Detecting Different Concentrations of Potassium Chloride Using the Sensor with Photonic Crystal in Nano Range

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Abstract

Sensitivity scheme with sensing and evaluating chemicals have been clued-up by means of photonic sensors by coalescing chemical constituents with their optophysical properties. In this article we have corroborated a 2D ring resonator using photonic crystal optical sensor which can detect potassium chloride by knowing the transmitted flux. According to the corresponding analogy peaks were explored. Yee's method has been used for the assessment. Electromagnetic 2D model implemented to do the initiation all pass ring resonator photonic crystal. The different concentrations of potassium chloride respectively shifts its values with the respected frequency used in the design. The quality factor from the sensor is found to be 347663 and the sensitivity included is found to be in the range of 1.2 NM. The distinction in the minor level of the refractive index occur the alteration for the cause in the judicious forming the frequency that is obtained by observing the simulation. These technique that is used to authorize the design which is unequivocally an active sensors. This analogy of the paper was been made using the deliberated   IPKISSIMEC tool. The GDSII file was generated with the OWL VISION tool and substantiated meticulously using the tool K-Layout . The ASCII code was formed using the generated OWLVISION tool.

Keywords: photonic crystal , OWL VISION, k-layout, potassium chloride, Yee's method , opto properties, quality factor.

1. Introduction

Potassium salt of hydrochloric acid KCl is used as fertilizer and in lethal injections. Blood levels in the hyokaelemia prevent to treating with low blood levels of Potassium chloride. Potassium levels are less as it results in different dieseace that are very harmful as it is dangerous leads with many illness like vomiting and diarrhoea. (*Amith Kumar Goyal, Suchandan , 2015*).
Chemical compound potassium halide is the metal component that have the content of chlorine and potassium that have salt. The potassium have a white colourless and it has a crystal the appearance readily dissolves in water and the solution taste like a salt odour. Even though chloride used in medicine, any excess amount of chemical compound in to the human body is harmful. Chloride is soluble in variety of solvents(*Sundar , Anup and Preeta, 2017).*
Potassium salts are obtained by mining and contaminated with other salts they are ground up and then dissolved in a hot saturated solution of chloride. Only salt that dissolve under these conditions is potassium chloride. The saturated solution is separated from the solid impurities the mixture is then cooled at lower temperatures. Potassium chloride has much lower solubility than sodium chloride so as a result potassium chloride precipitates from the solution(*Dennis, Shouyani, Januz, Garet, 2006*). Potassium chloride obtained by the method is used as fertilizer. Thus, it is important to note that the concentrations of potassium have to be duly checked and kept within the levels so as to prevent heart ailments and cardiac arrest .
A photonic crystal based biosensor consisting optical nano structure made with nano rods or holes of specific diameter etched in silicon wafer in case of holes in slab configuration and rods in silicon substrate in rods in air configuration and properties using chemical deposition *(Shuren Hu, Sharon , Weiss,2016). The* sensors that are used for fabricating for ineffectiveness and riggings to reveal the agents having the biological way to express the cause in the bio-war have ill. These effective subsequent having the biological PC provide solution for practical applications where monitoring of Refractive Index(RI) changes is important, such as, monitoring of changes in complex structures bio analytes measured and reckoned byThe early stage cancer are detected by considering the variation in refractive indices of cell in stages. In order to achieve better performance, the variation of defect in the photonic crystal (*Borel, Harpøth, Frandsen, Kristensen 2004).*
In case of optical biosensor system sensor integrated with biological elements optical nano structure called photonic crystal

configurations to produced wavelength change is then conveyed in detector Passage of light through the sample in photonic crystal rods in air or holes in slab configuration will bring out the change in the wavelength of light in monitors placed in light output. Change in optical properties is converted to electrical signal for easy understanding of users*(Hui Wang, Ke kin Zhang, 2013)* .

