Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

National Conference on Microwave & Optical Communication

Volume 5, Special Issue 08, May-2018

DESIGN OF PHOTONIC CRYSTAL FIBER BASED SENSING FOR THE DETECTION OF GLUCOSE

S.Suganya[1], P.Sangeetha[2] and T.K.Shanthi[3]

Department of Electronics and Communication Engineering,
[1,2,3]Alagappa Chettiar Government College of Engineering and Technology, Karaikudi -630 003, Tamilnadu

Abstract— *In this paper multi-core triangular lattice structured Photonic Crystal Fiber (PCF) sensor for sensing relevance with stunning countenance for the detection of glucose concentration. The proposed sensor is numerate inspected using finite element method (FEM). We analyzed the sensing equity of the proposed photonic crystal fiber structure with different concentration of the glucose from (10%-50%) is varied. The calculated moderate sensitivity is 146699.26 nm/RIU. In this, sensor can grant an effective platform for glucose sensing and potentiality imperative to a further improvement of optical sensing applications.*

Keywords— *Biosensor, Photonic Crystal Fiber, Glucose, Refractive index*

1. INTRODUCTION

Optical sensing mechanisms receive considerable attention in the areas of industrial process control, military, environmental monitoring, medical diagnostics, etc. Glucose concentration is affected by the physical properties of refractive index, specific gravity, surface tension ,and viscosity. Generally, glucose present in urine is referred as “Glycosuria” [2] and normal range from 0 mg/dl to 15 mg/dl. If the level is increased from the normal range, it means high glucose level in blood. Normal blood glucose level is between 165 mg/dl and 180 mg/dl. The level being too low is known as “Hypoglycemia”, i.e. the range from less than 40 mg/dl. High blood glucose level is known as“Hyperglycemia” and ranges from 270 mg/dl to 360 mg/dl [2]. It indicates as diabetes mellitus, liver, and kidney related diseases [3–5].

Glucose is the form of sugar to treat hypoglycemia which will bring the blood glucose concentration to their normal levels very quickly. Dextrose can be used in intravenous preparations and injections in clinics for hypoglycemia and dehydration and for intravenous feeding since dextrose has a very high glycemic index. we investigated a particular design of PCF based glucose sensor to diagnose the variation in the blood glucose level .the design of multi core and 2D-photonic crystal based sensor.

Diabetes mellitus has been well reported to be associated with increased risk of tuberculosis[14]. The presence of indefinite social factor, metabolic derangements .and comorbidities also poses major difficulties in dissecting the effect of diabetes mellitus from other potential confounders. Diabetes mellitus was diagnosed mainly fasting plasma glucose level of 126mg/dl, together with confirmatory symptoms and blood/plasma glucose determinations.
According to the World Health Organization(WHO),about 422 million people are affected by diabetes in the year of 2014[6].the global prevalence of diabetes among adults over 18 year of age has risen from 4.7% in 1980 to 9% in 2015.diabetes prevalence has been rising more rapidly in middle and low income countries. diabetes is fast gaining the status of a potential epidemic in india with more than 62 million diabetic individuals currently diagnosed with the disease.

In 2000, India (31.7 million) topped the world with the highest number of people with diabetes mellitus followed by china (20.8 million) and united states (17.7 million) in the second and third place respectively. the prevalence of diabetes is predicted to double globally from 171 million in 2000 to 366million in 2030 with a maximum increase in India. It is predicted that by 2030 diabetes mellitus may afflict up to 79.4 million individuals in India [7].In this context we optimized a multi-core structure based glucose sensor design utilizing the index guiding multicore fibers and present a numerical analysis based on the finite element method [FEM].it is worthwhile to mention that this PCF based glucose sensor is a novel sens or which offers high sensitivity and linearity over the other type of the sensors .the designed structure provides a very large dynamic refractive index detection range and comparatively provides high sensitivity rang for temperature sensing[18]. In our context, the multi core structure is proposed due to its high detection range for continuous monitoring of glucose in human blood providing high sensitivity, which will pave to identify the glucose concentration to replace the existing glucose sensor with high sensitivity as well for long term use .the proposed work creates a great deal for the physicians and patients.

2. STRUCTURE DESIGN

The section of the proposed sensor is shown in Fig.1.with multi core fiber triangular lattice structure with the increase of dynamic refractive index[RI] detection ranges [1]. to obtain the high sensitivity with easier fabrication, the air holes are arranged in a having pitch constant (^) of 2µm and diameters of air holes are optimized d1=0.6µm, d1=1.4µm, . the defect mode is created by removing the air holes which enhances the propagation of chosen wavelength of light into the liquid core. its mode propagation is studied using FEM and electric field distribution is shown fig 2.(a)-(i).

