DEVELOPMENT OF LOW COST ALCOHOL SENSING DEVICE BASED ON GLASS SUBSTRATES AS PLATFORM

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DECLARATION

I declare that this thesis entitled “DEVELOPMENT OF LOW COST ALCOHOL SENSING DEVICE BASED ON GLASS SUBSTRATES PLATFORM is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 5TH JULY 2021

APPROVAL

I hereby declare that I have checked this report entitled" **Development of low cost Alcohol sensing device based on glass substrates platform**" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name : EN MOHD HAFIZ BIN JALI

Date : 5TH JULY 2021

DEDICATIONS

To my beloved father, mother, sisters, my supervisor and my dearest friends.

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ABSTRACT

Driving vigilance is a pressing road safety issue that many people face in their daily lives. This project proposes to develop a low-cost sensing device that can help detect a driver's alcohol level. Alcohol is the world's most abused drug. Alcohol abuse affects more than 18.5 million adults in the US, with a loss of productivity, health, motor vehicle, criminal and other related costs in the company over USD 200 billion annually. The percentage of all hospital admission (> 20 percent) and death ~100,000 each year are due to alcohol-related diseases. This project's purpose is to develop a low-cost sensing device for alcohol sensors. The sensing system consists of Agarose Gel and HEC/PVDF as a coated material that are being optimized by applying 1 to 3-layer of coated to run the obtain the optimum voltage output. Those coated glass substrate will be kept dry for 24 hours before applying ethanol concentration on to the glass substrate to proceed the experiment. The data analysis that will be taken in this project is Optimization number of layers, Repeatability, Hysteresis, Stability and Time Response. In sum of, the best coated material will be taken for the proposed sensor. Arduino is used to obtain the output voltage for all the experiment.

ABSTRAK

Pada era sekarang, masalah mendesak mengenai keselamatan jalan raya yang banyak orang hadapi dalam kehidupan seharian mereka. Projek ini mencadangkan untuk membangunkan alat pengesan kos rendah yang dapat membantu mengesan tahap kehadiran alkohol pemandu. Alkohol (etanol) adalah ubat yang paling banyak disalahgunakan di seluruh dunia. Penyalahgunaan alkohol memberi kesan kepada lebih daripada 18.5 juta orang dewasa di A.S., yang menyebabkan kos produktiviti, perbelanjaan penjagaan kesihatan, kemalangan kenderaan bermotor, jenayah, dan kos lain-lain yang berkaitan dengan kos perbelanjaan masyarakat melebihi $ 200 bilion setiap tahun. Penyakit yang berkaitan dengan alkohol menyumbang kepada peratusan yang tinggi dari semua kemasukan ke hospital (> 20%) dan kematian ~ 100,000 setiap tahun. Tujuan projek ini adalah untuk membangunkan alat pengesan kos rendah untuk sensor alkohol. Sistem penginderaan terdiri dari Sistem penginderaan terdiri dari Agarose Gel dan HEC / PVDF sebagai bahan bersalut yang dioptimumkan dengan menerapkan lapisan berlapis 1 hingga 3 untuk menjalankan output voltan optimum. Substrat kaca yang dilapisi itu akan dikeringkan selama 24 jam sebelum menggunakan kepekatan etanol pada substrat kaca untuk meneruskan eksperimen. Analisis data yang akan diambil dalam projek ini adalah *Optimization number of layers*, *Repeatability*, *Hysterisis*, *Stability* dan *Time Response*. Ringkasnya, bahan bersalut terbaik akan diambil untuk sensor yang dicadangkan. Arduino digunakan untuk mendapatkan voltan keluaran bagi semua eksperimen.

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LIST OF SYMBOLS AND ABBREVIATIONS

HEC / PVDF	-	Hydroxyethylcellulose/ Polyvinylidenefluoride
V	-	Voltage
POF	-	Plastic Optic Fibre
EtG	-	Ethyl glucuronide
EtS	-	Ethyl sulphate
LED	-	Light Emitting Diode
$C_2 H_6 O$	-	Ethanol
UV-Vis	-	Ultraviolet-visible
ZnO	-	Zinc Oxide
CE	-	Capillary Electrophoresis
LIF	-	Laser Induced Fluorescence
GaN	-	Gallium Nitride
InGaN	-	Indium gallium nitride