2. Theory

Photonic crystal is system having dialectic constant is varying periodically in space. So this is the optical analogy to semiconductors. So in semiconductors we use crystal potential oscillating to a periodic to control the flow of electrons. Propagation through the medium having its own structure for the projection of the lights of waves through a medium endowed with periodic structure this is first introduction of idea of forbidden and gap. Rayleigh's wave equation is established with respect to frequency and wavelength rather than frequency which is established limits of the upper and lower edge of the band gap.
Refers to various techniques employed for band gap modification, optical waveguide in photonic crystal made of silicon have high refractive index and one sixth hundredth as thin as conventional waveguide*(Ana M. R. Pinto and Manuel Lopez-Amo 2012)*. Photonic crystal made with silicon has many featuressuperiorly for example bending radius on order of siliconmicrometre bent freely in the waveguide can be with and optical integrated circuitry can have small chip onhigh density . Photonic crystal has potential of revolutionizing technology in many field a silicon waveguide in photonic crystal configuration typically consist of silicon as base and silicon rods etched in silicon dioxide slab in case of rods in air configuration. And etching of pores in holes in slab configuration. It electron beam lithography technology and plasma etching to achieve the extremely small cross section and accuracy on micrometre level for example by fixing beam shot size and using multiple exposures roughness on side walls which directly related to propagation loss can be reduced and a smooth resist pattern micrometre accuracy can be defined.
In addition, low pressure ECR plasma edging can prevent side wall damage caused by norrell radicals and addition of etching residue enabling fabrication of low loss silicon waveguide having propagation loss of one decibel per centimetre. In addition to the fabrication technology photonic device design technology is also important in constructing optical circuit using silicon photonic crystal*(Ya-nan Zhang, Yong Zhao, Tianmin Zhou and Qilu Wu 2018)*. An issue of great concern is loss generated when light with relatively large amplitude and width of pulse from photonic crystal is introduced into sub microscopic silicon waveguide. To avoid this problem photonic crystal researchers introduced perfectly matching layer. This layer around the photonic crystal configuration will absorb the reflected light in waveguide and thereby reducing the propagation loss *(Cheng, Arbet-Engels, Scherer and Yablonovitch, 2008)*. Since silicon is semiconductor it should be possible to control light electronically if optically and electronic device combined.
 Propagation light within the waveguide will obstructed by change in refractive index of medium will reflected as wavelength change. High aspect ratio of non-metallic structures will exhibit different properties like transparent electrode, heat shield. These nano fabrication leads entirely with the new concept of analyzing the sensor in the approximate way which includes the framework to determine the analogy of the photonic*(Hakan , Muhammet , Fatih , Mark , Murat , Brian Cunningham,and Utkan , 2017)*. In rods on configuration silicon cylinder rods made with high refractive index dielectric material such as silicon or gallium arsenide semiconductor material place them in air with periodicity related to 1.5 micron in this way we can create efficient structure means for controlling light at the telecommunication wavelength of 1550nm.Maxwell equation for steady state can expressed by eigen value problem. In direct analogy to the quantum mechanics.

Future benefits using photonic crystal includes thin film silicon photonic crystal. Original layers of solar cells are planar now replacing with photonic crystal periodic array will improve efficiency*(Hota, Mihir, Tripathy, Sukanta Ku,2016)*.

3. Sensor Design

Proposed work consists of all pass ring resonator in PhC based crystal structure. Nano rods made up of silicon in square lattice configuration placed in air with silicon substrate. Sensor structure as ring resonator is carved from the rods in air configuration *(Hadi , Erich, Muntasir, Fatih, Emily, Henrich , Daniel, Brian & Utkan,2009)*. Analyte potassium chloride in the rig resonator structure will interact with light as it propagates through the waveguides. Analysis has been carried for different concentration of potassium chloride. As the concentration of potassium chloride changes optical properties of sample also changes which brings out the wavelength shift in PhC configuration. Left end port indicates the position of optical source and right end port in photonic crystal configuration indicates detector(Weiqing Yang,2003). Detector will records the change in wavelength. Light entering at the left end port will guided through the ring resonator waveguide , in junction shown in figure propagation of light splits in two such that power distributed equally in both direction,*(Nina, Amølie, Martin, Jørgen, Frandsen, and Borel 2007)* interaction light with the sample in this region will bring out the wavelength alteration for that particular concentration of potassium chloride.
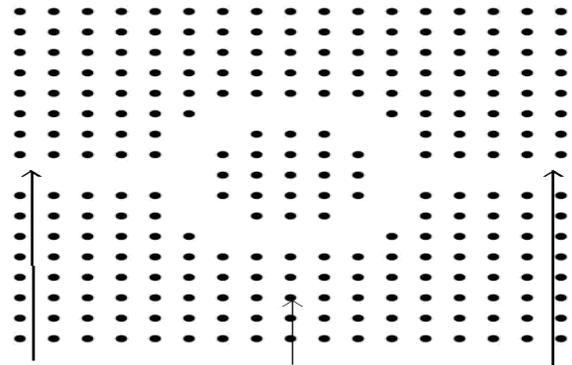

