

Design and Development of Non-Invasive Blood Glucose Measurement System using Near Infrared technique

K Sairam¹, Akesh Govada², Dr.CH Renumadhavi³, Dr.B.S.Satyanarayana⁴, Dr. K B Ramesh⁵

M.Tech, Department of Biomedical Signal Processing and Instrumentation^{1,2}

Associate Professor, Department of Electronics and Instrumentation Engineering³

Principal, RVCE⁴

Associate Professor & Head, Department of Electronics and Instrumentation Engineering⁵

Abstract: Diabetes has advanced as one of the foremost medicinal services pandemics of the present day period. At first blood glucose is measured with substance responses, later glucometer is created which can quantify the blood glucose immediately by taking a little drop of blood on the lancet and set on the glucose test strip. Non-obtrusive blood glucose estimation framework is utilized to quantify the blood glucose without taking the blood test. Non-obtrusive routines offer the principle favorable position of help from agony and uneasiness because of regular finger Pricks required for the intrusive examination. Therefore Near infrared beam's (NIR) spectroscopy is utilized which demonstrates that it can be conceivable to quantify glucose focus in blood non-intrusively. This glucose detecting gadget could change diabetes treatment by prompting enhanced agreeability with suggested glucose levels, accordingly diminishing long haul complexities and expense of diabetes. The framework setup is planned by utilizing multisim programming. According to the particulars accessible in the nearby market, a NIR drove working at 2500nm wavelength is decided for transmission of NIR beams and a photograph locator is decided for the gathering with the fingertip as the body site. Simple to advanced change (ADC) is performed to the got signal. PIC 16F877A microcontroller is decided to dissect the glucose values from the separate advanced values and showed in the 16x2 fluid gem show (LCD). The venture work has talked about the noteworthiness of non-obtrusive blood glucose estimation framework. This gadget gives a solid, immediate, financially savvy and agreeable estimation framework for the location of blood glucose fixation without pricking blood.

Keywords: Diabetes, spectroscopy, glucose, non-invasive, Near Infrared light, Voltage Regulator.

I. INTRODUCTION

Diabetes mellitus, generally known as diabetes is a gathering of metabolic infections in which a individual has high glucose [1], [2]. Diabetes is one among the preeminent wellbeing difficulties of the present century. Glucose focus changes in the blood in any bearing i.e. increment alternately diminish in blood glucose focus demonstrates lethal for the patient. The satisfactory extent of glucose fixation is from 70 mg/dL (milligram of glucose in 100 milliliters of blood) to 110 mg/dL or 3.9 to 6.0 mM/L. In any case, not long after in the wake of eating glucose convergance of a man may ascend to a level up to 140 mg/dL [3]. Today more than 366 million individuals live with diabetes in overall and the number is required to increment to 552 million by 2030 [1]. Disregarding advances in diabetic treatment the recurrence of diabetes is expanding at disturbing rates. Subsequently, changes are to be made in the administration of the diabetic control. Real basics for development incorporate self-administration through illness prevention and control. Diabetes thusly prompts real inconveniences including heart disappointment and visual impairment. Powerful

treatment for diabetic patients is to gauge blood glucose levels occasionally. At present the patients are making utilization of the pricking instrument called a glucose meter to know their blood glucose level. Building up a non-obtrusive method would be a great deal more valuable also, easy to understand from the client perspective. The innovations accessible in the Indian showcase today oblige a patient to take blood tests and measure utilizing compound responses which are both agonizing and exorbitant. Thus, there is a need of blood glucose measuring gadget which may give keeps observing of blood glucose fixation noninvasively. The most generally drew nearer routines are by utilizing optical discovery or optical examining strategies. i.e., Near- Infrared (NIR) spectroscopy [1], Raman spectroscopy [4], fluorescence spectroscopy [5], photograph acoustic spectroscopy, Mid-Infrared (MIR) spectroscopy [6] and optical rationality tomography [7] utilizing an Attenuated Absolute Reflection (ATR) crystal. NIR spectroscopy is utilized as a part of the improvement of a noninvasive blood glucose focus observing framework in this study. The upsides of

NIR spectroscopy over MIR spectroscopy incorporate more prominent entrance profundities (shorter wavelength) what's more, less foundation impedance because of water retention. The more prominent entrance profundities are favored for checking blood glucose in vessels and glucose in interstitial liquid and tissue. Plus, NIR spectroscopy likewise offers focal points over Raman spectroscopy, for example, higher SNR and broadband light source is utilized rather than the exceptionally monochromatic source vital for Raman spectroscopy. Non-obtrusive determination of the glucose likewise advances general testing, satisfactory control, intricacies decrease and thusly health awareness cost lessening.

