A NON-INVASIVE BLOOD GLUCOSE MONITORING DEVICE USING RED LASER LIGHT

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Abstract - *In those days, the blood glucose monitoring (BGM) techniques are invasive which require a blood sample of the diabetic patient that creates the risk of infection. But it is essential to avoid complications arising due to abnormal blood glucose levels in diabetic patients. This paved the proposed system to develop a non invasive monitoring technique. In this paper, the blood glucose level is non invasively measured by passing the suitable wavelength of red laser light through human finger. The 650nm wavelength of red laser is passed to the human finger which analyze the transmitted and absorbed blood samples to determine the glucose level (mg/lit). In this proposed method, the mathematical equation is derived to calculate the glucose level from the obtained voltage level. The corresponding values are investigated to determine the glucose level in blood. The hardware implementation of this blood glucose monitoring device is designed and the glucose level is calculated by deriving the mathematical equations.*

Key Words: **Non invasive, Red laser, Blood glucose monitoring, Phototransistor, Ardiuno.**

1. INTRODUCTION

Diabetes Mellitus is one of the common life threatening diseases in the world. Diabetes in general is known to increase blood glucose concentration which further introduces variations in the individual's metabolic pathways. The change in metabolism affects directly or indirectly the electrochemistry of various body fluids such as saliva, urine and tears. According to the recent report by Indian Diabetic Federation, 382 million people were found to be diabetic in the year 2013. Malaysia is ranked 10th in the world with the highest number of population with diabetes (World Health Organization, (WHO), 2013). The main cause of diabetes mellitus is still unrevealed, but it is closely related to body weight, gender, diet, genetic and physical activities. The effects of diabetes can only be seen between six (6) to twelve (12) months after having continuous high level of glucose in blood, which can further lead to other major health problems such as kidney failure, heart disease, blindness, stroke and neuropathy.

Glucometer is working on the principle of electrochemical detection. The major drawback associated with this kind of disease is blood dependency, which makes it an invasive approach and also increases the risk of infection for the patient. In order to reduce the discomfort to the patient various methods on non invasive approach is used such as reverse iontophoresis, bioimpedance spectrocopy, absorption spectroscopy, flourescence spectroscopy, electromagnetic sensing, polarimetry, raman spectroscopy and thermal emission spectrocopy to measure blood glucose. Increase in signal to noise ratio is the major concern for all non-invasive monitoring.

This work is designed by determining the microprocessor based application of glucose monitoring system. In those days, glucose levels can be monitored by GBP coated sensors such as on-body CGM devices. CGM devices typically have glucose sensors including a needle or probe that is inserted into the tissue of a user to measure the glucose levels in the surrounding tissue fluid. This monitoring is also done by the designing of detection blood glucose levels in non-invasive based Microcontroller. But the major drawback in testing blood glucose levels is still using invasive technique shot with a patient's blood using a syringe. In addition, the result of such testing requires a long time (± 2 hours).

The main objective of this project is to design a portable non-invasive blood glucose monitoring device. The device should be able to detect glucose level in blood using red laser. In addition, it can determine glucose level and displaying the glucose level on the LCD screen.

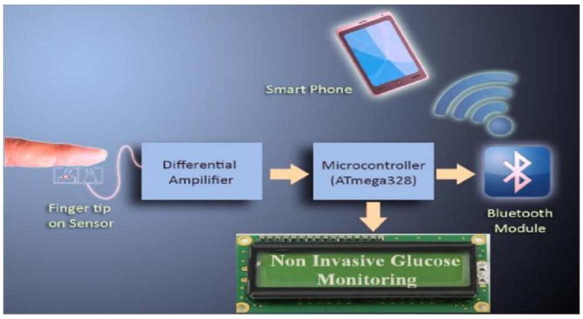

Fig -1: Proposed system Architecture

The continuous monitoring of this blood glucose level is done in non invasive technique using red laser light transmittance and absorbance. Hence, analysis performed to detect and an early checks aims to avoid blindness and mortality due to diabetes mellitus.

1.1 Problem Description

Diabetes is a metabolic disorder that threatens human at every age. It occurs not only among adults and elderly, but also among children and infants. The most common and simple measurement techniques used are invasive or minimally invasive techniques. These techniques have high accuracy measurement but are painful and has a high risk of infections such as thrombosis. Non-invasive techniques has are proposed as an alternative for pain free glucose measurements. But this process is computationally complex and requires more number of data samples.

