DEVELOPMENT OF LOW COST ACETONE SENSING DEVICE BASED ON GLASS SUBSTRATE PLATFORM

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DECLARATION

I declare that this thesis entitled "DEVELOPMENT OF LOW COST ACETONE SENSING DEVICE BASED ON GLASS SUBSTRATE 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.

Signature :

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Date : 5 JULY 2021

APPROVAL

I hereby declare that I have checked this report entitled “DEVELOPMENT OF LOW COST ACETONE SENSING DEVICE BASED ON GLASS SUBSTRATE 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 : TS DR MOHD HAFIZ BIN JALI

Date : 5 JULY 2021

DEDICATIONS

To my beloved mother, Zuilan Binti Bahrein,
and father, Ahmad Zamzuri Bin Abdul Rashid.

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First of all, praise to Allah that i get to accomplished my Final Year Project successfully and I would like dedicate my special thanks to my supervisor, Ts Dr Mohd Hafiz Bin Jali, that already guide me and provide me encouragement throughout the journey of completing this thesis. I am grateful that i get the chance to work under his supervision.

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ABSTRACT

The advancement of technology nowadays affecting the extension of the medical and health sectors. It plays an important role in improving the efficiencies of medical instrumentations and the recognition of diseases. Researchers found out that Diabetes can be diagnosed alternatively by identifying the concentration level of Acetone in human breathings with the aid of sensing application. In this proposed project, the analysis of the performance for sensing application is carried out experimentally using glass substrates with different coating materials. The steps taken to resolve uncertainties and changing requirements while enhancing the development of the sensor are defined, covering the stages of optimization and characterization of the sensor, development of sensor prototypes and tests. Several tests such as repeatability, stability and time response are carried out in this proposed project to ensure the reliability and quality of the sensing device. This works directly for in-line monitoring of the concentration level of Acetone at an economic cost and compact size.

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INTRODUCTION

1.1 Background

Different methods and techniques were used for many years in the exhaled human breath analysis. At the outset of a breath test, Hippocrates teach his students how to use the odour of the breath to identify hepatic patients with uncontrolled diabolic disease and even failure of the kidneys.[1] Due to the lack of adequate devices for detectting exhaled acetone in the breath and correlating them with specific diseases such as diabetes, it has been underestimated over the years.[1] Diabetes is a disease that affects millions of people worldwide and currently diagnosed through blood sampling, which is time-consuming, invasive, and potentially painful. This proposed project focuses on the applications of the detection of exhaled acetone as a possible tool for monitoring diabetes.

The development of sensor technology has made other techniques based on electronic noses or single sensors more attractive. Acetone sensors have been considered as an attractive area of study due to its promising application in the diagnosis of diabetes.[2] However, fabricating reliable acetone sensors in breathalyzers to obtain accurate data, in the aid of diabetes diagnosis is far from trivial. Amongst others, reliability under different working conditions, response, fabrication techniques and cost remain as issues.[2] Therefore, the main objective of this preliminary work focuses on the fabrication of a reliable sensor to detect acetone solution in the range of human breath acetone concentration.

The determination of the characteristics of the acetone sensing device will be established with regard to the variation of concentration level of acetone.[3] The benefit of this sensing device is that with a simple measurement method, low cost, fast production, can be linked with other measurement system instruments and can measured the concentration level of acetone more accurately.

1.2 Problem Statement

This proposed project employ the transmitted light and glass substrate as a platform which it exhibit several advantages such as a simple design, low-cost production and environmentally friendly device. As the light transmitted through the sensing region of the glass substrate, the transmission experience losses because the coating duration of the materials affects the output voltage. In order to generate the optimum output voltage, the coating duration of the materials 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.

1.3 Objectives

a) To fabricate glass substrate platform coated with Hydroxyethyl cellulose/Polyvinylidene Fluoride (HEC/PVDF) and Agarose Gel for Acetone sensing application.
b) To optically characterize and coating duration of the materials that effect the output voltage.
c) To validate the proposed sensor for Acetone sensing application.

1.4 Scope

The analysis of this proposed project is conducted based on output voltage that is monitorized by using Arduino Software. Next, the work focuses on detection of difference concentration level of Acetone ranging from 3%, 6%, 9%, 12% and 15%. Moreover, the coating duration of material on the glass substrate platform will be optimize from Day 1, Day 2 and Day 3. Last but not least, the light source used as the input to the proposed sensor is a green LED.