Figure 1: Design in the sensorbased crystal

Table 1.Parameter considered for design of photonic crystal

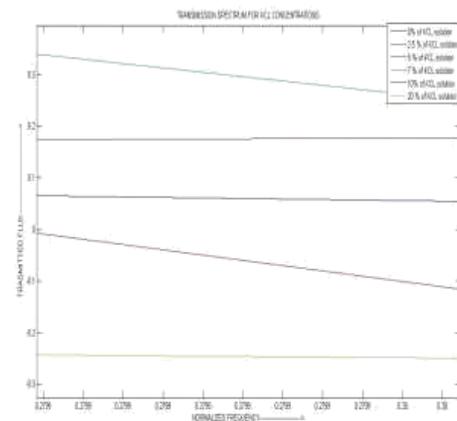| FDTD Tool	MEEP
PhC Lattice parameter	Square
Rod radius	200nm
ε (Delectric.constant)	= 11.56(silicon)
Light used	Gaussian pulse, frequency 0.295 and width 0.1

Figure 2: Transmission spectrum for wavelength shift

4. Result

From the obtained result and plotted graph says distinct shift in wavelength for each change in concentration of potassium chloride. Figure 3 shows combined transmission spectrum for potassium chloride concentration variation with respect to change in wavelength. As the concentration of potassium chloride changes in cavity optical properties of sample also changes which indirectly alteration wavelength of propagating light. Figure 4 shows wavelength change for varying potassium chloride concentration.
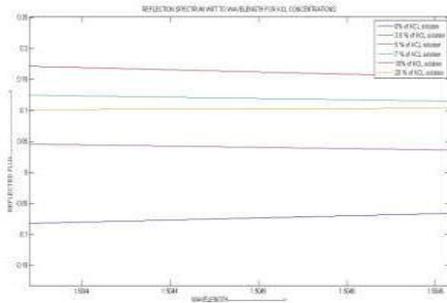
Figure 3: Frequency shiftspectrum of transmission
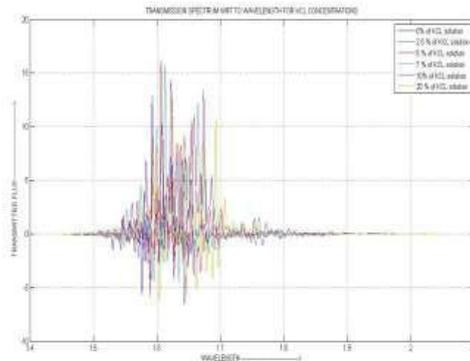
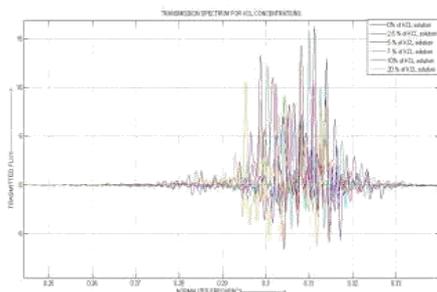**Figure 4**: Zoomed spectrum image of transmission

Figure 5:Transmission frequency shift for spectrum of Zoomed image.

The resonant frequency for corresponding 'k' points is obtained as in output of MPB design. The values are then implemented with a plot in MATLAB to obtain for different componentsband structures present in air. The band structures for chemical compounds are illustrated in the figures given below. The simulation diagrams obtained with the help of MPB are illustrated in Figure given below. The simulation diagrams shown below (Figure 6) are only for those frequency bands in which band gap is observed.
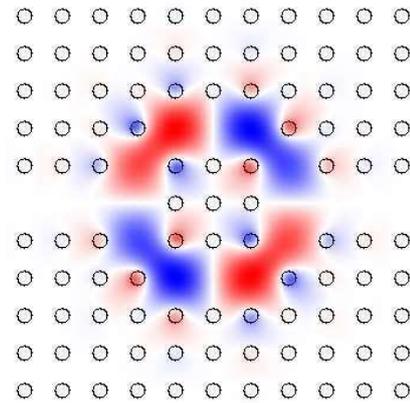

Figure 6: MPB simulation result for photonic crystal resonator

The transverse electric band structure for the photonic crystal ring resonator was calculated which was then designed using MIT photonic band gap tool (MPB).The transverse electric band structure for the resonator structure is as shown in figure 7.
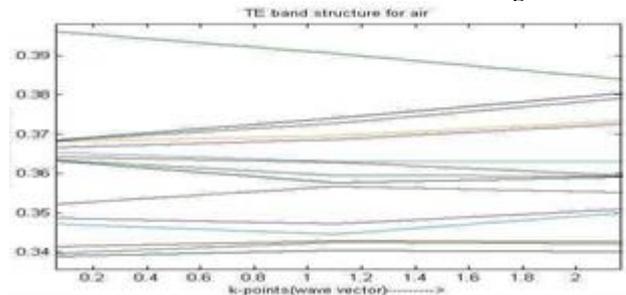