1.2 Literature Survey

Schichiri et al.(1985) were the first to introduce the minimally invasive technique by the development of subcutaneously implantable needle-type electrodes. The used of subcutaneous implantation technique able to avoid infection problems such as septicaemia, fouling with blood clots, and embolism. They have designed a glucose sensor with a fine needle, or flexible wire and the active sensing element is implemented on the tip of it and implanted in the subcutaneous tissue. Nowadays, there are various types of continuous glucose monitoring systems which has been commercialized. Example of such systems may be using electrochemical detection or and optical detection of glucose oxidase to measure glucose in blood.

Medtronic MiniMed Inc has introduced a latest continuous glucose monitoring system, which uses electrochemical detection of glucose in blood. To measure the glucose levels in a tissue fluid, a glucose sensor in the form of a tiny electrode is inserted under the skin and connected to the transmitter. The transmitter will send the signal through wireless radio frequency to a monitoring and display device. Afterwards, the device will detect and notify the patient if their glucose level is less or more than the normal range. The advantage of the system is it is able to continuously measure glucose levels in real time throughout the day and night.

Another approach using electrochemical detection is proposed by Jui et al.(2011). The application uses an electrochemical sensor which consists of a potentiostat with a glucose test strip and an automatic test system. In 2006, Dachao Li et al.(2006) from has proposed a new approach using ultrasonic. They have combined the interstitial fluid transdermal extraction with the surface of plasma resonance detecting. Both results showed that the techniques used are able to measure the glucose concentration in blood the blood accurately.

2. METHODOLOGY

Glucose molecules have the ability to vary the refractive angle of light to an extent proportional to its concentration, and the overall refractive index of a given media. Refraction based estimation is based on the principle of Snell's law and the magnitude of each parameter is related to the concentration of glucose in the aqueous solution. According to Snell's law, the refractive angle is inversely proportional to the concentration of glucose in aqueous sample. The light ray (ab) in Fig. 2 tends to incline towards the normal ac and decreases the refractive angle ($\theta 2$) as the glucose concentration increases hence more photons strike the photo-transistor.

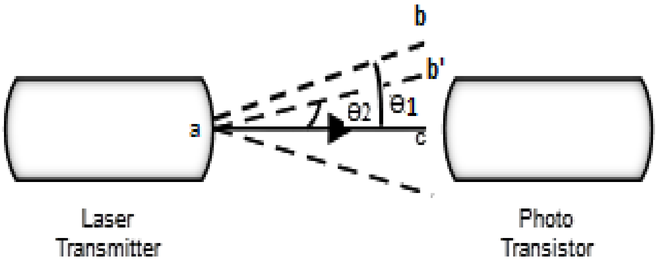

Fig -2: Refractive angle decreases with the increase in glucose concentration

In this proposed work, blood glucose level is measured using the non invasive technique, this can be done by the transmittance and absorbance of the red laser light. That is, the laser light is passed to the finger end and it gets reflected. The reflected light wave is emitted on the photo transistor and it results in voltage output. The outcome voltage value depends on the intensity of the blood.

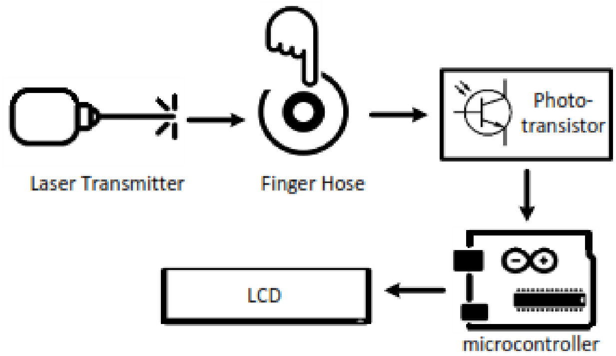

Fig -3: Experimental set up of the glucose monitoring device.

2.1 Formula

$$\text{Error \%} = \frac{\text{IV (mg/dL)} - \text{NIV (mg/dL)}}{\text{IV (mg/dL)}} \times 100$$

2.2 Hardware Implementation

Compact hardware is designed and fabricated for the proposed for non invasive technique. The main components of the proposed system are laser transmitter and phototransistor. The transmitter connected with +5V DC generates 650 nm laser light using KY-008.

