Detection Of Albumin And Urea Concentration In Urine Using 2d Photonic Crystals

Sanjeev Sharma¹, Shradha Gupta ²
¹²Department of Physics, GL Bajaj Institute of Technology and Management, Greater Noida, UP, India

e-mail: 'sanjeevsharma145@gmail.com

Abstract. A biosensor has been created for the detection of albumin and urea in urine by using 2-D photonic crystal. The refractive index of whole urine is a function of wavelength, it constitutes such as albumin, urea etc. for sensed transmittance, quality factor and power efficiency. In case of albumin and urea in urine, the concentration varies with respect to the refractive index of urine. The resonant wavelength as well as transmission efficiency of the biosensor is shifted towards the higher order of wavelength region when the refractive index of urine component varies from high to low. It’s also observed that both albumin and urea in urine have a low quality factor, high transmission efficiency and good sensitivity.

Keywords: Finite Difference Time Domain (FDTD), Plane wave Expansion (PWE); Refractive Index, urine, albumin.

1. INTRODUCTION

Oz The high percentage of albumin and urea in urine cause of different type of deceases in human such as kidney disease, liver, diabetes etc. [1-2]. The large amount of urea in the urine may cause too much protein in the diet. Albumin is also called a protein which passes from the blood into the urine. In an unhealthy human it passes into the urine. Population scrutinize have revealed the occupancies of the chronic kidney disease in 10% cases high amount of albumin in human is the source of this deceases. [3-4]. It is necessary to check the albumin, urea /or protein levels in urine of human agonizing the CKD time to time but there in current survey there is no more evidence to endorsed examining the kidney function [5].

The various diseases in urine such as albumin, glucose concentration, urea, serum creatinine etc. investigated in a human [6-8]. Photonic crystal possesses photonic bandgap which plays an important role to design various types of biosensors, DWDM, ODR mirror, optical filter etc.[9-15] Recently, 2D photonic crystal based biosensors has been used for the detection of different deceases in blood and urine components. M. Radhouene et. al. [16] theoretically design a ring resonator based temperature using 2D photonics technology. In 2018, S. Bendib et. al. [17] theoretically simulated the detection of Malaria in blood using 2D photonic crystals with the help of FDTD method. Here, a biosensor based on 2D photonic crystal is created and sensing the Q factor, resonant wavelength, power transmission of albumin, urea etc. in urine. In 2020, K. Aidinis et. al. design a optical sensor for measuring glucose in urine using 2D photonic crystals [18].
In the present communication, we have theoretically designed a double ring resonator based biosensor using FDTD method. It's detects various type of urine components such as albumin, urea and glucose concentration with their refractive indices in a human bodies. The refractive index of Germanium rod is 4.2 and the refractive index of air is 1. The transmission spectra of urine components such as albumin and urea have been obtained by using FDTD method. The refractive indices correspond to their concentrations such as 7-125mg/dl, 250-500mg/dl and 600-1000mg/dl are 1.335, 1.3355, 1.336 in case of albumin and 1.335, 1.337, 1.338, 1.339 in case of urea. The double ring resonator based biosensors are glamorous for various sensing applications and also deliver a better result. In case of urine diseases such as kidney, liver etc. it provides a low quality factor, high transmission efficiency and good sensitivity.

2. DESIGN OF A BIOSENSOR

In this paper, we have designed a double ring resonator based biosensor using FDTD method. The 3 dimensional picture of a biosensor with a large number of Ge rods in X and a Z direction (dimensional 21x19) is illustrated in Figure1. In this structure the radius and lattice constant of Ge rod are 265nm and 550nm respectively. The refractive index of Germanium rod is 4.2 and the refractive index of air is 1.

3. SIMULATION AND RESULT

To evaluate the power transmission and bandgap of double ring resonator biosensor the PWE and FDTD method are used. To investigate the photonic bandgap of the proposed structure for TE mode the PWE method is used. Figure 2 shows that the photonic bandgap of the structure lies between 1440nm-1725nm, 2035nm-2675nm and 335nm-505nm respectively. In this paper, we focus the photonic bandgap ranging from 1440nm to 1725nm. The photonic crystal biosensor is excited from the light source by a continuous pulse with a central wavelength of 1550nm.
The DFT electric field distribution graph of biosensor is shown in Figure 3. Using DFT simulation we will get the frequency domain which is responsible for central wavelength, it also gives the observation point, area, and a series of wavelengths at a particular point of wavelength range. At 1550nm, the input signal transmits into double circular resonator and we will receive a high transmittance at the output.