II. BLOOD GLUCOSE MEASUREMENT TECHNIQUES

a. Glucose oxidation methods

Conventional glucose determination is in view of the glucose oxidation response, catalyzed by glucose oxidase (GOD). It might be portrayed by



Glucose oxidase catalyzes the oxidation of β -D-glucose to D-gluconic corrosive and hydrogen peroxide. It is profoundly particular for β -D-glucose and does not follow up on β -D-glucose. Its significant utilization is in the determination of free glucose in body liquids. Albeit particular for β -D-glucose, glucose oxidase can be utilized to gauge the aggregate sum of glucose. This is on the grounds that, taking after the utilization of β -glucose; α -glucose at harmony is changed over to the β - structure via autorotation. The expended oxygen or the following generation of gluconic acid or hydrogen peroxide (H₂O₂) is in immediate extent to the glucose content. The glucose oxidase system is described by high affectability, exactness and unwavering quality. Conventional electrochemical systems, for example, potentiometry or amperometry can be utilized to focus the glucose substance amid the glucose oxidation reaction.

b. Types of Non-invasive Measurement Techniques

Non-intrusive glucose observing methods can be assembled as subcutaneous, dermal, epidermal and consolidated dermal and epidermal glucose estimations. As all techniques are in light of glucose oxidase oblige an immediate contact in the middle of glucose and some synthetic reagents, they require the extraction of glucose from the body. Be that as it may, a non-contact, non-intrusive technique is inconceivable with any compound based strategy. The main fascination is utilizing spectroscopic systems. In a spectroscopic procedure is utilized an optical bar communicates with glucose inside of the human body. Since optical routines don't require the extraction of glucose from the body, they are exceptionally suitable for the nonstop, non-obtrusive observing of glucose. An outline of the optical procedures and their notable component are compressed underneath:

- **Near Infrared Spectroscopy (NIR)**

Near infrared (NIR) spectroscopy is in view of concentrating on the body a bar of light in the

750–2500 nm range. NIR spectroscopy permits glucose estimation in tissues in the scope of 1–100 mm of profundities, with a lessening in entrance profundity for expanding wavelength values [13]. The assimilation coefficient of glucose in the NIR band is low and will be much littler than that of water by prudence of the substantial divergence in their separate fixations. Accordingly, in the NIR the powerless glucose ghostly groups just cover with the more grounded groups of water, additionally of hemoglobin, proteins and fats. As respects the scrambling coefficient, the impact of a solute (like glucose) on the refractive record of a medium is non-particular, and thus it is basic to other dissolvable analytes.

- **Mid- Infrared Spectroscopy (MIR)**

Mid infrared spectroscopy concentrated around light in the 2500-10000 nm range [31]. Mid Infrared contrasts with NIR is the Mid-Infrared groups of glucose and various blends offered are more than the ground of NIR, which are broad and weak regularly [32]. A number in obstacle is the poor input. Middle infrared is influenced conceivable progressed through comparative questions and shook variables as NIR, regardless of the glucose groups. For example, a few studies have shown remarkable dependence on the water content of the skin mid infrared spectrum.

- **Photo acoustic and Optoacoustic methods**

The photoacoustic (PA) strategy is in light of the recognition of weight waves produced by engrossing photons. Contrasted and optical assimilation systems, the photograph acoustic strategies offer the upside of higher location affectability, as the PA sign is affected by the optical ingestion coefficient, as well as by other physical parameters including warm development, particular warmth and acoustic speed. This has been shown in the determination of follows and oils in fluids. The essential standard behind the PA instrument is that a vitality source (a beat laser, for instance) lights some retaining material, bringing about a quick warm development in the lit up volume. The vitality of the development is discharged as an acoustic wave.