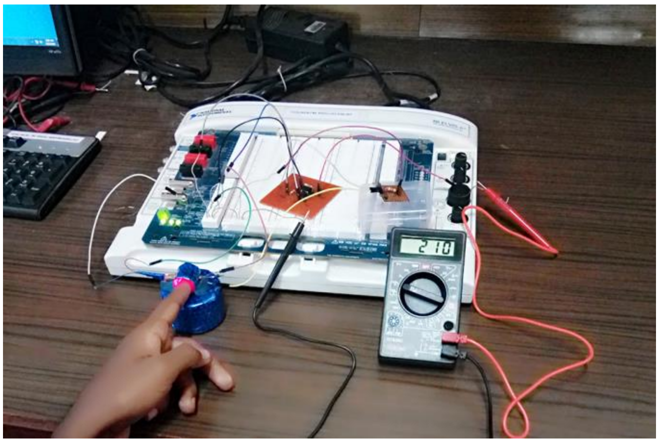

Fig -4: Transmitter and receiver set up of the glucose monitoring device

The photo-sensor has wavelength sensitivity of 600 nm to 800 nm and detects the laser light passed through glucose sample to convert the optical energy into electrical energy. The output voltage detected by the photo-sensor depends on the intensity of the received laser light. The photo-sensor is actually a photo-transistor, connected with two OP-AMP 741 ICs. before and after the buffer to provide actual DC input to the voltmeter and LCD.

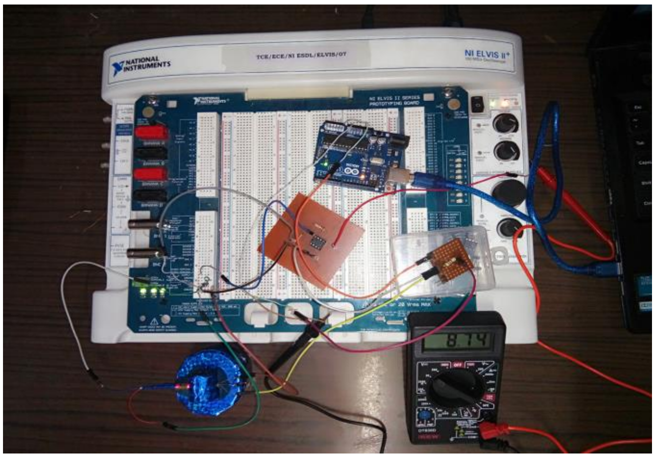

Fig -5: The portable non-invasive glucose monitoring device

Fig -6: Glucose concentration

Other elements of the red laser blood glucose monitoring are Arduino-UNO microcontroller, connected with PC to display the output voltage. The suitable wavelength for BGM is determined experimentally by measuring the transmittance and absorbance of different wavelengths of light ranging from 500 nm to 1200 nm. The light is passed through the human finger. The highest absorbance is of NIR of wavelengths from 700 nm to 1000 nm making it the least suitable for BGM applications. Red laser light of 650 nm has the capability of penetrating into the water and the human finger as it has the highest % transmittance as compared to other wavelengths.

3. RESULT

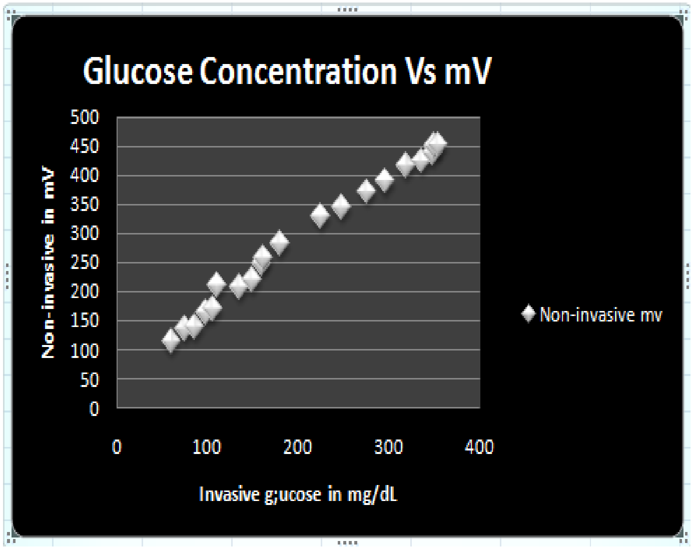

Chart -1: Relationship between glucose concentration (mg/dL) and voltage (mV)

