UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A Fibre Optic Sensor on Acetone Concentration Detection Using Beam-through Technique

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

by

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I hereby, declare that this thesis entitled "A Fibre Optic Sensor on Acetone Concentration Detection Using Beam-through Technique" is the result of my own research except as cited in references.

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Date : ……….. January 2016

APPROVAL

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

…………………………………………….

(Project Supervisor)

ABSTRACT

The design of current sensor technology especially when related to the chemical still requires a certain degree of the quantitative reliability. The conventional chemical-related sensor may enable a cross sensitivity to happen as the chemical used as the parameter requires an ultra active electrode catalyst and a high operating potential for its oxidation. In this case, chemical substances that are more easily oxidised such as alcohol and carbon monoxide could interfere the sensitivity of the sensor. The chemical such as acetone is mostly to be found in the bodily fluid during the fasting period especially those who are in a diabetic condition. Along with glucose, the acetone level may also need to be monitored as it could indicate the severity of the diabetes. Thus a fibre optic sensor which is more inert to the oxidation reaction may be developed. Fibre optic sensor has gained much attention in the research field, as it is considered to be more sensitive, fast detection rate and reliable sensors. The development of fibre optic sensor on acetone detection by using beam-through technique could be a milestone in the health and sensor field.

Keyword: fibre optic sensor, acetone detection, beam-through technique

ABSTRAK

Rekaan teknologi sensor pada masa kini terutama yang melibatkan bahan kimia, masih memerlukan kebolehpercayaan pada tahap tertentu. Sensor konvensional yang berkaitan dengan kimia boleh menyebabkan berlakunya sensitiviti silang kerana bahan kimia yang digunakan sebagai perimeter memerlukan pemangkin elektrod yang sangat aktif dan potensi operasi yang tinggi untuk proses pengoksidaan. Dalam hal ini bahan kimia yang lebih senang untuk berlakunya proses pengoksidaan seperti alkohol dan karbon monoksida boleh menggangu kepekaan sensor tersebut. Bahan kimia seperti aseton kebanyakkannya boleh dijumpai dalam bendalir badan sewaktu tempoh berpuasa terutamanya bagi golongan yang mengidap diabetes. Selain glukosa, paras aseton dalam badan juga perlu untuk dipantau kerana ia boleh menunjukkan betapa tahap parah diabetes itu Oleh itu sensor berasaskan gentian optik yang lebih tidak reaktif kepada tindak balas pengkosidaan boleh dibangunkan. Sensor berasakan gentian optik telah mendapat sambutan meluas dalam bidang penyelidikan, kerana ia dianggap sebagai lebih sensitif, kadar pengesanan yang tinggi, san sensor yang booleh dipercayai. Pembangunan sensor berasaskan gentian optic terhadap pengesanan aseton menggunakan teknik pancaran-terus boleh menjadi bermakna dalam bidang kesihatan dan bidang sensor.

Kata kunci: sensor berasaskan gentian fiber, pengesanan aseton, teknik pancaran terus

DEDICATION

To my mother, Madam Agnes Mawal, who has taught me that knowledge is gold.

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Thanks be to God, who with His willing; giving me the opportunity to complete this Final Year Project entitled Fibre Optic Sensor on Acetone Detection Using Beam-through Technique. This final year project report was prepared for Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), basically for student in final year to complete the undergraduate programme that leads to the Bachelor Degree in Electronic Engineering Technology (Telecommunications).

