MATEC Web of Conferences **97**, 01109 (2017) DOI: 10.1051/matecconf/20179701109
ETIC 2016

Development of Acetone Liquid Concentration Detection Sensor by Using Fiber Optic for Diabetic Level Detection

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Abstract. The design of current fiber optic sensor technology especially when related to the chemical still requires a certain degree of the quantitative reliability. The acetone is one of chemical found in the bodily fluid for diabetic person and it would be obvious during fasting. The acetone level could be monitored which is indicate the severity of the diabetes. In this experiment, 4 samples of acetone are used with different concentrations between 20% until 80%. It is represented four different level of diabetic. Fiber optic would be dipped in every concentration before measuring process. Each concentration presented in different line graph and analyze for sensitivity value using statistical method. By using 1550nm wavelength of light source, the maximum sensitivity of 1.064 is obtained at second slope for 40% of concentration, respectively. This is showed that fiber optic sensor could be use as diabetic level sensor. However this sensor would be in high performance at 40% concentration of acetone.

1 Introduction

In recent years, fiber optic sensor received more considerable research efforts as the need for more sensitive and reliable sensors to measure a large of physical, chemical and biomedical quantities [1 – 5]. These research efforts are done due to the fact that fiber optic sensor has a potential sensitivity, detection speed and abilities to the widely assay condition [6]. Acetone is an organic compound with the formula $(CH_3)CO$. It is a colorless, volatile, flammable liquid, and is the simplest ketone. The term was named by IUPAC (International Union of Pure and Applied Chemistry) which 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. Measurement of ketone in urine and blood are widely used in the management of patients with diabetes as adjuncts for both diagnosis and ongoing

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monitoring of Diabetic Ketoacidosis (DKA). Overall this project is mainly focusing on the fiber optic sensor of acetone detection development.

A precise and highly sensitive sensor is highly preferred when it's come to measurement and analysis a chemical substance. In medical laboratories for example, a blood sample is obtained from a diabetic ketoacidosis patient and thus it requires accurate and precise acetone concentration information for further evaluation. Various kind of sensor has been developed nowadays. In general, the chemical sensors are broadly classified into gas, liquid, and solid particulate sensors based on phases of the analyte. They can be further categorized as optical, electrochemical, thermometric, and gravimetric sensor according to the operation principle of the transducer. The design of chemical sensor also requires appreciation of needed degree of quantitative reliability (precession and accuracy). An electrochemical sensor for example, has been also introduced to determine the chemical concentration. Nonetheless, a cross sensitivity could happen because of the chemical that is used might require a very active working electrode catalyst and high operating potential for its oxidation. In this case a chemical substance which is more easily oxidized such as alcohol and carbon monoxide could interference the sensitivity of the sensor. Thus, this fiber optic sensor in purposed to overcome these problems.

2 Experiment setup

The experiment setup show in Fig. 1, consist of light source, a silicon detector and lock-in amplifier. A fiber-optic cable is used as a main component in this experiment. It would be connected to be a transmitting and receiving fiber which is made from plastic material with 0.25 of core diameter and have a NA of 0.35. The end of each fiber-optic cable is connected to the light source and silicon detector using pig-tail connector. The middle of the fiber-optic cable would be scraped from its cladding and be used as a tasted area. This experiment used the light source of 1550 nm. The tasted fiber-optic cable is positioned in the middle and will be immersed in the container full with acetone liquid for every experiment. Three different acetone concentrations are used and only one of concentration value is used for every session. The fiber-optic would be undergo immersing process which is take 2 to 30 minutes of duration time, in a way to reinsure that all the results taken would be same and accurate. This will contribute to have accurate results. There are 15 values of final voltage output be taken for every 2 minutes time interval. The fiber-optic cable would be taken out from the container and be cleaned after finished.