Glucose of 50% concentration with refractive index of 1.4501 at room temperature (20◦C) is filled into the central air hole of the designed PCF structure. Refractive index of the glucose in water solution is tunable for different concentration (10%-50%). All the modes in the PCF are leaky modes because the real part of the refractive index is lower than background material. The leaky mode can be controlled by choosing the suitable liquid material with the appropriate refractive index. The energy transfer between the liquid core mode and defect mode can be identified by the peak wavelength

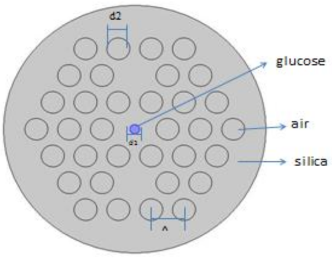


Fig. 1.cross section of glucose sensor based PCF

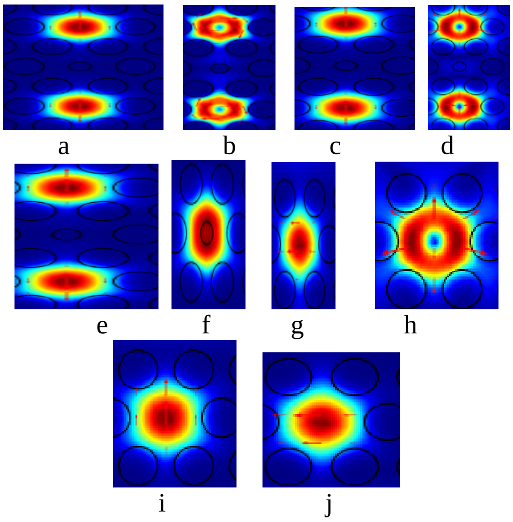


Fig.2. Electric field distribution of a defect mode and core modes. the arrow represents the direction of the electric field. the coupling between defect and core modes are shown in Fig 2(a)-2(e) and 2(f)-2(j).

Table 1 Concentration of glucose

Mass%	Refractive index(RIU)	Peak wavelength
10	1.3695	1550
20	1.3896	1480
30	1.4098	1460
40	1.4299	1440
50	1.4501	1420

The background material of fiber is filled silica whose refractive index is calculated by eq.(1). The refractive index of analyte is taken for differents concentration of glucose in water and values are tabulated in Table 1.

$$n^2(\lambda)=1+\frac{B_1\lambda^2}{\lambda^2-C_1}+\frac{B_2\lambda^2}{\lambda^2-C_2}+\frac{B_3\lambda^2}{\lambda^2-C_3} \qquad (1)$$

PCF act as a waveguide and in this wave guide and targeted analyte and light interact with each other. We have analyzed the evanescent field distribution of the PCF. using the finite element method(FEM), the properties of propagating modes of proposed PCF is numerically investigated.in our glucose sensor. the coupling between the liquid core and defect modes are shown in Fig .2(a)-2(i).

3. NUMERICAL RESULTS

Due to the finite number of air holes in the cladding part, there may cause leakage of light. The leakage of light from core to exterior material results in confinement loss (dB/m) which can be obtained from the imaginary part of n_{eff} by using the following equation(2) .

$$\alpha(x,y)=8.686\text{Im}(n_{eff})*10^6 \qquad (2)$$

The illustrations of mode field distributions are displayed in Fig.3 which represents the real part of refractive index and loss dependence on the operating wavelength λ for the different samples of glucose for the upper mode, the mode field is mainly distributed in liquid core at shorter wavelength. Mode field begins to transfer the liquid core to defect core as wavelength increases, the energies of liquid-core mode to defect mode are equal to the energy transfer from liquid core to defect core at longer wavelength.