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LIST OF ABBREVATIONS, SYMBOLS AND NOMENCLATURES

˚C	: Degree Celcius
$(CH_3)_2CO$	: Acetone / propane-2-one
$[CH_3COCH_2COH(CH_3)_2]$	: Diacetone alcohol
Δ	: Birefringence
µm	: Micrometre
µm / rad	: Micrometre per radian
Λ	: Wavelength
2-[14C]-acetone	: 2-Carbon-14 acetone
3D	: Three dimensional
A	: Core radius
AO	: Acousto-optics
AOT	: Dioctyl sodium sulfosuccinate
$CH_3{\bullet}CO{\bullet}CH_2{\bullet}COH(CH_3)_2$	: Diacetone alcohol
$CH_3{\bullet}CO{\bullet}CH_3$	: Acetone / propane-2-one
CO_2	: Carbon dioxide
CTL	: Cataluminescence
DC	: Direct Current
DKA	: Diabetic Ketoacidosis
FBG	: Fibre Bragg Gratings
FO-SPR	: Fibre Optic Surface Plasmon Resonance
FOBDS	: Fibre Optic Bundle Displacement Sensor

FODS	: Fibre optic displacement sensor
He-Ne	: Helium-Neon
HRTEM	: High-resolution transmission electron microscopy
IO	: Inverse Opals
IUPAC	: International Union of Pure and Applied Chemistry
LDO	: Layered double oxide
MBK	: Methyl iso-butyl Ketone
mFBG	: Microfibre Bragg Gratings
mg / dL	: Milligram per decilitre
mM	: Millimole
MMZI	: Microfibre Mach-Zehnder interferometre
MOX	: Metal Oxide
mV / %	: Millivolt per percentage
MWCNT	: Multiwall carbon nanotubes
NH^+	: Ammonium ion
NH_3	: Ammonia
nm	: Nanometre
Nm / %	: Nanometre per percent
PAA-ran-PAAPBA	: Borate polymer
PAni	: Polyaniline
PdAu	: Lead-Gold
PMMA	: Polymethylmethacrylate

ppm : Parts per million

RI : Refractive index

RIU : Refractive-index unit

RSD : Relative standard deviation

SEM : Scanning electron microscope

SMF : Single Mode Fibre

SMS : Single-mode-multi-mode-single-mode

SPA : Surface plasmon sensor

SnO_2 : Tin Oxide

UV : Ultraviolet

VOCs : Volatile Organic Compounds

WO_3 : Tungsten trioxide

XPS : Xray Photoelectron Microscopy

XRD : Xray Powder Diffraction

ZnO-CuO : Zinc Oxide – Copper Oxide

CHAPTER 1
INTRODUCTION

1.1 Introduction

This chapter discusses about the project background, the problem statement, objectives of the project, project limitation and the scope of the project.

1.2 Background

A sensor is a device that is used to sense some characteristic of its environs. It detects events or changes in quantities and provides a corresponding output. Technological progress allows more and more sensors to be manufactured on a microscopic scale as micro-sensors. In most cases, a micro-sensor reaches a significantly higher speed and sensitivity compared with macroscopic approaches.

In recent years, fibre optic sensors received more considerable research efforts as the need for more sensitive and reliable sensors to measure a large range of physical, chemical and biomedical quantities. These research efforts are done due to the fact that fibre optic sensor has a potential sensitivity, detection speed and abilities to the widely assay condition.

Acetone is an organic compound with the formula $(CH_3)_2CO$. It is a colourless, volatile, flammable liquid, and is the simplest ketone. Its IUPAC (International Union of Pure and Applied Chemistry) name is propan-2-one.

Along with acetoacetate and β-hydroxybutyrate, acetone is produced in periods of glucose deficiency or insulin insufficiency as an alternative energy source. All these three substances are commonly known as ketone body. Measurements of ketone in urine and blood are widely used in the management of patients with diabetes as adjuncts for both diagnosis and ongoing monitoring of Diabetic Ketoacidosis (DKA).

Overall this project is mainly focusing on the fibre optic sensor of acetone detection using beam-through technique development.

1.3 Problem Statement

A precise and highly sensitive sensor is highly preferred when it comes to measurement and analyse a chemical substance. In medical laboratories for example, a blood sample is obtained from a diabetic ketoacidosis patient and thus it requires an accurate and precise acetone concentration information for further evaluation.