The transmission spectra of urine components such as albumin and urea have been obtained by using FDTD method. The refractive indices correspond to their concentration are 1.335, 1.3355, 1.336 in case of albumin and 1.335, 1.337, 1.338, 1.339 in case of urea. Figure 4 represents the power transmission spectra of albumin concentration in urine at refractive indices 1.335, 1.3355 and 1.336 respectively. The transmission peaks of albumin concentration in urine centered at wavelength 1.550μm and the output efficiency of albumin at concentration 7-125mg/dl, 250-500mg/dl and 600-1000mg/dl are 91%, 83% and 78% respectively. Figure 5 represents the power transmission spectra of urea concentration in urine at refractive indices 1.335, 1.337, 1.338 and 1.339 respectively. The transmission peaks of urea concentration in urine varies from 1.548μm 1.554μm and the output efficiency of albumin at concentration 60-100mg/dl (normal range), 0.625mg/dl, 1.25mg/dl and 2.5mg/dl are 92%, 84%, 74% and 69% respectively. Also, the transmission peak of albumin concentration in urine varies from 1.549μm 1.554μm. From these transmission spectra of urine components such as albumin and urea it’s clear that the power transmission efficiency of the sensor is increasing with decreasing of refractive indices. Also, the proposed structures have high efficiency and good sensitivity in comparison of the pervious published research work [8].
Figure 4. Power transmittance of Albumin concentration in urine.

Figure 5. Power transmittance of urea concentration in urine.

Table 1. Efficiency and Quality Factor of Albumin in Urine

| S. No. | Concentration     | Refractive index | Resonant wavelength (nm) | Quality Factor | Transmission Efficiency % |
|-------|-------------------|------------------|---------------------------|----------------|--------------------------|
| 1     | 7mg/dl-125mg/dl   | 1.335            | 1549                      | 55             | 91                       |
| 2     | 250mg/dl-500mg/dl | 1.3355           | 1552                      | 57             | 83                       |
| 3     | 600mg/dl-1000mg/dl| 1.336            | 1554                      | 60             | 78                       |

Table 2. Efficiency and Quality Factor of Urea in Urine

| S. No. | Concentration     | Refractive index | Resonant wavelength (nm) | Quality Factor | Transmission Efficiency % |
|-------|-------------------|------------------|---------------------------|----------------|--------------------------|
| 1     | Normal (60-100mg/dl) | 1.335            | 1548                      | 56             | 92                       |
| 2     | 0.625mg/dl        | 1.337            | 1550                      | 58             | 84                       |
| 3     | 1.25mg/dl         | 1.338            | 1551                      | 62             | 74                       |
| 4     | 2.5mg/dl          | 1.339            | 1554                      | 64             | 69                       |
The quality factor and power efficiency of urine component albumin with their refractive indices is shown in Table1. Here, in normal case for human health the output efficiency of albumin in uric acid is recorded as 91%. When the concentration of albumin in urine is increased the efficiency of the sensor is decreased. At concentrations 250-500mg/dl and 600-1000mg/dl it’s recorded as 83% and 78% respectively. The quality factor of this sensor is very low. In Table 2 the quality factor and power efficiency of urine component urea with their refractive indices is indicated. The output power efficiency and quality factor of this sensor at concentrations (60-100mg/dl), 0.625mg/dl, 1.25mg/dl and 2.5mg/dl is recorded as 92%, 84%, 74%, 69% and 56, 58, 62, 64 respectively. It’s clear that the resonant wavelength as well as transmission efficiency of the biosensor is shifted towards the higher order of wavelength region when the refractive index of urine component varies from high to low and also, the output transmission efficiency of the biosensor is increased with decrease the concentration. Hence, a double ring resonator based biosensors are glamorous for various sensing applications and also deliver a better result. It also provides a low quality factor, high transmission power efficiency and good sensitivity 3525nm/RIU in case of urine diseases such as kidney, liver etc.

4. CONCLUSION
A double ring resonator based 2D photonic crystal biosensor detects albumin and urea in urine components with their concentrations as well as refractive indices. Hence, a double ring resonator based biosensors are glamorous for various sensing applications and also deliver a better result. It also provides a low quality factor, high transmission power efficiency and good sensitivity 3525nm/RIU in case of urine diseases such as kidney, liver etc. The proposed work will be highly commercialized for medical solicitations.

