Blood Glucose Monitoring Device using Red Laser Light

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1- ***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 ,Laser transmitter,Light dependent resistor, Arduino,optical density.

2-INTRODUCTION:

Continuous monitoring of blood sugar level is highly required for efficient management of diabetes mellitus. The existing “finger piercing” method, which measures the glucose level from blood sampling, is not practical for continuous measurement as it is painful. As technology grew vast world shrunk and our lives became easier then evolved non invasive methods allowing more frequent and even continuous measurement without any pain and bleeding. Many non-invasive glucose monitoring concepts were proposed and reported to have acceptable accuracy, few devices have even became saleable products. Nevertheless, none of them is yet successful due to their poor accuracy from systemic noises in practical environment or clinical applications one major challenge in non invasive glucose monitoring system is to achieve low noise in noisy environment.

So, developing a noninvasive way of measuring blood glucose would be much more user friendly from the end user. The main advantage of noninvasive methods is the aid from pain and malaise due to frequent finger pricks. Noninvasive determination of the glucose reduces all the above difficulties involved and hence reduces the healthcare cost. The method proposed, makes use of the difference in voltage measured in both the before and after occlusion condition of the received signal from the laser transmitter, to detect whether the patient is diabetic or not along with the approximate glucose level.

A typical forearm skin tissue consists of three layers, i.e., epidermis, dermis, and subcutaneous tissue. The epidermis contains the stratum corneum and capillary vessels are not developed sufficiently in it, which does not contain useful information about blood glucose content. The subcutaneous tissue is mainly composed of fatty tissues. This tissue also does not provide any information about blood glucose content. Whereas on the other hand, there are well-developed capillary vessels in the dermis tissue and blood glucose is easily transferred to the dermis tissue due to its high permeability. Thus, the glucose content in the dermis is assumed to correlate with the blood glucose content in the same way as that in the interstitial fluid. As a result, with the growing concentration of glucose, fewer photons are absorbed and the light intensity increases. The proposed method is based on the principle of absorbance transmittance photometry. Here the value of absorption, of light energy, is dependent on the number of molecules present in the absorbing material. Intensity of light leaving the matter is used as an indication of concentration of that particular matter. According to a survey made by the International Diabetes Fed-eration (IDF) [4], it was estimated that 8.3% of adults (382 million)were suffering from diabetes in 2013, which may rise to 592 millionin 2030. It shows there will be 55% rise in people with diabetes in next 25 years. The number of diabetic people in various regions in2013 by IDF survey is shown in Fig. 1. Poorly managed diabetes leads to serious complications such as cardiovascular diseases, damage of blood vessels, stroke, blindness, chronic kidney failure,nervous system diseases and even amputation of the foot due to ulceration in extreme cases [5–8]. Health spending on diabetes accounted for 10.8% (548 billion USD) of total health expenditure worldwide in 2013.

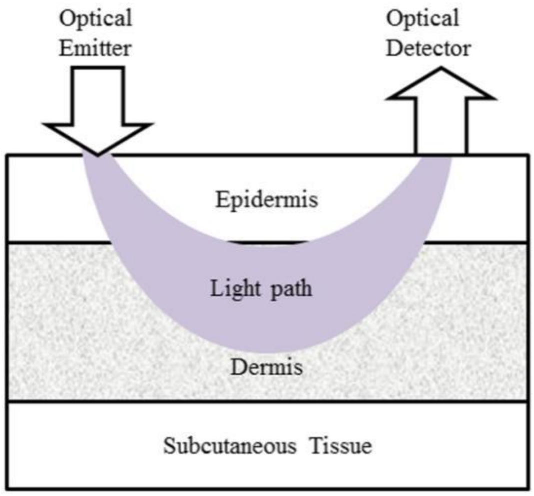


Figure 1:Cross Section of Skin and Light Path

3-Different non invasive techniques:

A. Bio impedance spectroscopy

Bio impedance is a measure of the resistance to electric current flowing through the tissues of a living organism. The measurement of bioelectrical impedance has proved useful as a noninvasive method for measuring body composition. 10 The impedance spectrum, or dielectric spectrum, is measured in the frequency range of 0.1 to 100MHz. According to Hillier et al, 11 variations in plasma glucose concentration induce, in red blood cells, a decrease in sodium ion concentration and an increase in potassium ion concentration. Bio impedance spectroscopy does not require the use of statistically-derived, population specific prediction models .The limitation of this technology is that it requires an equilibration process, wherein the user must rest for 60minutes before starting the measurements.