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CHAPTER 1

INTRODUCTION

1.1 Background

For the period 2006 to 2009, a total of 710 fatal traffic accidents were registered with the Department of Forensic Science, Kuala Lumpur Hospital. The study found that 23.3% of fatally injured drivers were under the influence of alcohol, 11% were under the influence of drugs, and 2.3% were under the influence of drug-alcohol. A total of 1,035 traffic accidents due to alcohol influence were reported, resulting in 618 deaths from 2010 to 2015, according to statistics from the Ministry of Interior. According to research reports on driving under the influence of drugs or alcohol (DUI) in February 2015, 16.7% tested positive for alcohol (Kuala Lumpur) and 167 fatalities were recorded. [17]. Alcohol is the world's most abused drug. Alcohol abuse affects more than 18.5 million adults in the US, with a loss of productivity, health, motor vehicle, criminal and other related costs in the company over USD 200 billion annually (Zhao X el al.,2014). The percentage of all hospital admission (> 20 percent) and death ~100,000 each year are due to alcohol-related diseases (Xingjian et al., 2014). Therefore, to diagnose high-risk drinking activity and alcohol-induced tissue damage, there is an immediate and unmet need for the creation of successful diagnostic tests. The most objective method for easily verifying its existence in a person of interest is the assessment of ethanol in the blood itself. The low specificity and very short detection window, however, makes ethanol itself a less accurate marker for long-term physiological and behavioural impact diagnosis and monitoring (JC Fell et al., 2007). Ethanol has an added drawback that it can also be found in diabetic bacteria-exposed sugar containing body fluids, rendering it not an effective marker for body fluids other than blood (Nicholas V et al. 1998). In a variety of body fluids not limited to blood, the ideal marker should be sensitive, accurate, and have a long detection window. In recent years, the emergence of non-oxidative direct metabolites of ethanol biochemical markers ethyl glucuronide (EtG) and ethyl sulphate (EtS) for the detection of alcohol has increased. The recent upsurge in EtG research and testing has led to the need for such biochemical indicators as reliable tests for the evaluation of new drugs or therapeutic treatments for alcohol problems to meet these requirements. In general, 0.7% of ingested ethanol has been found to be excreted in the breath, as determined by a breath alcohol detector. However, an additional 0.1% of the ethanol ingested is transferred by sweat to the surface of the skin where it leaves the body. Oxidation by cytosolic enzymes, alcohol dehydrogenase and aldehyde dehydrogenase and much less microsomal CYP2E1 are other storage pathways of ethanol in blood. Ethyl glucuronide (EtG) and, more recently, ethyl sulfate (EtS), minor ethanol metabolites formed by conjugation pathways, have recently been studied as well-characterized markers of ethanol exposure and its pharmacokinetics. EtG is a minor alcohol metabolite formed when alcohol interacts with glucuronic acid in the liver, a product that acts in the detoxification of substances.

1.2 Motivation

Generally, there were about 2,281 drunk driving accidents in Malaysia from 2011 to 2018, of which about 50 percent were fatal and the other half sustained either serious or minor injuries. Ethanol is an organic chemical compound. It is a simple alcohol that can be very harmful to humans. It is a psychoactive drug, a recreational drug, and the active ingredient in alcoholic beverages. One of the toughest habits done by people all over the world is speeding car while drunk. People assume that after consumption of alcohol, it is safe to drive themselves to town or even to their houses. This one thing, though, leads to collision happening on our roads that lead to major repercussions. Most of the times when someone is under the influence of alcohol, they tend to think that they are invincible. However, this incorrect option will lead to fatal outcomes which should be tackled and avoided. The higher contains of this chemical compound in a drink can cause a lot of problem such as damage to liver, stroke, heart failure and can lead to accidental serious injury or death. The main purpose of this project is to develop the ethanol sensing based on glass substrate platform and the main focus is to detect the different concentration level of alcohol in human. This project is performed by conducting output voltage analysis from the proposed sensor when exposed to the different concentration level of ethanol ($C_2 H_6 O$).

1.3 Problem Statement

There are several problems in current alcohol sensor. First problem as the light transmit through the sensing region of the glass substrate, transmission losses would happen because of the number of layer coated effects the output voltage. In order to generate the optimum output voltage, the number of layers coated on glass substrate need to be optimized. The sensing response of the uncoated glass substrate is quite low due to small refractive index difference. In order to increase the sensing response, the glass substrate will be coated with a higher refractive index which is Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel. Furthermore, in terms of device configuration, current devices sensor has complex hardware design which may lead to more expensive manufacturing cost due to its complexity.

1.4 Objectives

The objectives of the study are:

- To fabricate glass substrate platform coated with Hydroxyethyl cellulose/Polyvinylidene fluoride (HEC/PVDF) and Agarose Gel for ethanol sensing application.
- To optically characterize and optimize the number of layers coated
- To validate experimentally the sensing applications of a low cost alcohol sensor.