1.5 Motivation

Malaysia experiencing crucial diabetes rates from time to time which this country enlisted as one of the Top 50 Countries that commonly received patients diagnosed with diabetes. The initiative to minimize these rates can be done by identifying the early symptoms of diabetes in a person. Instead of examine bloods, a new method is discovered by monitoring the Acetone concentration level in human breathings. The purpose of this project is to develop the Acetone sensing based on glass substrate platform. Also, the main focus is to detect different concentration level of Acetone in human breathings.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Diabetes are generally monitored by the household blood glucose metre and are not particularly adequate in their exactness and sensitivity. At present, the existing technology for the detection of blood glucose in the market comprises mainly the professional blood test equipment and the handheld domestic blood glucose detector.[4] Both are invasive testing devices, which require constant needle detection, difficult operation and expensive costs.

Marco Righettoni et al. created a non-invasive breathing control detector resistant to chemical corrosion, able to quickly measure extremely low acetone concentrations under ideal settings and real conditions.[5] The signal-to-noise ratio is likewise high. It indicates that a portable, cost-effective device for the substitution of the burdensome invasive diabetes sensors that can detect diabetes through breath analysis can be provided.[5]

The portable and convenient feature of the acetone recognition detector is more useful to assist the diagnosis, monitoring and evaluation of diabetes, compared with the traditional intrusive and standardised approach for blood sugar detection using expensive and large devices.

2.2 Light Emitting Diode (LED)

Light Emitting Diode (LED) has progressed from numerical displays and indicator lights to a variety of modern applications. Significant advances were made after several years of research by increasing GaN (Gallium Nitride) on a foreign element, sapphire (Al2O3), in 1986.[6] Then, the p-type conductivity in Gallium Nitride doped with Magnesium by triggering the material in a post-growth is annealed. This breakthrough leads to the first high-performance blue LEDs with 1.5 percent efficiency in early 90's, and then the researchers discover green LED with 10 percent efficiency in mid 90's.[6] Recent advances have also resulted in yellow LEDs with high visibility, but still very inefficient.

Any of the benefits of using an LED are the option of LED as a light source, high theoretical performance, bright white light source and cheap price. These advantages, however, come at the cost of a lower color-rendering index value, which is usually so low that such equipment is inefficient for indoor use. Ultraviolet LED phosphorus mixtures have a larger CRI advantage and are ideal for limited applications, although this results in poor efficacy.[6] The third option is to dynamically initiate white light by mixing three or more LEDs of different wavelengths, which can lead to better efficiencies than ultraviolet phosphorus LEDs, but would generally be a costly alternative.[6]

The benefits of LEDs, such as compact scale, long lamp life, low heat emission, energy savings and reliability. They also allow exceptional design flexibility in color change, dimming and distribution by combining these small units into ideal shapes, colors, sizes and lumen packets.

2.2.1 Luminous Efficacy

It is common to assume the potential to produce a visual impression in order to calculate the energy efficiency of a white-light source. The number is referred to as luminous efficacy. It emerges from the combination of the spectral power spectrum of the light source with the spectral sensitivity of the human eye, which peaks at 555 nm (green).[6] The ratio of the produced visual sensation expressed in lumens, where 1,700 lumens is essentially equal to the light intensity of a 100-W incandescent bulb to the electrical power necessary to generate the light expressed in watts, is taken to determine the luminous efficacy.[6]

2.2.2 Color Rendering-Index

The ability to replicate the colors of an object as seen under an ideal white-light source, such as the Sun, is another significant parameter. The colour-rendering index (CRI) is calculated from these deviations. The colour of objects with different degrees of perfection, significant with lower CRI that is replicated by other white-light sources. For indoor lighting, values above 80 are usually considered appropriate, whereas lower values are reasonable for outdoor lighting (street lights).[6]

2.2.3 Color Temperature

White light can be categorized as warm, neutral or cold, and is referenced at a certain temperature with respect to the white light produced by an optimal source of white light, such as blackbody radiation sources such as the Sun or a body. The emitted white light goes from reddish (warm) to bluish as the temperature of an ideal black body is increased from 2,000 K to 10,000 K (cold).[6] Actually, LEDs can be engineered from warm to cold (2,500 K to 10,000 K), but there is a need to consider cost and performance factors.[6] Incandescent bulbs usually shine a bright yellowish white without filters. Fluorescent lights are normally bluish, but their color has been forced into a warmer, yellowish white by recent phosphorous engineering.