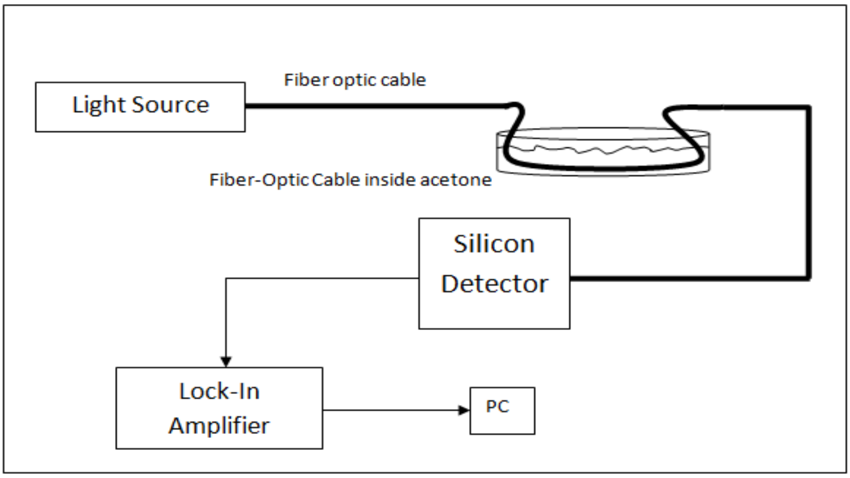

Fig. 1. Schematic diagram of the proposed fiber-optic sensor

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The modulated light source is transmitted inside fiber-optic cable through pig-tail connection until the end of connection. At the olive oil liquid container, this light source would experience uneven transmission and some of the light particle will be lost. Each of concentrations used will produce different final results. The light source reached inside silicon detector and be filtered before regenerated inside lock in amplifier which then translate the result into decibel (dB) numbers. A lock-in amplifier is connected with the detector to reduce the dc drift voltage due to an ambient light.

The experiment begins with the soaking process of fiber-optic cable inside olive oil liquid for more than 2 minutes. The result will be taken since that moment until the time reached 30 minutes in total. The soaking process is importance which is to ensure olive oil particle would folded around microfiber which than producing differences in final result.

By the time experiment conducted, there are several situation would happen which influence the final result. One of uneven situation could be thermal noise which is normally caused by equipment used or certain unpredictable circumstances. An action should be considered to overcome this matter such as by repeating the same experiment more than once in different atmospheres. However, this would not reduce thermal noise disturb, but it could help to get batter result. Consideration to use Continuous Wavelet Transform off-line technique to de-noise during data collection also could help to reduce uncertainty during data collection.

3 Results and discussion

Fig. 2 shows the output power value collected for different concentrations of acetone in 30 minutes time durations. There are 15 collections of data which represented 2 minutes time interval to complete 30 minutes in overall. The date collected in 15 output power value. During experiment, fiber optic sensor would be disregarded in acetone with different concentration for 30 minute. The result will be taken every 2 minutes. This step would be handled carefully because of time consummation which is too short.

This experiment started with 20% concentration of acetone and ended with 80% concentration. As overall, each grafts showed different pattern. For concentrations between 20% and 40%, it showed the same pattern which is increase at beginning and finally became constant until the end. However, for concentration of 60% and 80%, the graft started increased at early stage and finally decreased until final. The pattern which is not same for these grafts became the main reason to separate the graft into two slopes for sensitivity analysis.

