone sensor systems are used by the oil industry as well as a few countries' navies. Both bottom-mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a laser microphone for use with optical fibers.

A fiber optic microphone and fiber-optic based headphone are useful in areas with strong electrical or magnetic fields, such as communication amongst the team of people working on a patient inside a magnetic resonance imaging (MRI) machine during MRI-guided surgery.

Optical fiber sensors for temperature and pressure have been developed for down whole measurement in oil wells. The fiber optic sensor is well suited for this environment as it functions at temperatures too high for semiconductor sensors (distributed temperature sensing).

Optical fibers can be made into interferometric sensors such as fiber optic gyroscopes, which are used in the Boeing 767 and in some car models (for navigation purposes). They are also used to make hydrogen sensors.

Fiber-optic sensors have been developed to measure co-located temperature and strain simultaneously with very high accuracy using fiber Bragg gratings **[Trpkovski, S 2003]**. This is particularly useful when acquiring information from small complex structures. Brillouin scattering effects can be used to detect strain and temperature over larger distances (20–30 kilometres).

2.3.2 Operating Principle

Optical fibers are also attractive for applications in sensing, control and instrumentation. In these areas, optical fibers have made a significant. For these applications are made more susceptible and sensitive to the same external mechanisms against which fiber were made to be immune for their effective operation in telecommunications. An optical fiber system is basically composed of a light source, optical fiber, a sensing element or transducer and a detector (see **figure. 2.1**). The principle of operation of a fiber sensor is that the transducer modulates some parameter of the optical system (intensity, wavelength, polarization, phase, etc) which gives rise to a change in the characteristics of the optical signal received at the detector.

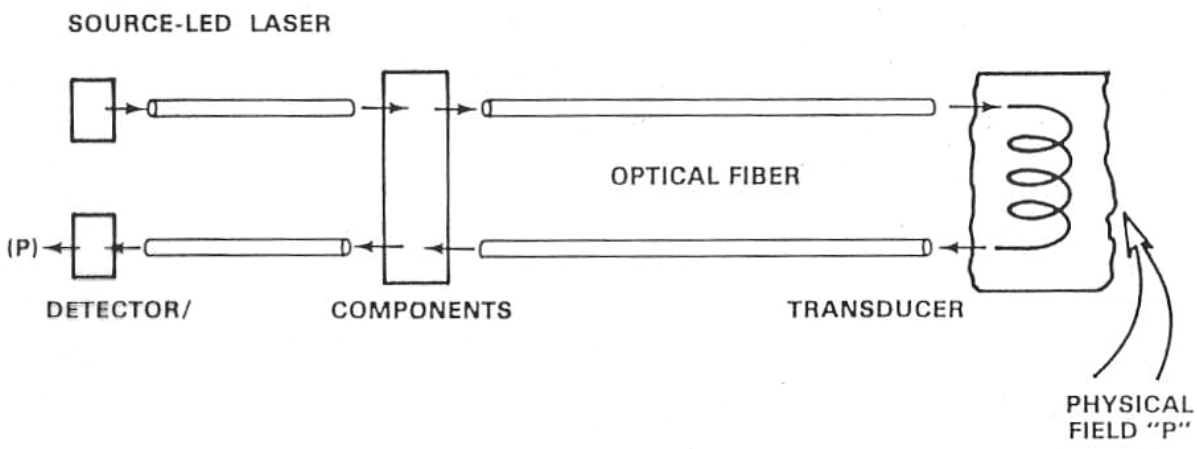

Figure 2.1: Basic elements of an optical fiber sensing system

The fiber sensor can be either an intrinsic one--if the modulation takes place directly in the fiber--or extrinsic, if the modulation is performed by some external transducer as depicted in **Figure: 2.2**.