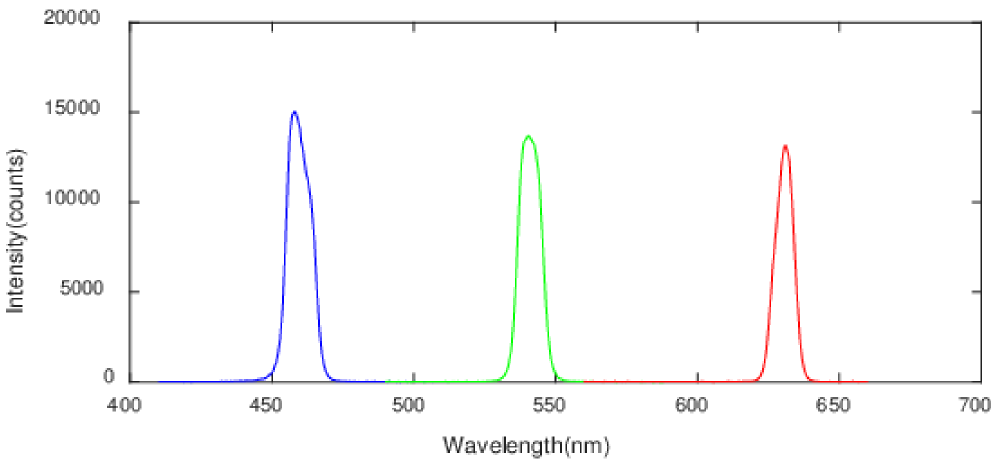

Figure 2.1 Wavelength of Red, Blue and Green LED

2.3 Photodiode

The photodiode is the passive componeent that consist of two terminals that measures light in the form of electricity. The basic configuration of the photodiode is similar to the simple PN interface diode, but intended to react to light. As mentioned above, the PN intersection is light-sensitive so that the photodiode's PN intersection is lighted, the transparent window is shielded so that the light reaches the PN intersection with photography. The photodiodes have an extremely slow response to improve the response time, so most photodiodes have now come with a PIN interface rather than with a PN interface.

With reverse bias, photodetectors (photodiodes) are widely used. The current voltage dependence (I-V characteristics) of the photodiode is the same in the dark as the characteristics of the rectifier diodes.[7] In that case, just the leakage current flows through the photodiode. The photon energy is used to break the electron-releasing covalent bond and create a hole in the process if the photodiode is subjected to light impact. If in the depletion zone, electrons and holes have been formed, then the current electric field eliminates them from the area until they have a chance to recombine.[7] As a result, the opposite current (photocurrent) appears. In proportion to light intensity, the photocurrent increases. Photocurrent does not depend on the applied voltage for larger reverse bias voltage values, but is practically constant.[7]

The photocurrent is limited by the intensity of producing electron-hole pairs under the influence of light. With the increase in the strength of light, the amount of electron-hole pairs created only increases. Also, the number of collisions of electrons with phonons in the semiconductor crystal lattice increases at the higher reverse bias voltage, since the speed of lateral motion of charge carriers depends less on the electric field.[7] The velocity of moving carriers through the crystal is minimal. The further raising of the electric field would not increase the speed of directional motion of the carriers, but rather the kinetic energy of the carriers as the full speed is achieved by the traveling carriers. This means that for the voltage at which the photodiode is connected to be constant, it is not necessary. The current that passes through the photodiode would be constant if the voltage is DC and the RMS is sufficiently high.[7]

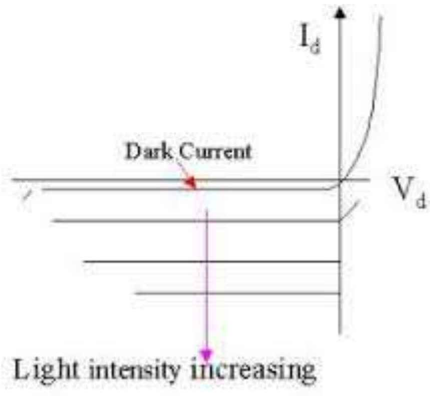

Figure 2.2 Photodiode reverse biased characteristics

Figure 2.3 Photodiode

2.4 Arduino UNO R3

Focused on easy-to-use hardware and software, Arduino is an open-source electronics platform. Arduino boards are able to read inputs - light on a sensor, a finger on a button, activating a motor, turning on an LED, or publishing something online. We can manage what to do on our board by sending a series of instructions on the board to the microcontroller. We use the Arduino programming language (based on wiring) and Processing-based Arduino Software (IDE) to do so.