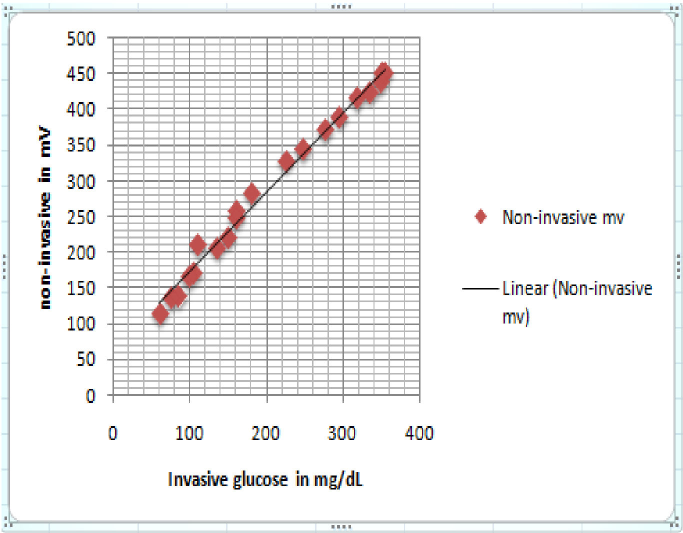

Chart -2: linear description of mg/dL and mV

Table -1: Comparison table for invasive and non invasive glucose concentration measurement.

S.no	Glucose concentration measurement		Non invasive (mg/dL)	Error %
	Invasive (mg/dL)	Non invasive (mV)		
1.	60	114	56.68	5.53
2.	75	135.56	75.24	0.32
3.	85	138.03	77.32	9.03
4.	98	164.4	99.97	1.97
5.	105	170.66	105.35	2.01
6.	110	210	139.14	0.33
7.	149	221	148.59	0.66
8.	160	248	171.78	0.27
9.	161	256	180.37	7.36
10.	180	282.6	201.51	12.62
11.	247	344	254.25	2.9
12.	276	371	240.33	12.92
13.	295	389.5	293.33	0.56

4. CONCLUSIONS

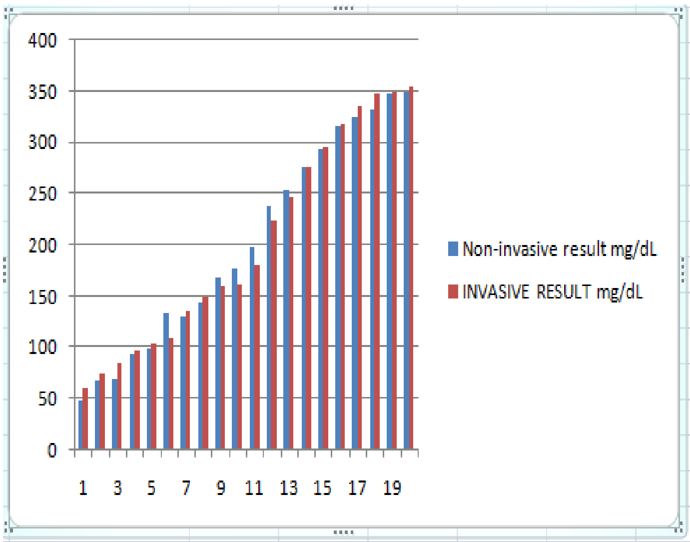

Chart -3: Comparison with the invasive and Non invasive

Thus the design of blood glucose monitoring device is implemented and tested successfully. The glucose concentration for different patients are measured using the detection sensor. It was developed by the laser light of wavelength 650nm and photo transistor. The Aurduino microcontroller is used to control the operation. Hence the glucose level is tested and the value (mg/dL) is displayed.