- **Polarization Changes**

The premise of this optical methodology is that the straight polarization vector of light will pivot when the light is gone through a substance and that the revolution measured is corresponding to the convergence of the substance being observed. Polarimetric procedure can make utilization of obvious light that is effectively accessible. Additionally, the optical parts can be effortlessly scaled down. This strategy is touchy to the diffusing. Properties of the explored tissue, since disseminating depolarizes the light. As a result, skin can't be researched by polarimetry, since it demonstrates high diffusing due specifically to the stratum corneum. Also, the specificity of this system is poor, since a few optically dynamic mixes are available in human liquids containing glucose, for example, ascorbate and egg whites. Notwithstanding, specificity can be mostly enhanced by utilizing numerous light wavelengths. Other general wellsprings of slips are varieties in temperature and pH of the arrangement. Some lapse sources particular

of the explored site are accounted for.

• **Fluorescence**

The fluorescence methodology is not the same as the other optical methodologies depicted in that it obliges the specimen be in contact with the sensor and, in this manner, can't be created as an absolutely non-obtrusive innovation yet rather obliges liquid extraction or an insert. Light in the unmistakable range can be utilized and more satisfactory for concentrating on fluorescence of tissues. In tissues, the utilization of bright light could prompt solid diffusing phenomena, notwithstanding fluorescence. Besides, notwithstanding when utilizing diverse wavelengths, the fluorescence sensation can depend on glucose, as well as on a few parameters, for example, skin pigmentation, redness, and epidermal thickness.

• **Time of Flight (TOF) estimations**

Time of Flight (TOF) estimations has been received to quantify the impact of glucose on blood in vitro at a wavelength of 906 nm. The TOF procedure with a streak camera takes a long estimation time.

• **Optical Coherence Tomography**

The optical rationality tomography (OCT) is in light of the utilization of a low cognizance light, for example, a super luminescent light, an interferometer with a reference arm and a specimen arm, a moving reflect in the reference arm and a photograph finder to gauge the interferometric sign. An increment of glucose fixation in the interstitial liquid causes an increment in its refractive record, subsequently deciding a diminishing in refractive list befuddle, and consequently of the diffusing coefficient[36]. Subsequently, from the OCT information, produced by the backscattered light, it is conceivable to get an estimation of glucose fixation in the interstitial liquid. OCT procedure can be delicate to movement relics.

Also, albeit little changes in skin temperature have unimportant impacts, changes of a few degrees have a critical impact on the sign. There is presently no unmistakable sign that this system has focal points contrasted with other dispersing based procedures.

• **Raman spectroscopy**

Raman spectroscopy is construct with respect to the use of a laser light to affect wavering and revolution in atoms & subsequent outflow of scattered light impacted by this particle vibration, which relies on upon the convergance of the glucose atom. The nonobtrusive obstruction from radiance and fluorescence phenomena. Altered wavelength lasers at moderately ease can be utilized. As of late, a change in conventional Raman spectroscopy has been proposed (surface-upgraded Raman spectroscopy), which may expand the affectability of the procurement as well as diminishing the obtaining time.

Fundamental restrictions are identified with shakiness of the laser wavelength and force, and long otherworldly procurement times.

Besides, likewise to different systems portrayed some time recently, the issue of the obstruction identified with different mixes remains.

III. METHODOLOGY

The framework is in light of the standard of absorbance transmittance photometry. The estimation of ingestion of light vitality is subject to the quantity of particles present in engrossing material. In this manner, force of light vitality leaving the engrossing substance is utilized as an evidence of convergance of that specific substance subjectively, the absorbance is communicated by Beer Lambert Law. The proposed framework comprises of 6 segments. The primary area is power supply used to give the 12V supply to the glucose sensor. Glucose sensor is to transmit and get the close infrared beams through the finger. Voltage divider is to partition the voltage to get the yield under 5V. Voltage controller is to change over 12V to 5V for the info supply microcontroller and LCD, Microcontroller is to process and examine the glucose values and to show on LCD.