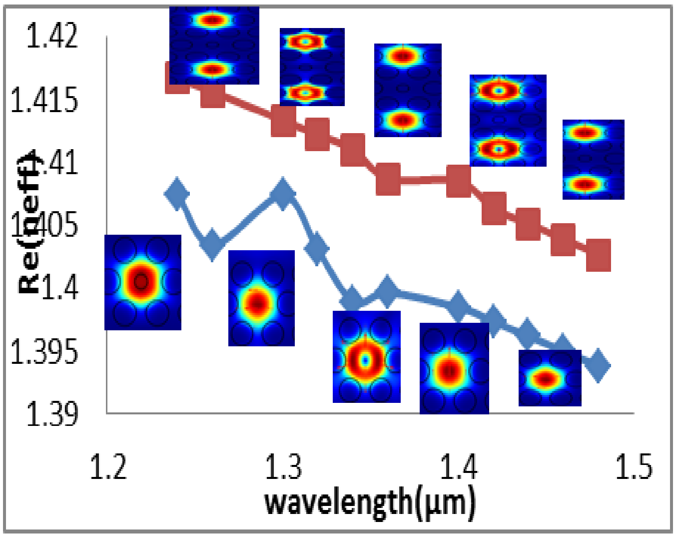
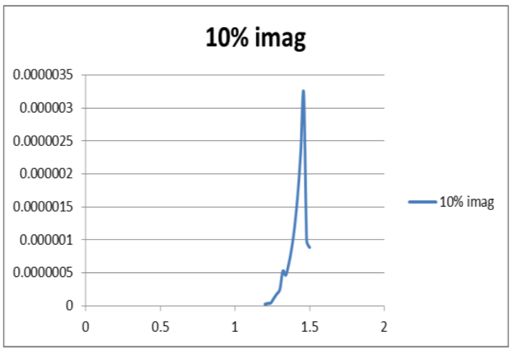
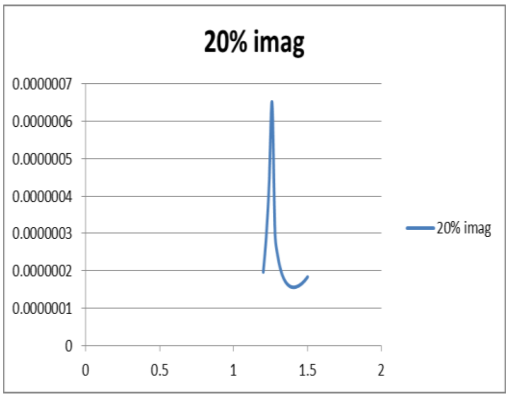


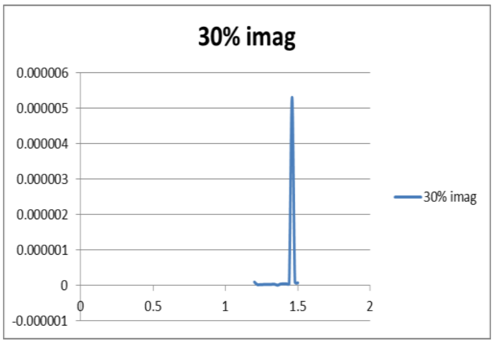
Fig.3.The real part of core mode and defect mode refractive index for the chosen wavelength .the shows electric field distributions and transfer of energy between fundamental and liquid mode



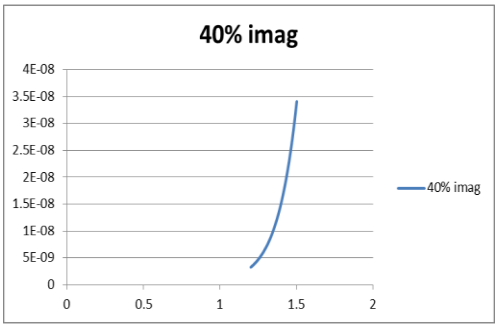
(a)



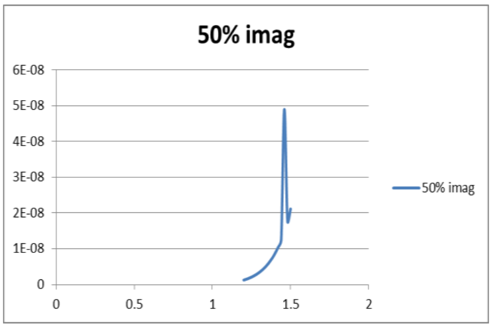
(b)



(c)



(d)



(e)

Fig. 4(a)-4(e) Stimulated results in different concentration of glucose solution.

The simulated results Fig.4(a)-4(b) gives relationship between wavelength for different concentrations of the samples. the spectral sensitivity of the corresponding sensor can be obtained as

$$\mathbf{S(nm/RIU)} = \frac{\Delta\lambda}{\Delta n} \qquad \mathbf{(3)}$$

Where $\Delta\lambda$ is the offset of the resonant wavelength and Δn is the change in the RI of glucose solution. When the RI of glucose solution is changed, the resonance spectrum will be varied. therefore we can obtain information about the analyte according to the change of the resonance wavelength. when the glucose concentration changes from 10mg/dl to 50 mg/dl the offset of the resonance wavelength $\Delta\lambda$ is 0.08 nm. the increment solution RI is 4.169×10^{-3}
The average spectral sensitivity 146699.26 nm/RIU can be obtained.

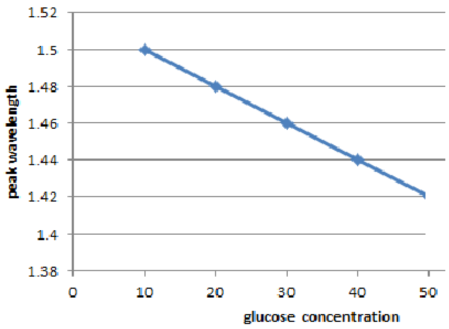


Fig. 5.The resonance wavelength as the function of varying glucose concentration.