5. ACKNOWLEDGMENT
I am thankful to Prof. R. K. Agarwal, Director, GL Bajaj Institute of Technology and Management, Greater Noida (UP) for their valuable cooperation.

REFERENCES
[1] Mulay SR., Anders HJ. 2017 “Crystal nephropathies: mechanisms of crystal-induced kidney injury.” Nat. Rev. Nephrol., 13, 226–240.
[2] World Health Organization, Fact Sheet N312, 2014 Available online: http://www.who.int/mediacentre/factsheets/fs312/en/.
[3] Matsushita K., Vander Velde M., Astor B. C., Woodward M., Levey A. S., de Jong P. E., Coresh J., and Gansevoort R. T. 2010, “Association of estimated GFR and albuminuria with all-cause and cardiovascular mortality in general population cohorts: a collaborative meta-analysis,” The Lancet, 375(9731), 2073-2081.
[4] K/DOQI Clinical Practice Guideline of CKD, Kidney International Supplements 2013, 3.
[5] Rosenberg M., and Pechter U., 2007  “Microalbuminuria – sudame- ja veresoonkonnahaiguse riski naitaja,” Eesti arst, 86(7), 470-473.
[6] Sharma P. 2014, “Photonic crystal based ring resonator sensor for detection of glucose concentration for biomedical application,” International Journal of Emerging Technology and Advanced Engineering, 4(3), 702–706.
[7] Sharma P. and Sharan P., 2015 “Design of photonic crystal based biosensor for detection of glucose concentration in urine,” IEEE Sensors Journal, 15(2), 1035–1042.
[8] Robinson S. and Dhanalaksmi N., 2016 “Photonic Crystal Based Biosensor for the Detection of Glucose Concentration in Urine” Photonic Sensors. DOI: 10.1007/s13320-016-0347-3.
[9] Sharma S., Kumar A. and Singh Kh. S. 2020 “Design of a tunable DWDM multiplexer using four defect layers of GaAs nonlinear photonic crystals” Optik- International journal of Light and electron optics, 212, 164652.
[10] Sharma S., Gupta S., Suther B., and Singh Kh. S., 2020 “Design of a tunable transmission mode filter using 1D Ge based nonlinear photonic crystal” AIP Conference Proceedings 2220, 050016; https://doi.org/10.1063/5.0001128.
[11] Kalhan A., Sharma S., and Kumar A., 2018 “16-channel DWDM based on 1D defect mode
nonlinear photonic crystal” AIP Conference Proceedings 1953, 060046; doi: 10.1063/1.5032777.

[12] Sharma S., Kumar R., Singh Kh. S. and Kumar A., 2017 “Temperature dependence ODR reflection by using 1D Binary and Ternary photonic crystal” Optoelectronics and Advanced Materials-Rapid Commu., 19(5-6), 319-324.

[13] Jiang Wu Ji-, Jin-Xia Gao, 2015, “Low temperature sensor based on one-dimensional photonic crystals with a dielectric-superconducting pair defect”, Optik. 126 , 5368–5371.

[14] Sharma S., Kumar R., Singh Kh. S., Kumar V. and Kumar A., 2015, “Omnidirectional reflector using linearly Graded refractive index profile of 1D binary and ternary photonic crystal” Optik- International journal of Light and electron optics, 126 (11-12), 1146-1149.

[15] Sharma S., Kumar R., Singh Kh. S., Kumar V. and Kumar A., 2014 “Single channel tunable wavelength division demultiplexer using one dimensional defect mode nonlinear photonic crystal, Optik- International journal of Light and electron optics, 16 (9-10),1015-1019.

[16] Radhouene M., Chhipa M. K., Najjar M., Robinson S., and Suthar B., 2017 “Novel design of ring resonator based temperature sensor using photonics technology,” Photonic Sensors, 7(4): 311–316.

[17] Bendib S. and Bendib C., 2018 “Photonic Crystals for Malaria Detection” J Biosens. Bioelectron., 9(3), 1000257.

[18] Aidinis K., Goudarzi K., and Esmaeili A. H., 2020 "Optical sensor based on two-dimensional photonic crystals for measuring glucose in urine,” Optical Engineering, 59(5), 057104. https://doi.org/10.1117/1.OE.59.5.057104.