REFERENCES

[1] “Diabetes Information Sheet (English)" in Translated Resources for the Management of Diabetes, National Diabetes Service Scheme, Diabetes Australia

[2] F. Chee and T. Fernando, Closed-Loop Control of Blood Glucose, ed. New York: Springer. 2007

[3] V. V. Tuchin, Handbook of Optical Sensing of Glucose in Biological Fluids and Tissues. New York: CRC Press, 2008

[4] M. Shichiri, Y. Yamasaki, R. Kawamori, N. Hakui and H. Abe, "Wearable Artificial Endocrine Pancreas With Needle-Type Glucose Sensor", The Lancet, vol. 320, no. 8308, pp. 1129–1131, 1982 st969

[5] J. Lai, H. Wu, H. Chang, and R. Chen ,"Design a Portable BioSensing System for Glucose Measurement", In the IEEE International Conference On Complex, Intelligent And Software Intensive Systems (CISIS),Seoul,Korea,2011,pp.71–76.

[6] D. Li, X. Huang, H. Yu, Z. Zhang, F. Huang, K. Xu, and X. Hu, "A Novel Minimally Invasive Method to Detect Glucose Concentration without Blood Extraction, in the IEEE International Conference on Nano/Micro Engineered and Molecular Systems, Zhuhai, 2006, pp.1185–1189.

[7] S. K. Vashist , " Non-invasive Glucose Monitoring Technology in Diabetes Management_: A Review", Anal. Chim. Acta, vol. 750, pp. 16–27, 2012

[8] O. Olarte, J. Chilo, J. Pelegri-Sebastia, K. Barbe and W. Van Moer "Glucose Detection in Human Sweat Using an Electronic Nose", in the IEEE 35th Annual Engineering in Medicine and Biology Society (EMBC),Osaka, 2013, pp. 1462–1465.

[9] A. Ergin and G. A. Thomas , "Non-Invasive Detection of Glucose in Porcine Eyes" in the IEEE 31stAnnual Northeast Bioengineering Conference, 2005, .pp. 2–3.

[10] C. E. F. do Amaral and B. Wolf , "Current Development in NonInvasive Glucose Monitoring",Medical. Engineering & Physics,vol.30,no.5,pp.541–549,2008

[11] Dino Sia, "Design of a Near-Infrared Device for the Study of Glucose Concentration Measurements", Undergrduate dissertation, MacMaster University, 2010.

[12] I. Gabriely, R. Woznial, M. Mevorach, J. Kaplan, Y. Aharon and H.Shamoon, "Transcutaneous Glucose Measurement Using Near Infrared Spectroscopy During Hypoglycemia", Diabetes Care. vol. 22, no. 12, pp. 2026-2032, 1999.

[13] K. Maruo, M.Tsurugi, J.Chin, T.Ota, H.Arimoto, Y.Yamada, M. Tamura, M. Ishii and Y.Ozaki, "Noninvasive Blood Glucose Assay Using a Newly Developed Near-Infrared

System", IEEE Journal of Quantum Electronics, vol. 9, no. 2, pp. 322–330, 2003

[14] Barnard, Karen, Bryan C. Batch, and Lillian F. Lien. "Subcutaneous Insulin: A Guide for Dosing Regimens in the Hospital." Glycemic Control in the Hospitalized Patient. Springer New York, 2011. 7-16.

[15] A. Duncan and J. Hannigan, "A Portable Non-Invasive Blood Glucose Monitor", Solid-State Sensors.pp. 455–458, 1995.

[16] J.R. Blanco, F. J. Ferrero, J. C. Campo, J.C Anton, J.M.Pingaron, A. J Reviejo, J. Manso, "Design of a Low-Cost Portable Potentiostat for Amperometric Biosensors", IEEE Instrumentation and Measurement Technology Conference, Sorrento, 2006, pp. 690–694.

[17] M. Takahashi, Y. J. Heo, T, Kawanishi, T. Okitsu and S. Takeuchi, "Portable Continuous Glucose Monitoring Systems with Implantable Fluorescent Hydrogel Microfibers." IEEE 26 International Conference on Micro Electro Mechanical Systems (MEMS), Taipei, 2013, 1089-1092

[18] A. Tura, A. Maran, and G. Pacini, "Non-invasive glucose monitoring: Assessment of technologies and devices according to quantitave quantitative criteria," Diabetes Research and Clinical Practice, vol.77,no.1,pp.16–40,Jul.2007