1.5 Scope of work

This project focus on detection of alcohol concentration instead of selectivity of other type of alcohol. The light propagation will attenuate when interact with the surround analyte. This will lead to variation of output voltage when expose to different alcohol concentration level. From these data, the number of layers coated will be optimize ranging from 1 layer up to 3 number of layers. The concentration of the ethanol solution is set from 20%,40%,60%, 80% and 100%. There are few analyses that will be carry out to determine the correlation of the data such as Optimization number of coated layers, Repeatability, Hysteresis, Stability and Time Response. The software to be used for the data analysis will be Arduino Ide to obtain the output voltage reading. The light source used as the input to the proposed sensor is a green LED. There are also two type of coated solution that will used in this project which is Agarose Gel and HEC/PVDF. The expected outcome for this project is a low cost, compact and highly sensitive coated used for alcohol sensor will be produced.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An electronic system that provides electrical access to the bandgap structure and allows efficient light generation is a light-emitting diode. Essentially, LEDs are made of three different types of materials stacked on top of each other. The bottom layer has a high concentration of free electrons (e.g. n-type GaN doped with Si), followed by several alternating thin layers (1-30 nm) of smaller bandgap materials (InGaN/GaN), also known as quantum wells. By embedding a smaller bandgap material (InGaN) in layers of larger bandgap material (GaN), a well is created in which electrons and holes are spatially trapped so that they can effectively recombine and produce light at the wavelength of the smaller bandgap material. Above this "active layer" is a layer of material with a high concentration of holes (p-type GaN doped with Mg) [10].

After several years of research, major advances were made in 1986 by growing high quality GaN on a remote material, sapphire (Al2O3) (Ref. 21), so that p-type conductivity in GaN doped with Mg could be demonstrated by activating the tissue in an extremely post-growth annealing. These breakthroughs led to the first high-efficiency blue LEDs of the time in 1992 (1.5% efficiency) and then to the first viable blue and green LEDs in 1995 with efficiencies up to 10% (Ref. 22). More recent developments have also produced high brightness yellow LEDs, but they are still quite inefficient, comparable to the first usable blue and green LEDs in 1995 with efficiencies up to 10% (Ref. 22). More recent developments have also produced high brightness yellow LEDs, but they are still quite inefficient.

2.2 Optical Sensor

Optical sensor converts light to electrical signals and enable instruments to read through wavelength. Plastic Optic Fibre (POF) is an optical sensor. POF serves as optical measurement system of alcohol concentration (Masayuki et al., 2012). There are three (3) shapes as tapered u-shape, polished u-shape and polished coil shape. The shape made by heating the sensor probes indirectly at 80^{o}C. Optical measurement using POF (plastic optic fibre) is at utmost advantage as easy in handling, costs low, immune from electric interface. This POF is extremely sensitive as even water tend to absorb the polymer network and cause the fibre to swell due to expansion of volume. Its sensitivity is 0.02% - 0.10% (Hasnida Saad et al., 2015). This sensor head has small diameter and can be used to detect optical detection of alcohol concentration in real liquors. It is extremely useful in brewery. This polymer also response to methanol leakage system [29].

2.3 Alcohol Sensor

Gas-liquid chromatography is a gold standard detection through blood analysis of intoxication of methanol. This serves as indirect diagnosis in most nosocomial and it is not possible to be done without trained personnel. A much reliable detection technique is extremely expensive and not easily available in many countries. Since only ethanol is used as benchmark or antidote for alcoholic beverage detection, methanol is much higher to be detected though. To avoid usage of most expensive items, portable devices along with rapid screening is invented and its usable by either paramedics or layman. Alcohol sensor depends on the humid condition and temperature to perform its accuracy. The breathalyzer hanwey, an existing sensor needs to be pre-heated for 24hours before usage to attain the baseline (Gabriel G, 2018)).

Chemical gas sensors are promising due to their low cost, high miniaturization potential, and ease of use. In particular, metal oxide sensors exhibit high sensitivity when nanostructured and are capable of detecting analytes as low as 5 ppb within seconds. But such sensors are typically not selective, especially for chemically similar molecules (such as methanol and ethanol), which has been a long-standing challenge in the field. As a result, current chemoresistive and electrochemical methanol gas sensors show cross-interference with ethanol and other alcohols, which hinders them for the targeted applications (Rosenberg E., 2016).