The Arduino board gradually evolved to adapt to new demands and problems as soon as it entered a broader audience, differentiating its offer from basic 8-bit boards to IoT app products, wearable, 3D printing, and embedded environments. All Arduino boards are entirely open-source, enabling users to independently develop them and ultimately customize them to their individual needs.[8]

There are many other physical computing microcontrollers and microcontroller platforms accessible. Similar functionality is supported by Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard and many others. The messy specifics of microcontroller programming are taken from all these tools and wrapped in an easy-to-use box.[8] Arduino also simplifies the process of working with microcontrollers, but it provides some benefit over other systems, such as inexpensive, requires basic programming and is an open source for instructors, students, and interested amateurs.[8]

Moreover, The Arduino UNO R3 module, the most commonly used variant of Arduino controllers, has been chosen as the controller. Running on an ATmega328 microcontroller, Arduino UNO R3 has 14 digital I/O ports (6 of which support 8-bit PWM modulation mode), 6 analog inputs, 16 MHz clock frequency, USB port, power connector, in-circuit programming port, reset button. It is possible to use each of the 14 digital outputs as an output or input. At the terminals, the voltage level is 5 V. It is recommended to restrict the output and input of each output to 20 mA. This parameter's maximum value is 40 mA. With a resistance of 20-50 k, each output has an internal tensile resistor.

Figure 2.4 Arduino Uno R3 and its parameters

2.5 Refractive Index

The refractive index is also known as the ratio between speed of light travels in vacuum and the speed of light in medium. The speed of light of a medium is depends on its properties. As in electromagnetic waves, optical density of the medium is related to the speed of the medium.[9] Optical density is the propensity to recover the absorbed electromagnetic energy of the atoms in a substance. The more the thickness of the medium, the slower the speed of light. The refractive index is such measure of the optical density of a medium.[9]

The velocity of light in the vacuum, divided by the velocity of light in the medium, is the refractive index, defined by the symbol n. The Refractive Index formula is as follows:

$$n = \frac{c}{v}$$

Where,

- n is the refractive index
- c is the velocity of light in vacuum which is $3 \times 10^8 ms$
- v is the velocity of light in a substance

There is a refractive index of 1 in the vacuum. From the equation above, you can determine the refractive index of other materials. The greater the refractive index, the optical density will also be greater, thus the slower the speed of light.[9] A refractive index for various media is shown in the table below:

Table 2.1 Example of materials and its Refractive Index

Material	Refractive Index
Air	1.0003
Water	1.333
Diamond	2.417
Ice	1.31
Ethyl Alcohol	1.36

On the other hand, the effects of the refractive index of resin on the light extraction output of LEDs has been extensively studied by various researchers. To improve the absorption of light from LED packets, it is important to decrease the refractive index gap between the encapsulant and phosphorus. The critical angle of complete internal reflection is roughly 56° for a phosphor/epoxy interface.[9]

2.5.1 Angle of incidence

The angle formed between the normal and the incident rays at the point of incidence is referred to as the incidence angle. The angle of incidence, by the law of reflection, equals as reflected angle.[10] The angle of incidence and the angle of reflection are both the same and the two are on the same plane.

As light with distinct densities moves from different velocity which also experienced different refractive index, the direction is deviated.[10] This phenomenon is called the refraction of light. The angle of incidence is formed between the incident ray and the normal line of the plane. The angle that lies between the refracted ray and normal line is called as the angle of refraction.