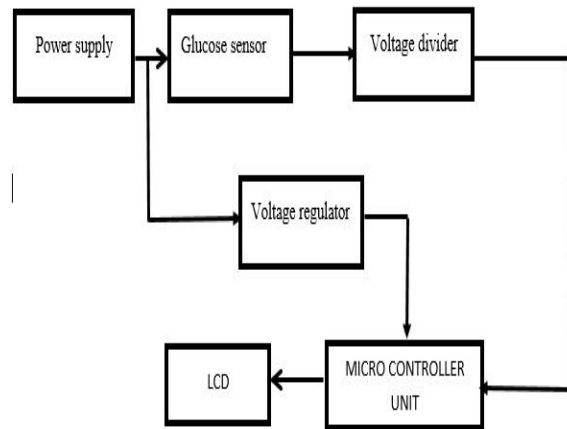


Fig 1: Block diagram of the proposed non-invasive blood glucose meter

IV. RESULTS

The consistency of all reading recorded (both invasively and non-invasively) taken from different subjects are tabulated .Table 1 shows the absorbance value of 20 subjects and their corresponding blood glucose reading measured.

Subject	Age	Non-invasive
1	25	106
2	24	95
3	24	145
4	24	112
5	23	76
6	24	134
7	22	123
8	32	189
9	30	168
10	42	356
11	23	145
12	23	134

13	35	200
14	24	89
15	23	175
16	23	188
17	28	105
18	22	148
19	24	125
20	25	112

Table 1: Non-invasive blood Glucose reading

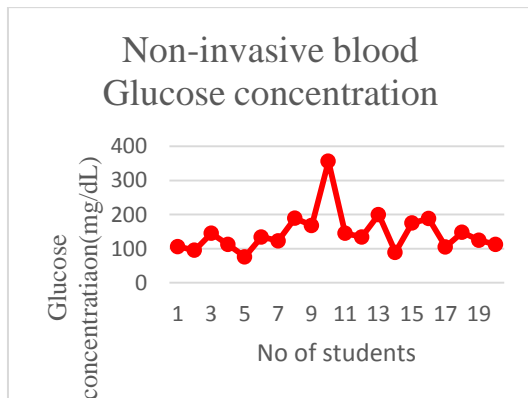


Fig 2: Graphical representation of the non-invasive blood glucose concentration

Subject	Age	Glucose concentration	
		Non-invasive	Accu-check
1	25	106	96
2	24	95	87
3	24	145	138
4	24	112	123
5	23	76	82
6	24	134	128
7	22	123	114
8	32	189	181
9	30	168	172
10	42	356	345
11	23	145	138
12	23	134	127
13	35	200	205
14	24	89	93
15	23	175	169
16	23	188	182
17	28	105	98
18	22	148	140
19	24	125	132
20	25	112	105

Table 2: Accu-check method versus non-invasive method

From the above table 2 and graph fig 3 shows the variation of glucose levels between the accu-check method and the Non-invasive method. There is slight difference observed in the non-invasive method compared to the conventional accu-check method.

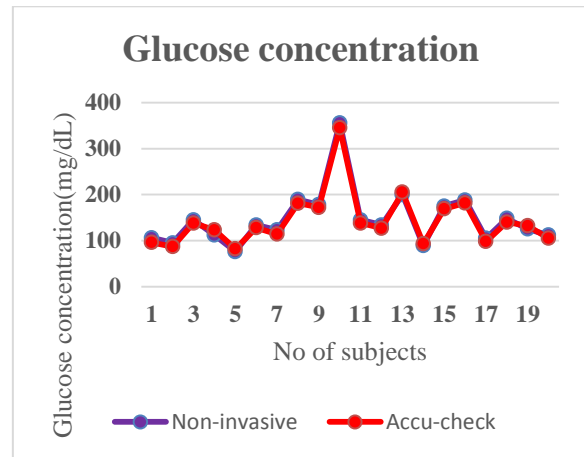


Fig 3: Accu-check method versus non-invasive method

To check the effectiveness and precision in estimation of blood glucose fixation, 10 subjects were considered and readings were taken from the exhibited model and it was found that blood glucose focus measured from the exhibited instrument was practically connecting to the blood glucose level utilizing standard intrusive system (Accu-check).