Fig.5 represents the wavelength and varying the different concentration of glucose sensor. The sensitivity of designed PCF sensor is 146699.26nm/RIU for 20% of glucose concentration with the solution of 0.004169 RIU.

4.CONCLUSION

In this paper we analyzed the electric field distributions of defect modes and liquid core modes in solution. we analyzed a PCF glucose sensor filled with different concentration of glucose solution. The results show that the RI of filling analyte and the average spectral sensitivity of 146699.26 nm/RIU. A high sensitivity glucose sensor based on compact PCF proposed by the finite Element method.

In Our proposed PCF it has been provided that higher relative sensitivity and fiber sensing in different samples such us Urea, Albumin, using in photonic crystals fiber .The structure can be further optimized.

REFERENCES

[1] Harikesavan thenmozhi,MuruganSenthil mani rajan,Veluchamy devika, dhasarathan vigneshwaran,natesan ayyanar ,D-glucose sensor using photonic crystal fiber.
[2] Michael S. Boyne, David M. Silver, Joy Kaplan, Christopher D. Saudek, Timing of changes in interstitial and venous blood glucose measured with acontinuous subcutaneous glucose sensor, Diabetes 52 (2003) 2790.
[3] Julie Wagner, Howard Tennen, Howard Wolpert, Continuous glucose monitoring: a review for behavioral researchers, Psychosom. Med. 74 (4)(2012) 356.
[4] H. Barry, G. Ginsber, An overview of minimally invasive technologies, Clin. Chem. 38/9 (1992) 1596.
[5] Abdulhalim Srivastava, Spectral interrogation based SPR sensor for blood glucose detection with improved sensitivity and stability, J. Biosens.Bioelectron. 6 (2015) 172.
[6] Poonam Sharma, Preeta Sharan, Photonic crystal based ring resonator sensor for detection of glucose concentration for biomedical applications, Int.J. Emerging Technol. Adv. Eng. 4 (2014) 702.
[7] P. Sharma, Photonic crystal based ring resonator sensor for detection of glucose concentration for biomedical application, IJETAE 4 (2014) 706.
[8] M.R. Pintoa, M. Baptistaj, J.L. Santos, M.A. Lopez, O. Frazão, Micro-displacement sensor based on a hollow-core photonic crystal fiber, Sensors 12(2012) 17497.
[9] C.M.B. Cordeiro, M.A.R. Franco, G. Chesini, E.C. Barretto, R. Lwin, C.H.B. Cruz, Micro structured-core optical fiber for evanescent sensing applications,Opt. Exp. 14 (2006) 13056.
[10] A.M. Cubillas, S. Unterkofler, T.G. Euser, B.J.M. Etzold, A.C. Jones, P.J. Sadler, P. Wasserscheid, S.T.J. Russell, Photonic crystal fibers for chemical sensingand photochemistry, Chem. Soc. 42 (2013) 8629.
[11] P. Sharma, P. Sharan, Design of photonic crystal-Based biosensor for detection of glucose concentration in urine, IEEE Sens. 15 (2015) 1035.
[12] R. Savarimuthu, N. Dhanlaksmi, Photonic crystal based biosensor for the detection of GlucoseConcentration in urine, Photonic Sens. 7 (2017) 11.
[13] P. Sharma, P. Sharan, Design of photonic crystal based biosensor for detection of glucose concentration in urine, IEEE Sens. 15 (2) (2015) 1035.
[14] R. Lide David, Handbook of Chemistry and Physics, 84th edition, CRC PRESS), 2003 (2003–2004).

[15] The Diabetes control and complications Trial Research Group.The effect of intensive treatment of diabetes on the development and progression oflong-term complications in insulin-dependent diabetes mellitus, J. New Engl. Med. 329 (1993) 977.

[16] D.M. Peterson, D.L. Jones, A. Dupuis, Bernsteinr, M. O'shea, Feasibility of tight control of juvenile diabetes mellitus through patient monitoredglucose, Diabetes 27 (1978) 437.

[17] P.H. Sönksen, S.L. Judd, C. Lowy, Home monitoring of blood glucose, Lancet 1 (1978) 729.

[18] S. Walford, E. Gale, S.P. Allison, B. Tattersallr, Self-monitoring of blood glucose, Lancet 1 (1978) 732.

[19] L.I.U. Qiang, L.I. Shuguang, Hailiang Chen, Zhenkai Fan, L.I. Jianshe, Photonic crystal fiber temperature sensor based on coupling between liquid-Coremode and defect mode, IEEE Photonics 7 (2015) 2