Snell's law describes the relationship between the angle of incidence and the angle of refraction. It also states that the ratio of the sine of the angle of refraction and the sine of the angle of incidence is always constant and equal to the ratio of phase velocities of the two mediums which it passes through.[10]

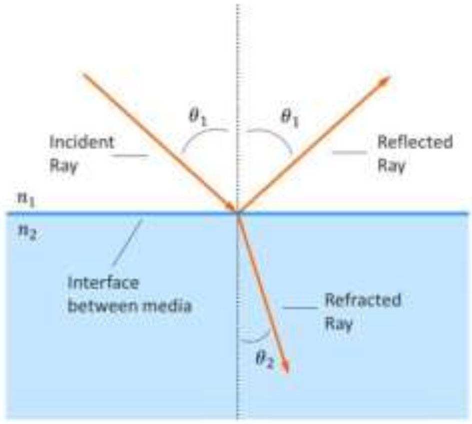

Figure 2.5 Angle of incidence and angle of refraction

2.5.2 Critical Angle

Total internal reflection is a total reflection in a medium of a ray of light such as water or glass back into the medium from the surrounding surfaces. It only happens if any of the two conditions are met. First, a light ray is in the more dense medium and approaching the less dense medium. Second, the angle of incidence for the light ray is greater than the so-called critical angle.[11]

The critical angle is the angle of incidence beyond which rays of light are no longer refracted, but fully reflected, moving through a denser medium to the surface of a less dense medium. It is the smallest incidence angle that produces total reflection.[11]

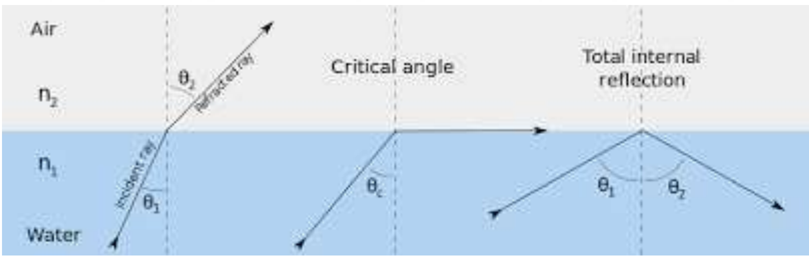

Figure 2.6 Graphical representation of Critical Angle and Total Internal Reflection

2.6 Acetone

Acetone is also known as propanone as a naturally occurring chemical. Consisting of the carbon, hydrogen and oxygen components, acetone is a very flammable, transparent liquid which typically serves as cleaning in industrial environments.[12] It is found in volcanic gases, plants, forest fire leftovers, and the body fat decomposition. Acetone evaporates quickly and, whilst being produced in kind, it is manually produced for commercial purposes in order to produce the compound element (CH3)2CO that we refer to as acetone by joining three carbon atoms with six hydrogen atoms and one oxygen atom.[12]

Acetone is classified as ketone comprising organic carbonyl contained in the group of two hydrocarbons. Acetone has a carbonyl group, which is regarded as the simplest ketone, with carbon and oxygen linked to each other in two bonds.[13] Since acetone is organic as well as untoxic, various goods are utilised every day when handled correctly. Acetone is the principal element in a paint thinner used to remove glucose or resin as a solvent in a variety of cosmetics and facial treatments as well as a cleansing agent. Acetone is also utilised as a gasoline additive which reduces the gas that allows it to more easily diffuse via the motor, leading to greater fuel economy.[14]

In 1897 Geelmuyden and Nebelthau established quantitative methods for measuring acetone in Germany, and by 1898 Muller had reported a methodology suited for the breath acetone measurement of diabetes-patients. Acetone is a high-performing and flexible chemical solvent utilised in various industries, including industrial manufacturing.[13]

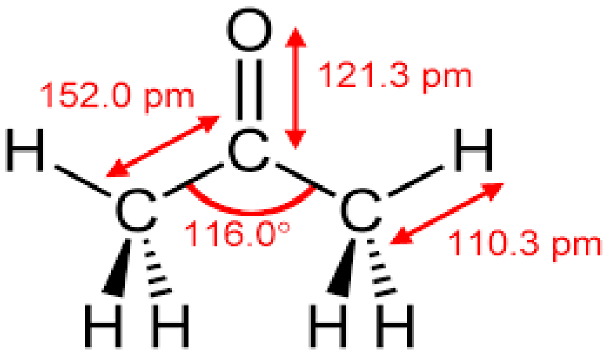

Figure 2.7 Lewis Structure of Acetone