The table 3 demonstrates the blood glucose level of 10 subjects measured from our setup and it was relating blood glucose level measured utilizing Accu-check. The rate blunder between the accu-check strategy and the non-intrusive system is show in the above chart Fig 4. The greatest positive rate lapse got is 9.4% also, negative slip is 9.8%. Consequently the framework has an exactness of 90%.

SUBJECTS S _N	NON-INVASIVE BLOOD GLUCOSE READING (mg/dL) , M	ACCU-CHEK BLOOD GLUCOSE READING (mg/dL) N	ERROR PERCENTAGE (%) (M-N)/M
S ₁	106	96	+9.4
S ₂	95	87	+8.4
S ₃	145	138	+4.8
S ₄	112	123	-9.8
S ₅	76	82	-7.8
S ₆	134	128	+4.4
S ₇	123	114	+7.3
S ₈	189	181	+4.2
S ₉	168	172	-2.3
S ₁₀	356	345	+3.0

Table 3: Error percentage between accu-check reading and non-invasive method

From above trials, the blood glucose qualities taken oblivious room were closer to the exact qualities. i.e. to the accu-check values. Subsequently, the displayed non-obtrusive blood glucose framework created gave 90% precision when the perceptions were done in dim room.

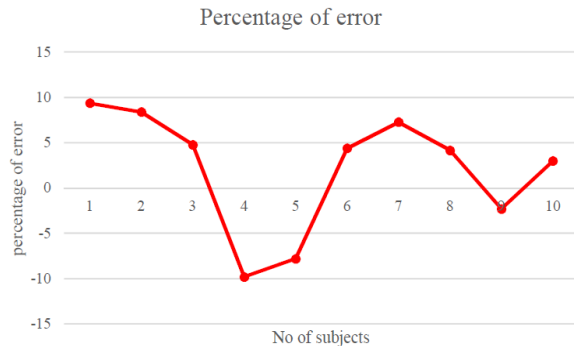


Fig 4: Graphical representation of error percentage

V. CONCLUSION

An Instantaneous, Cost-successful, Non-obtrusive blood glucose estimation framework model was created taking into account the connection between blood glucose fixation and the measure of light consumed by the glucose particles. The exhibited work showed the achievability of non-invasively observing blood glucose levels. NIR spectroscopic estimation of shifted glucose levels of diverse subjects demonstrated promising results. This methodology permitted the utilization of the Near Infrared Radiation straightforwardly on the skin abstaining from pricking. On the other hand, numerous parameters for development are made to expand exactness and accuracy of estimation utilizing the gadget. In view of the above results, it was found that the readings of the model were 90% precise. It was conceivable to enhance the exactness and execution of an uncommonly outlined non-obtrusive glucometer by including distinctive IR wavelengths extending from 700nm to 2500nm. Future endeavors will be situated to streamline module execution, to build exactness, and to enhance client interface.