Various kind of sensors have been developed nowadays. In general, the chemical sensors are broadly classified into gas, liquid, and solid particulate sensors based on the phases of the analyte. They can be further categorised as optical, electrochemical, thermometric, and gravimetric (mass sensitive) sensors according to the operating principle of the transducer. The design of chemical sensors also requires appreciation of the needed degree of quantitative reliability (precision or accuracy).

An electrochemical sensor for an example, has been also introduced to determine the chemical concentration. Nonetheless, a cross sensitivity could happen because the chemical that is used as the might require a very active working electrode catalyst and high operating potential for its oxidation. In this case a chemical substance which are more easily oxidised such as alcohol and carbon monoxide could interfere the sensitivity of the sensor.

Thus, a fibre optic sensor is proposed and developed to overcome these problems. This fibre optic sensor could be a milestone in the health and sensor field.

1.4 Objective

The objectives of this project are:

i. To study fibre optic sensor
ii. To develop fibre optic sensor for acetone detection
iii. To analyse the performance of fibre optic for different value of acetone concentration

1.5 Limitation

This project would be implemented by optimising the usage of fibre optics sensor based on beam-through technique. This sensor will be used to detect the concentration of acetone.

1.6 Scope

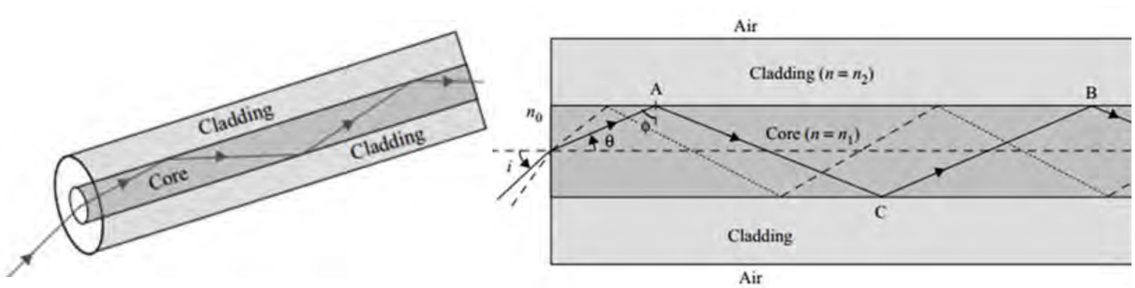
Although there are various techniques used in fibre optic sensor, but this study will only cover fibre optic sensor based on beam-through technique. Neither the acetone physical properties nor the chemical properties of acetone will be studied in this paper. Instead, this study will mainly focus on the application of fibre optic as a sensor for the detection of acetone concentration.

CHAPTER 2
THEORETICAL BACKGROUND

2.1 Introduction

This chapter will provide the review form previous research that is related to this final year project. There are previous researches understanding on the fibre optic sensor, technique used in fibre optic sensor, the role of acetone in the diabetic ketoacidosis, acetone in industrial usage, and the current acetone sensor.

2.2 Fibre Optic



(a) A cylindrical glass fibre core cladded by lower refractive index glass.

(b) Light rays incident are trapped inside the fibre core.

Figure 2.1 Basic anatomy and mechanism of fibre optic

Figure 2.1 shows an optical fibre, which consists of a (cylindrical) central dielectric core (of refractive index n_1) cladded by a material of slightly lower refractive index n_2 ($< n_1$). The necessity for a cladded fibre rather than a bare fibre (i.e., without cladding), arises from the fact that for transmission of light from one place to another, the fibre must be supported, and supporting structures may distort the fibre considerably, thereby affecting the guidance of the light wave. This can be avoided by choosing a sufficiently thick cladding. When the core radius *a* is large (≈ 25 μm or more); *a* more detailed description of single and multimode fibre is given in the next section. For a typical (multimode) fibre, $a \approx 25$ μm, $n_2 \approx 1.45$ (pure silica), and $\Delta \approx 0.01$, giving a core index of $n_1 \approx 1.465$. The cladding is usually pure silica, while the core is usually silica doped with germanium; doping by germanium results in an increase in the refractive index.[1]