B. Electromagnetic sensing

Similar to bio impedance spectroscopy, this technology assesses dielectric parameters of blood. The difference between them is that an electric current is used in bio impedance spectroscopy, while the electro magnetic coupling between two inductors is used in electromagnetic sensing. The sensor uses electric currents to detect variation of the dielectric parameters of the blood, which may be caused by glucose concentration changes. The frequency range used in this technique is 2.4–2.9 MHz. Using a specific frequency range can isolate the effect of blood glucose and minimize the characteristics of other substances, such as cholesterol, which might skew readings. Limitation of this method is that Temperature has a strong effect on this form of measurement, because it influences the optimal investigation frequency.

C. Mid infrared spectroscopy

Mid infrared (MIR) spectroscopy employs the same principles as infrared spectroscopy; in other words, it is the absorption measurement of MIR frequency by a sample positioned in the path of an MIR beam. It is based on light in the 2500–25,000 nm region of the spectrum .Absorption differences when MIR light meets human tissues can be represented by certain modeling techniques in spectral quantitative analysis. A partial least squares algorithm is now normally used for multivariate calibration for these constituents. Advantage of MIR spectroscopy is that the response peaks of glucose and other compounds are sharper with MIR than with NIR, where they are often broad and weak.. Poor penetration is the main limitation of MIR

D. Near infrared spectroscopy

Near infrared (NIR) spectroscopy is located in the wavelength region of 730–2500 nm. The principle is similar to that of MIR spectroscopy. NIR spectra are made up of broad bands corresponding to overlapping peaks: the overtones (ie, first, second, third, and combination overtones), formed by molecular vibrations. It allows blood glucose measurement in tissues by variations of light intensity, based on transmittance and reflectance. The high sensitivity of the photoconductive detectors is the main advantage of NIR spectroscopy. Water is reasonably transparent to the signal bandwidth used by NIR, which makes it possible to use for blood glucose monitoring. In addition, the measuring signal has high energy compared with MIR spectroscopy. Perhaps even more important, this method is less expensive than MIR. Materials are relatively low in cost, and there is a wide range of commercial products available. These advantages make NIR popular in this research area. Some issue with this method is despite much promising work, researchers still cannot overcome important shortcomings, in particular, the scanning pressure that must be applied ,physiological differences not related to blood glucose,

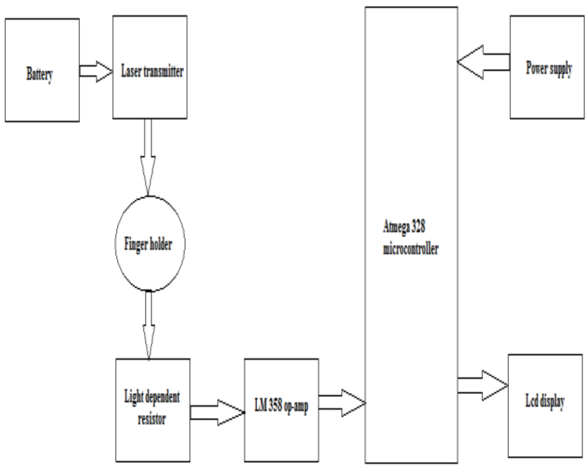
E. Raman spectroscopy

Raman spectroscopy is based on the use of a laser light to in du Raman spectroscopy is based on the use of a laser light to induce oscillation and rotation in human fluids containing glucose. Because the emission of scattered light is influenced by molecular vibration, it is possible to estimate glucose concentration in human fluids.

This effect depends on the concentration of the glucose molecules. This technique can measure very weak signals, even in human fluids. The wavelength range of Raman spectrum is considered to be 200 cm to 2,000 cm .35Raman spectrum of glucose can be differentiated from those of other compounds in this band oscillation and rotation in human fluids containing glucose. Because the emission of scattered light is influenced by molecular vibration, it is possible to estimate glucose concentration in human fluids. This effect depends on the concentration of the glucose molecules. This technique can measure very weak signals, even in human fluids. The wavelength range of Raman spectrum is considered to be 200 cm to 2,000cm. Raman spectrum of glucose can be differentiated from those of other compounds in this band

4-PROPOSED APPROACH:

In this research, the technology is based on the scattering property which has direct effect on glucose . This includes passing a red laser light through the finger and the amount of light present on the other side of the finger is measured. The presence of glucose blocks the light from passing through the finger. The blood glucose present can be measured by analyzing the variations present in the light intensity



4.1: ABSORBANCE AND TRANSMITTANCE:

The optimum wavelength for BGM was determined by passing visible and NIR light starting from 500 nm wavelength to 1200 nm wavelengths through water using a spectrophotometer. The obtained experimental results are expressed in transmittance (T), which shows the ratio of the radiant powers for water sample shown mathematically . The absorbance of each wavelength through the water can be calculated . This experiment was also repeated for the human finger in order to determine the transmittance and optical density (OD). As the Human finger is a complex medium where the striking laser light can possibly reflect, refract, absorb, scatter and transmit depending upon the nature of the light . Wavelengths of laser light from 500 nm to 1200 nm are generated using LEDS of 1.5 watt power (Po) and the generated laser light is passed through the human finger. The transmitted light through the human finger is measured as a ratio between the output power (P) at the phototransistor and the power (Po) when laser light directly falls on the phototransistor, when there is no human finger inserted in the RL-BGM. The transmittance is converted into OD by using and the absorbance can be estimated . OD measures the throughput of the human finger whereas OD is directly related to the transmittance.

$$Transmittance\ (T) = P\ Po$$

Where, P is the radiant power of the rays leaving water or human finger and Po is the radiant power for monochromatic laser light.

$$Absorbance\ (A) = -\,log\ (\%\ T\ 100\ )$$

The transmittance of human finger was measured $T = 10{-}OD$

5-METHODOLOGY:

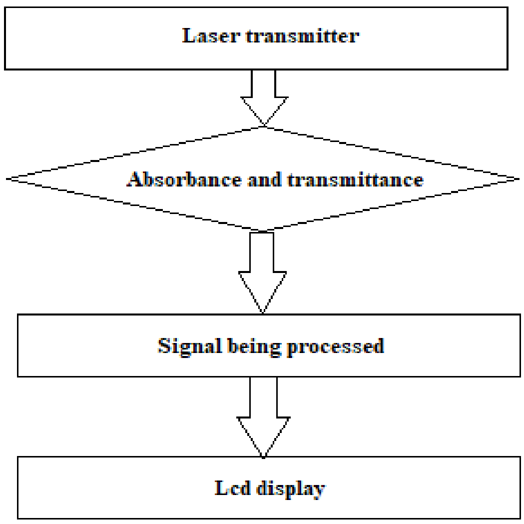


Figure: Flow chart

5.1:SELECTION OF WAVELENGTH:

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.

5.2:HARDWARE DEVELOPMENT:

The main hardware components in the system consists of five parts which includes a transmitter (Laser transmitter),light dependent resistor, ,microcontroller (Arduino Uno), and a liquid crystal display(LCD) keypad shield.

A. Laser module:

The laser module consists of a transmitter and a receiver.Transmitter and receiver positioned side by side and points to a reflective surface. Both transmitter and receiver operate at 5V and are powered by the Arduino microcontroller. The transmitter is an ultra-bright 650nm which emits infrared light with a spectral output.The maximum reversed output voltage is 5V.Receiver circuit consists of a noise filter. A low pass filter is connected to the voltage source to reduce the noise frequency from the source.The laser diode is suitable to be used with the transmitter as It has a wavelength sensitivity which is within 600 nm-750nm.The laser diode is used to measure continuous wave fiber light source and converts the optical power received from the transmitter to an electrical current value . In our work, we convert the electrical current into voltage by placing a load resistor (RL).The value of the output voltage depends on the intensity of the infrared signal it receives, which is between 0V to 5V.Since the output voltages from the receiver are usually less than 1V.

B. Arduino Uno Board:

Arduino Uno is an ATmega328 microcontroller board.There are 14 digital output or input pins. Among which 6 pins are used as Pulse Width Modulator (PWM) outputs. It also consists of 6 analog input pins, a power jack, a 16 MHz ceramic resonator, a USB connector, a reset button and an ICSP header. The board can be powered by AC-to-DC or battery adapter if it is not connected to the computer. The code is uploaded onto the board using USB connector and it also used in testing. The Arduino Uno board operates with 5V. Even So, there commended supply voltage is lies in between 7V to 12V. The input and output pins of this board uses 40mA DC current. It operating clock speed is 16MHz along with flash memory of32KB.

C. Lcd Keypad Shield

The LCD keypad shield, as in Figure 5 is developed to be used with any compatible Arduino boards. It consists of six (6) momentary push buttons and a 2x16 LCD screen. It does not require any soldering, only to be plugged to the main Arduino board. Pin 4 to pin 9 of the main Arduino board is used to control the LCD display, While pin 8 and pin 9 are used for Register Select (RS) and Enable pin. The LCD keypad shield is used to key in the height and weight of the users and also to display the measured glucose concentration and calculated insulin dose needed.

5.3:WAVELENGTH ABSORBANCE AND GLUCOSE CONCENTRATION:

Lower absorbance gives the higher glucose concentration and vice versa. It is understood by the following graph.