REFERENCES

- [1] K A Unnikrishna Menon, Deepak Hemachandran, Abhishek T K "A Survey on Non-Invasive Blood Glucose Monitoring Using NIR" International conference on Communication and Signal Processing, April 3-5, 2013, India.
- [2] O.Abdullah,A.Bolz,J.Hansmann,H.walles and T.Hirth "Design of a Compact Multi-Sensor System for Non-Invasive Glucose Monitoring Using Optical Spectroscopy" IEEE precedings-jan 11-2013.
- [3] Viswanathan Mohan, Siddharth Shah, Banshi Saboo "Current Glycemic Status and Diabetes Related Complications Among Type 2 Diabetes Patients in India: Data from the Achieve Study" 5:2021,Jan-2013.
- [4] Lambert J, Storrie-Lombardi M & Borchert M. " Measurement of physiological glucose levels using Raman spectroscopy in a rabbit aqueous humor model." LEOS Newsletter 2008; 4: 1922.
- [5] Pickup JC, Hussain F, Evans ND, Rolinski OJ & Birch DJS "Fluorescence based glucose sensors". Biosensors and Bioelectronics -2005; (20): 2555 – 2565)
- [6] Klonoff DC, Braig J, Sterling B, Kramer C, Goldberger D & Trebino R. "Midinfrared spectroscopy for non-invasive blood glucose monitoring". IEEE Laser Electro-Optics Society Newsletter 1998; 12: 1314.
- [7]Esenaliev RO, Larin KV & Larina IV "Non-invasive monitoring of glucose concentration with optical coherence tomography" Optics Letters – 2001;26: 992-994.
- [8]Burmeister J & Arnold MA. "Evaluation of measurement site for non-invasive blood glucose sensing with near-infrared transmission spectroscopy". Clinical Chemistry 1999; 45(9): 1621 -1627.
- [9]Blank TB, Ruchti TL, Malin SF & Monfre SL. "The use of near-infrared diffuse reflectance for the non-invasive prediction of blood glucose levels". IEEE Laser Electro-Optics Society Newsletter 1999; 13(5): 9-12.
- [10] Heise HM, Marbach R, Koschinsky TH & Gries HM. Non-invasive blood glucose sensors based on near-infrared spectroscopy. Artificial Organs 1994; 18: 439 - 447;
- [11] Jagemann KU, Fischbacher C, Danzer K, Muller UA & Mertes B. Application near infrared spectroscopy for non-invasive determination of blood /tissue glucose using neural network". Fresenius Journal of Analysis Chemistry 1997; 359: 78-82;
- [12] Dongmin Guo,David Zhang, Lei Zhang,Guangming Lu "Non-invasive blood glucose monitoring for diabetics by means of breath signal analysis" IEEE july 2012: 55: 34-43
- [13] V.Ashok,A.Nirmalkumar,and N.Jeyashanthi "A Novel Method For Blood Glucose Measurement by Noninvasive Technique Using Laser" IEEE-Aug 2011: vol 3: 556-562
- [14] Prof..Mrs.A.A.Shinde "Non Invasive Blood Glucose Measurement using NIR technique based on occlusion spectroscopy" International Journal of Engineering Science and Technology (IJEST)-2011
- [15] E.Guevara and F.J.Gonzalez "Joint Optical-electrical Technique for non-invasive glucose monitoring" IEEE-OCT 2010: 2:212-219.
- [16] Cot GL., Cameron B. D. "Noninvasive polarimetric measurement of glucose in cell culture media." J. Biomed. Opt. 1997; 2:275-281.
- [17] King TW, Cot GL, McNichols R, Goetz MJ, JR Multispectral polarimetric glucose detection using a single pockels cell. Opt. Eng. 1994;33(8):2746-2753;
- [18] Cameron BD, Baba JS & Cot GL "Optical polarimetry applied to the development of a noninvasive in vivo glucose monitor". SPIE-BIOS 2000 Conference proceedings V3923.
- [19] Chou C., Han CY, Kuo WC, Huang YC, Feng CM, Shyu JC. "Noninvasive glucose monitoring in vivo with an optical heterodyne polarimeter". Appl. Opt. 1998;37:3553 -3557;
- [20]Jaspreet Kaur, Jagdish Kumar, H K Sardana, R Bhatnagar, N S Mehla "Non Invasive Blood Glucose Measurement Using Optical Method: Feasibility Study And Design Issues" International Conference on Optics and Photonics- 30 Oct.-1 Nov. 2009.
- [21] Y. Yamakoshi, M. Ogawa, T. Yamakoshi, M. Satoh, M. Nogawa S. Tanaka, T. Tamura,P. Rolfe & K. Yamakoshi "A New Non-invasive Method for Measuring Blood Glucose Using Instantaneous Differential Near Infrared Spectrophotometry" Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France August 23-26, 2009
- [22]S. K. Garg, R. O. Potts, N. R. Ackerman, S. J. Fermi, J. A. Tamada and H. P. Chase "Correlation of fingerstick blood glucose measurements with gluco watch biographer glucose results in young subjects with type 1 diabetes", diabetes care, 22, pp. 1708-1714, (1999).
- [23] Masab Ahmad, Awais Kamboh & Ahmed Khan "Non-invasive blood glucose monitoring using near-infrared spectroscopy" oct-16, 2013.
- [24] Miguel a.pletez, Tobias lieblein, Alexander Bauer, Otto Hertzberg, Hermann von lilienfeld-Toal, and Werner Mantele "Windowless ultrasound photo acoustic cell for in vivo mid-IR spectroscopy of human epidermis: Low interference by changes of air pressure, temperature and humidity caused by skin contact opens the possibility for a non-invasive monitoring of glucose in the interstitial fluid" IEEE -2013
- [25]Sergey Krivenko,Anatolli Pulavskiyi "Accuracy improvement of noninvasive determination of glucose concentration in human blood" vol-5 IEEE-19 Feb 2013
- [26]Mohd Mohsin, M.Z.Abidin, Lata Nischal, Hemant Kardam, Altaf Ahmad "Genetically encoded FRET-based nanosensor for in vivo measurement of leucine" IEEE—2013
- [27]S.Camou, Y.Ueno, E.Tamechika "Isothermic determination of aqueous solution glucose concentration in low mg/dl range by CW-photo acoustic-based protocol" IEEE- 2013.