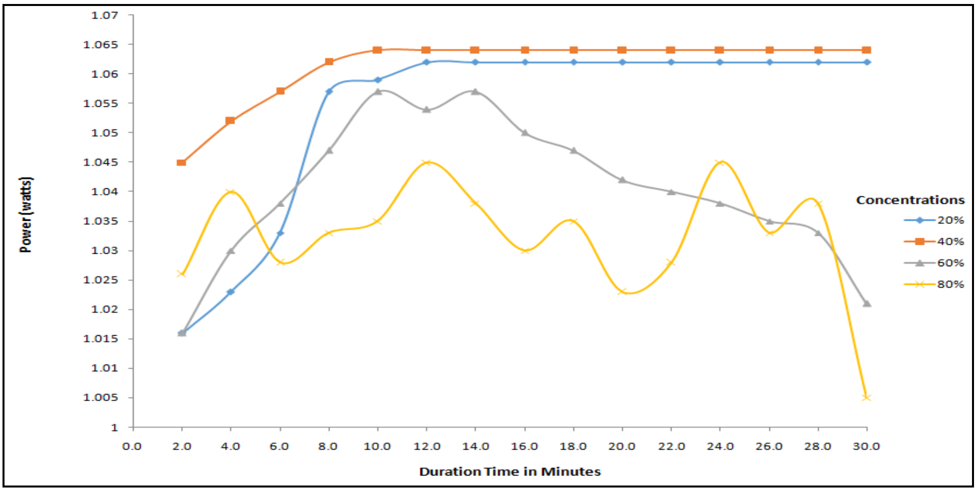

Fig. 2. Fiber-optic sensor responses to different value of olive oil concentrations in time duration

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The analysis of these slopes recorded in Table.1. The graft divided into 2 different slopes which is the first slope is between 2 minutes until 14 minutes time interval and the second slope is between 16 minutes up to 30 minutes time interval. This separation would help to understand the pattern of the graft and easy for linearity analysis. The concentrations of acetone are 20%, 40%, 60% and 80% only. Due to the liquid analysis using fiber optic, these ranges of concentration is the best to produce accurate result [6].

The first concentration used is 20%, which is showed highest sensitivity value 0.008. However, sensitivity value decreased when the concentration changed to 40% and remained the same for concentration 60%, which is 0.003. Sensitivity value dropped to 0.001 for 80% concentration. In the second slope, the trend showed as same as before, which is decreased when the concentration of acetone is increase. Started from 20% concentration, sensitivity value is 1.062. However, sensitivity value was increasing a little to be 1.064 when the concentration changed to 40%. The sensitivity value only reached 0.003 for 60% and 0.001 for 80% concentration. From the overall results, light source of 1550nm showed highest sensitivity which is 1.064 for 40% concentration, which is almost perfect. In other words, in every changes of time would definitely affect the output power value. This is due to the natural behavior of liquid with low concentration contained active particles which is affecting the final result.

4 Conclusion

Fiber-optic sensor experimentally demonstrated experimentally using intensity modulation technique in different concentrations of liquid. At the end of this experiment, results show variation value of power output for each of different concentrations. The result could be observed in the graft which contains two different slopes in power response. In this experiment, the liquid concentrations sensing in the range of 4 different acetone concentrations using 1550nm wavelength for the main input light sources. The sensitivity and linearity are totally depends on these concentration, condition of fiber-optic and light sources. With the 1550nm light source, the maximum sensitivity of 1.064 had been obtained in second slope of fiber-optic sensor with 40% of concentration, respectively. This is an evidence that fiber optic could be a sensor for acetone level monitoring for diabetic purpose. Fiber optic sensor would be in high performance condition at 40% of acetone concentration. The development of fiber optic sensor on acetone detection could be a milestone in the health and sensor field.

Table 1. Summary of the performance for the fiber-optic sensor.

Concentration of Acetone (%)	Sensitivity of the 1st Slope (watt/min)	Linear range (minutes)	Sensitivity of the 2nd Slope (watt/min)	Linear range (minutes)
20%	0.008	2 ~ 14	1.062	16 ~ 30
40%	0.003	2 ~ 14	1.064	16 ~ 30
60%	0.003	2 ~ 14	0.003	16 ~ 30
80%	0.001	2 ~ 14	0.001	16 ~ 30

Our appreciations and gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing the necessity in completing this project. This work was financially supported by UTeM short term grants

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PJP/2015/FTK(25B)/S01446. To our group members for their great teamwork and our family and friends whom without their support this project would not be a success.

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