Figure 7: MPB simulation result for the transverse electric band structure

Designed all pass ring resonator sensor structure is viewed in GDS tool and fabrication setup verified with K Tool. Figure 8 shows layer structure in GDS tool and Figure 10 shows fabrication setup of sensor structure in K- Tool
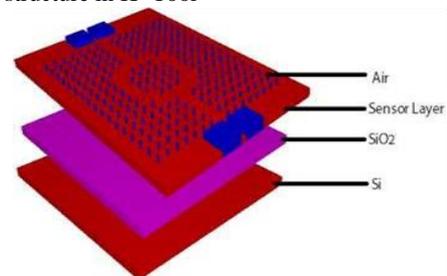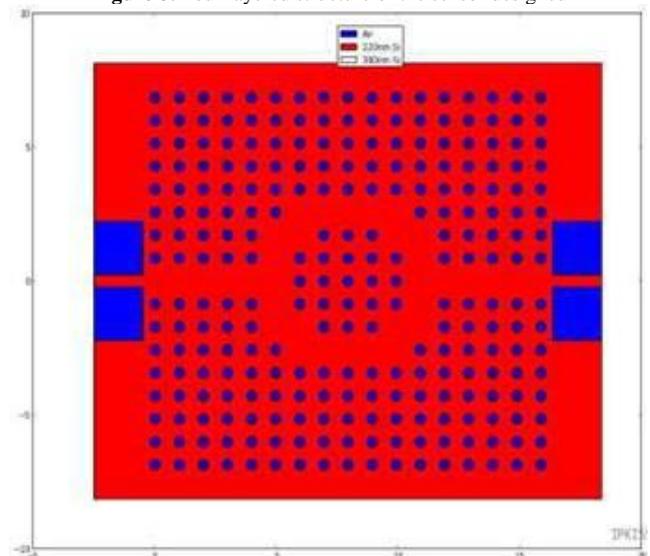

Figure 8: Four layered structure of the sensor designed

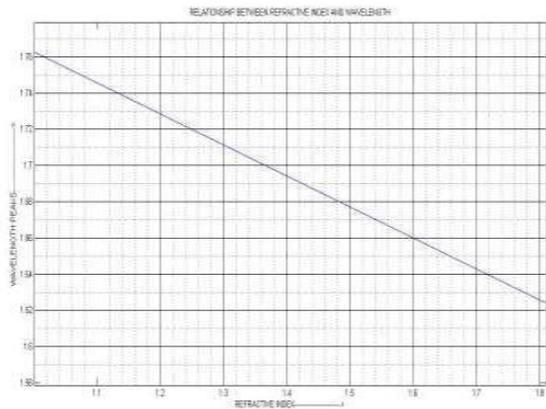**Figure 9**: OWLVISION GDS II viewer for the sensor designed

Figure 10. Refractive Index Vs Wavelength satisfying Maxwell equation

TABLE 2: Frequency spectrum analysis

% of KCL solution	transmission	Difference	reflection	Difference
0	0.3139	-----	0.3037	----
2.5	0.3111	0.0028	0.3043	0.0006
5	0.3099	0.0012	0.3081	0.0038
7	0.3081	0.0018	0.3099	0.0018
10	0.3077	0.0004	0.3111	0.0012
20	0.2837	0.024	0.3151	0.004

Table 3: *Wavelength spectrum analysis*

% of KCL solution	Wavelength spectrum analysis			
	transmission	Difference	reflection	Difference
0	1.763	------	1.587	----
2.5	1.625	0.138	1.607	0.02
5	1.623	0.002	1.613	0.006
7	1.613	0.01	1.623	0.01
10	1.607	0.006	1.643	0.02
20	1.593	0.014	1.646	0.003

The result in the above table sustaintial shifts that has been helped us in defining the concentrations of potassium chloride.

5. Conclusion

Proposed PhC configured all pass ring resonator analysed with the help of FDTD simulation tool for detection different concentration of potassium chloride. As the concentration of potassium chloride changes there is distinct shift in wavelength of spectrum graphs. Analyte which is detected by passage of light through the waveguide will bring out signature for each concentration of potassium chloride. High quality factor of 347663 obtained indicates feasibility of fabrication of photonic crystal sensor in proposed configuration. Remarkable sensitivity of 1nm/RIU is achieved during analysis. Designed high sensitive photonic crystal biosensor configuration is having beneficial in identifying intensity of chemical which is dangerous to human life.

Acknowledgment

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