- [28] Brintha.A, Tharani.R, Sharmilagowri.R, Ragesekar.L “A Non-Invasive IR Based Embedded Sensor for Human Blood Glucose Monitoring” IEEE –March-2013
- [29] Christopher McCormick, David Health, Patricia Connolly “Towards blood free measurement of glucose and potassium in humans using reverse iontophoresis” IEEE- March 2012
- [30] Wendy Van Moer, Kurt Barbe, Sven Verguts, Yves Van Ingelgem, annick hubin “Using the Best Linear approximation as a First Step to a Non-invasive Glucose Measurement” IEEE-2012.
- [31] Neeraj Kumar sharama, Sukhwinder Singh “Designing a Non-invasive Blood Glucose Measurement Sensor” IEEE-2012
- [32] Christison GB & MacKenzie HA. “Laser photoacoustic determination of physiological glucose concentrations in human whole blood.” *Medical & Biological Engineering & Computing* 1993;31: 284-290;
- [33] Zhong Ren, Guodong Liu, Zhen Huang, Lvming Zeng “Design of a Novel Noninvasive Blood Glucose Monitor based on Improved Holography Concave Grating NIR-Spectrometer” IEEE- 2011: 563-569
- [34] McShane MJ, Rastegar S, Pishko M, Cot GL. Monte Carlo “Modeling for implantable fluorescent analyte sensors”. *IEEE Trans. Biomed. Eng.* 2000;47:624 - 632;
- [35] Yoo KM, Das BB, Liu F & Alfano RR (1993) “Ultrashort laser pulse propagation and imaging in biological tissue and model random media - steps towards optical mammography” *SPIE Medical Optical Tomography: Functional Imaging and Monitoring IS11: 425 – 449*
- [36] Shuo Gaun, Jingren Gu, Zhonghan shen, Junyu Wang “A Wireless powered Implantable Bio-Sensor Tag System-On-Chip for Continuous Glucose Monitoring” *IEEE: vol-5: Issue 2, 2011:342-348*
- [37] Yuki Miyauchi, Takuro Horiguchi, Hiroaki Ishizawa, Shin-ichirou Tezuka and Hitoshi Hara “ Blood Glucose Level Measurement by Confocal Reflection Photo detection System” *IEEE-SICE Annual Conference 2011: 233-243.*
- [38] Chuah Zheng Ming, P. Raveendran “Comparison Analysis Between PLS and NN in Non-invasive Blood Glucose Concentration Prediction” *IEEE Vol. 1, Issue 1, April-2009*
- [39] Anuj Srivastava, Md Koushik Chowdhury, Dr. Shiru Sharma, Dr. Neeraj Sharma, “Blood Glucose Monitoring Using Non Invasive Optical Method: Design Limitations and Challenges”, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 1, January 2013*
- [40] Shouhei Koyama, Yuki Miyauchi, Takuro Horiguchi, Hiroaki Ishizawa, “Non-invasive Measurement of Blood Glucose of Diabetic Based on IR Spectroscopy”, *SICE Annual Conference, The Grand Hotel, Taipei, Taiwan 2010.*
- [41] Brince Paul, Melvin P Manuel, Zachariah C Alex, “Design and Development of Non invasive Glucose Measurement System”, *MEMS and Sensors Division, School Electronics Engineering VIT University, Vellore.*