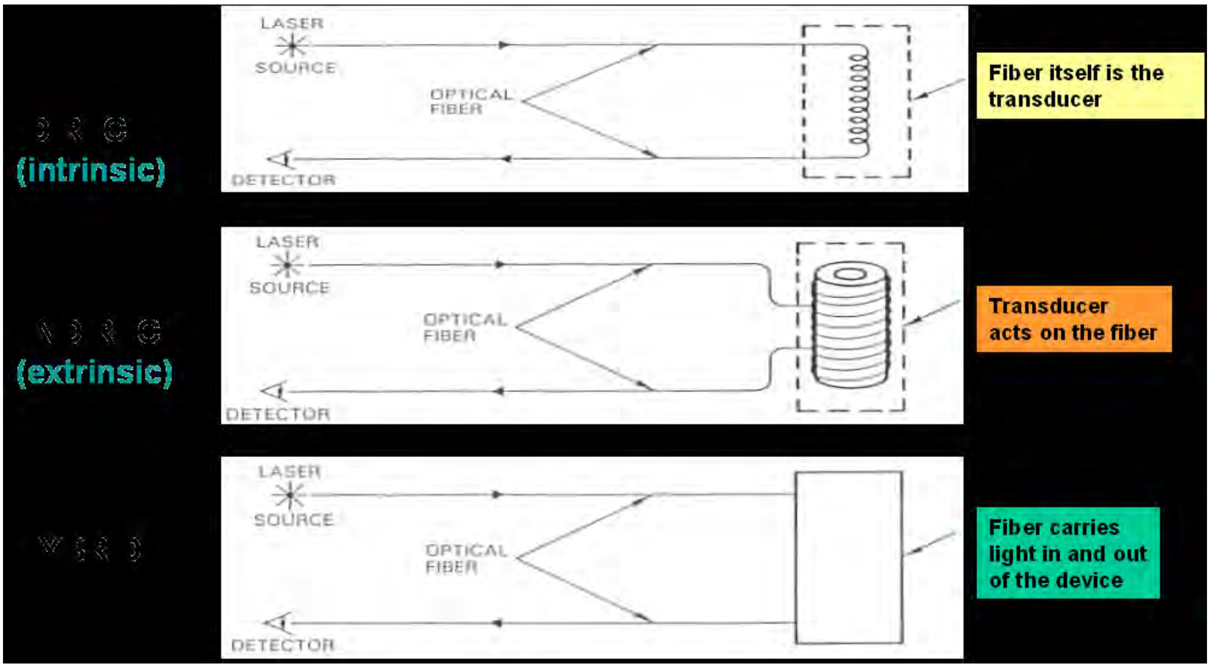

Figure 2.2: Classification of optical fiber sensors

2.4 Microfiber Optic [George Y. 2013]

Optical microfibers and nanofibers (MNF), also known as optical/photonic micro wires and nanowires, are optical fiber tapers with a uniform waist region size comparable to the wavelength. MNFs are usually manufactured by heating and stretching regular-sized optical fibers. The result is a biconical taper that provides a smooth lossless connection to other fiberized components. By controlling the pulling rate during the fabrication process, the taper profile can be fine-tuned to suit the application. Optical materials other than silica have been used to manufacture MNFs, including phosphate, tellurite, lead silicate, bismuth ate and chalcogenide glasses and a variety of polymers. The remarkable optical and mechanical properties exhibited by MNFs are constantly exploited for optical sensing and include large evanescent fields, strong optical confinement, flexibility, configurability and robustness. Such desirable characteristics have gathered much attention in recent years and it is what makes MNFs an excellent platform for optical sensors.

Light launched into a MNF will propagate as core modes which are defined to be the state when their effective index lies between the cladding and core indices. The effective index decreases monotonically along the down-taper transition, and the mode becomes guided by the cladding/air interface. To analyze the mode propagation in the MNF, the exact solution of the Maxwell equations needs to be found since the weakly guiding approximation is not valid as a result of the large index difference between the cladding and air:

$$\left[\frac{J_v'(U)}{UJ_v(U)}+\frac{K_v'(U)}{WK_v(U)}\right]\left[\frac{J_v'(U)}{UJ_v(U)}+\left(\frac{n_{surr}}{n_{MNF}}\right)^2\frac{K_v'(U)}{WK_v(U)}\right]= \\ v^2\left(\frac{1}{U^2}+\frac{1}{W^2}\right)\left(\frac{1}{U^2}+\left(\frac{n_{surr}}{n_{MNF}}\right)^2\frac{1}{W^2}\right) \tag{1}$$

where $U = r\sqrt{k_0{}^2 n_{MNF}{}^2 - \beta^2}$, $W = r\sqrt{\beta^2 - k_0{}^2 n_{surr}{}^2}$, J_v is the v^{th} order Bessel function of the first kind, K_v is the v^{th} order modified Bessel function of the second kind,

n_{MNF} and n_{surr} are the refractive indices of the MNF (~1.45) and the surrounding medium. β is the effective propagation constant of the optical mode. r is used to denote the core radius and correspond to the center from the core-cladding interface in solid fibers and to the cladding-air interface in MNFs. The propagation constant of hybrid modes can be calculated by solving Eq. 1.

The V number can be expressed as:

$$V = \sqrt{U^2 + W^2} = \frac{2\pi}{\lambda}\cdot r\cdot \mathrm{NA}$$

2.4.1 Sensitivity

Sensitivity describes the change in the detected parameter as a result of a change in the measurand. For example, in the case of refractometric sensors a change in the refractive in- dex (measured in refractive index units – RIU) is very often understood in terms of wavelength shift relative to an initial wavelength. This detection parameter is measured in nm, yielding the value of sensitivity in nm/RIU.

2.4.2 Resolution of Detection System

Resolution indicates the smallest detectable change in the parameter used for detection. The resolution is related to the precision with which the measurement is made and hence is usually affected by the specifications of the detection system.

2.4.3 Response Time

Response time (τ) is typically defined as the time required taken for the detection parameter to rise from 10% to 90% of its final value.

2.4.4 Operating Range

Operating range (OR) is the range of values of the parameter under examination, which can be measured by the sensor, and hence by definition large OR values are highly desirable.

2.4.5 Repeatability

Repeatability is an indication of the agreement between the measured performances of the same sample taken under the same experimental conditions at different times. A good repeatability reflects the stability and life-time of the sensor head.

2.4.6 Reproducibility

Reproducibility is based on the agreement between the measured performances between different samples taken under the same experimental conditions. A good reproducibility is ideal for the manufacturing of multiple sensor heads with the same specifications.