2.4 Nanomaterial in optical sensor

Nanomaterial is made to monitor levels of ions and biomolecules. This is not as the traditional method, no need of extensive system to operate the system. Nanomaterial sensors are extremely important for real-time monitoring analytes. There are few types of the sensor. Biosensors, nanoparticles' optical properties change with the polymeric aggregate. Chemical sensor, optical absorbance changes detected in gas atmospheres. Optical transmittance can be altered by NO exposure. Humidity sensor, sensitivity shown by Cobalt Oxide films as changes in wavelength well observed (Jinjun.S et al., 2004). (Affa.R et al., 2020) mentioned that the optical properties such as transmittance, absorbance and refractive index of ZnO is determined by using ultraviolet-visible (UV-Vis) spectrophotometer. ZnO coated POF has better performance and it is done by getting the power transmitted through power meter. From this study, it is known that power output increase as alcohol concentration increase.

2.5 Light emitting diode

Light emitting diode also known as LED, applied for chemical sensors in devices to configure the application and this also focus on transmittance absorption metric measures (Martina et al., 2008). LED is highly reliable, low cost and power consumption, auto operating capability. This is the best to be used as it is helpful for today's world as there is high demand for health and environment. Sensitivity of system is lower in LIF detection system. Higher LEDs with more sensitive photodiodes to be used for improvement (Feng et al., 2009). LEDs have many advantages than the common usage such as laser and laser induced fluorescence (LIF). To curb over the disadvantages of common goods, LEDs were started to be in use. There are several of types to be used for detection systems for analytical application especially portable instruments of CE (capillary electrophoresis).

2.5.1 Luminous Efficacy

To evaluate the energy efficiency of a white light source, it is common to start from its ability to produce a visual impression. This quantity is called luminous efficacy. It results from the combination of the spectral power spectrum of the light source and the spectral sensitivity of the human eye, which peaks around 555 nm (green) [10]. Luminous efficacy is calculated as the ratio of the visual experience produced, expressed in lumens, to the electrical power required to produce the light, expressed in watts, where 1,700 lumens is roughly equivalent to the luminous intensity of a 100 W incandescent bulb [10].

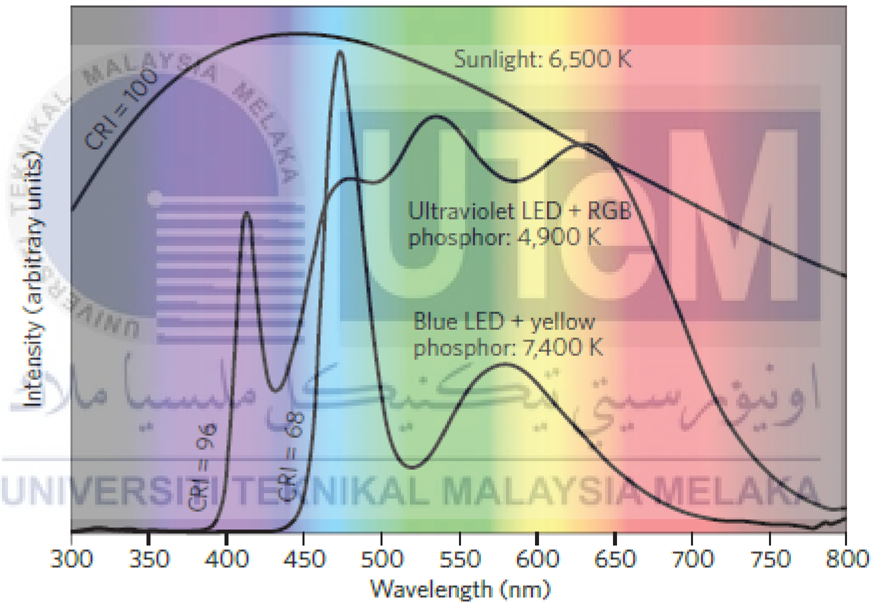

Figure 2. 1: Comparison of the spectrum of ideal sunlight with two LED-based white-light sources [10]

2.6 Agarose gel

Agarose gel is widely used in DNA electrophoresis. It is inexpensive and very easy to be applied and also found to be stable solvent which is water insoluble. It has inert property chemically. It absorbs water from the environment which eventually changes the refractive index. The entry of water is due to its humidity level and capillary action [28].

Agarose has high sensitivity, porosity and both makes it to be great performer for sensor for humidity. Refractive index changes as the polymer has hydrophilic nature of the gel which propagate the light through fibre. The pore size with average of 100nm and the content of agarose will be influential factor for sensitivity [27].

2.7 HEC

HEC is acronym for hydroxyethylcellulose which is blend along with plastic optical fibre to have better sensitivity. The sencor undergoes fabrication as a probe. This HEC will increase the relative humidity and alter the propagation of light which will eventually improve the response of sensor. The coating with HEC has better resonance of humidity [26].