2.3 Fibre Optic Sensor

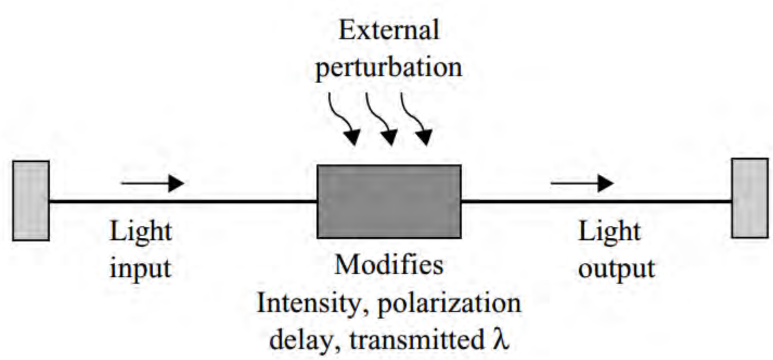


Figure 2.2 Schematic of a fibre optic sensing system

Figure 2.2 is a schematic diagram of a fibre optic sensor system. Light from a suitable source is coupled into an optical fibre. The external disturbance modifies some property of the light beam, which is then guided through the optical fibre to a detector. Fibre optic sensors can be classified broadly into two categories: extrinsic and intrinsic. In extrinsic sensors, the optical fibre simply acts as a device to transmit and collect light from a sensing element that is external to the fibre. The sensing element responds to the external perturbation, and the change in the characteristics of the sensing element is transmitted by the return fibre for analysis. The optical fibre here plays no role other than transmitting the light beam to and from the sensing region. Such fibre optic sensors are easy to design and fabricate and relatively inexpensive. Examples of such sensors are

Doppler anemometers, noncontact vibration measurement, and pressure sensors which find wide applications in automobiles and aerospace, for example.[1]

2.3.1 Fibre optic surface plasmon resonance sensor

Singh and Gupta (2013) [2] reported that the fabrication and characterisation of a surface plasmon resonance (SPR) based fibre optic sensor, working on wavelength interrogation method, to measure the low glucose concentration (similar to the human blood) in aqueous fluid. The sensing probe is prepared by coating of films of silver and silicon on the optical fibre core followed by immobilisation of enzyme (glucose oxidase) using gel entrapment method.

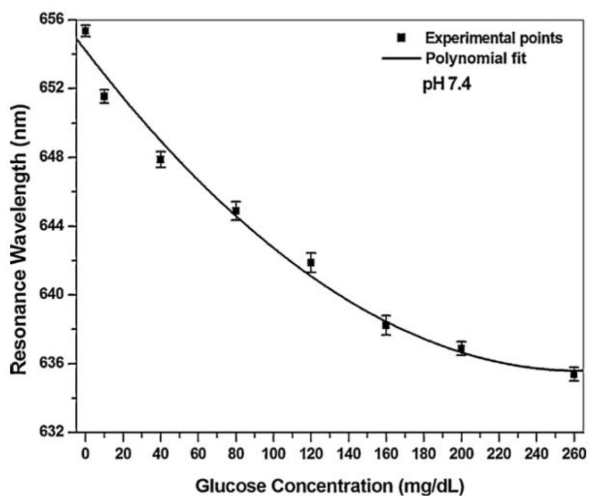


Figure 2.3 Variation of resonance wavelength with the concentration of glucose

Experimental results on SPR spectra show a blue shift in the resonance wavelength on increase in the concentration of the glucose in samples. Further, the sensitivity of the sensor decreases as the concentration of the glucose increases whereas the detection accuracy is almost independent of the glucose concentration. In addition, for 80 mg/dL glucose concentration, the influence of pH of the sample on the performance of the sensor