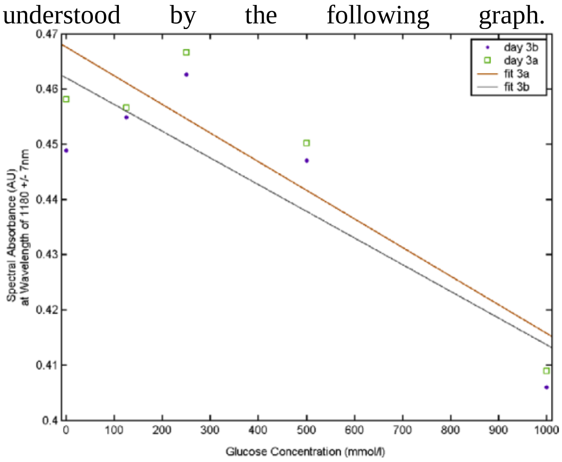


Figure: glucose concentration vs absorbance rate

6-SOFTWARE DEVELOPMENT:

The Arduino Integrated Development Environment (IDE) tool is used in designing the firmware for the device. In our design, we first developed the code using this tool and later we uploaded the code onto the board. The code was developed in such a way that the concentration of glucose level is calculated.

7-RESULTS:

The results that were observed while operating the device are shown below. Initially when we power ON the device LED will being blinking. When the individual finger is placed in the finger holder it will display output voltage. Later it will display glucose concentration level as “Glucose: xx.xx”, after was developed by the laser light of wavelength 650nm and LDR. The Arduino microcontroller is used to control the operation. Hence the glucose level is tested and the value (mg/dL) is displayed. The key challenges that the next generation continuous BGM devices are facing such as operational cost, sensitivity, and accuracy, precision and settling time for the glucose level measurement [7] are addressed in the fabricated RL-BGM device. The RL-BGM device has also exhibited additional practical advantages such as lower response time ~7-10 seconds.

9-FUTURE SCOPE:

There are various approaches that are recommended for future implementation and for the development of this work. Along with that, the infrared light of higher wavelength may lead to highly accurate result as the difference between the voltages will be higher. On conducting additional tests with different concentrations at higher wavelength may result accurate analysis. Besides using the absorbance technique ,the reflection technique should be considered in the design to determine which technique is able to provide a more accurate measurement in glucose detection. Further researches with the help of clinical experts can be conducted to determine the relationship of insulin dose, body mass index, and glucose level in blood using patients as subjects.

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8-CONCLUSION:

Thus the design of blood glucose monitoring device is implemented and tested successfully. The glucose concentration for different patients are measured using the LDR. This research successfully demonstrated the relationship between the output voltage and the glucose concentration, where the output voltage increases as the glucose concentration increases. The proposed noninvasive glucose monitoring system has low manufacturing and maintenance cost and showed good accuracy . Our future work will be also focused to further improving the accuracy and robustness of our device in order to perform real time measure. This would have a great impact on personal health monitoring and recording the history of patients

References:

1) Shirish Mule, Dr.Tabbsum Mujawar, Meghana sambhaji kasbe, “Microcontroller based glucose meter: Design and development”. Article in international journal of engineering science & emerging technologies. March 2016
2) Shyqyri Haxha, Jaspreet Jhoja, “Optical Based Non-invasive Glucose Monitoring Sensor prototype”. 2016.
3) Jonas kottmann, Jlien M.Rey, and Markus W.Sigrist, “Mid infrared Photoacoustic Detection of Glucose in human skin: Towards Non-Invasive Diagnostics. October 2016.
4) M.Vanitha, Glory Mathew, K.S.Divya, R.Vignesh, “ Non-Invasive glucose Estimation Using IR Spectroscopy” May 2016.
5) Jyoti Yadev, Asha Rani, Vijander singh, Bhaskar Mohan Muraru, “Prospects and limitation of non-invasive blood glucose monitoring using near-infrared spectroscopy”. January 2015 .
6) M.Tamilselvi,G.Ramkumar, “Non-invasive tracking and monitoring glucose content using near infrared spectroscopy. 2015.
7) Mohammed Goodarzi, Sandeep Sharma, Herman Ramon, Wouter saeys, “Multivariate calibration of NIR Spectroscopic sensors for continuous glucose monitoring”. December 2014.
8) K A Unnikrishna menon, Deepak Hemachandra, Abishek Thekkeyil Kunnath. “Voltage Intensity Based Non-Invasive blood glocose Monitoring”. July 2013.
9) Sandeep kumar vashist, Dan zheng, Khalid Al-Rubeaan, John H.T.Luong, Fwu-Shan Sheu, “Technology behind commercial device for blood glucose monitoring in diabetes management: A Riview” , July 2011.
10) Boris P.Kovatchev,Linda A.Gonder,Daniel J.Cox,William L.Clarke, “Evaluating the accuracy of continuous glucose monitoring sensors”.2004.