Retraction

Retraction: Design of high sensitive glucose concentration sensor of photonic crystal cavity (IOP Conf. Ser.: Mater. Sci. Eng. 1046 012015)

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Design of high sensitive glucose concentration sensor of photonic crystal cavity

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Abstract. Photonic sensors, in light of proposed structures comprised of rhombus–molded gaps matched with two waveguides, have been developed as another enthusiasm for specialists in science and technology. In this paper, it has been demonstrated that by utilizing the rhombus–formed openings examination, they got outcomes which are brilliant inside the depression locale. Consequently, the quality factor (Q) and the affectability (S) can be essentially improved for the proposed structure. This investigation are performed by reproduction utilizing limited contrast time area (FDTD). Different affectability are acquired as 494.15 nm/RIU and 445.75 nm/RIU and 482.84 nm/RIU and 483.63 nm/RIU and quality factor as high as 5739.5 and 1.17×10^4, 8.7×10^4 and 3489.9 have been accomplished, deducing in a location breaking points of 5.52×10^-5, 2.84×10^-5, 3.67×10^-6 and 9.14×10^-4. This blend angle gives the proposed structure an extra exhibition as a component to play out a name free biosensing for the biomedical visualization.

1. Introduction

Optical sensors, that offer prompt revelation and measurement of organic investigation, have pulled in an extraordinary consideration owing to their promising highlights, for example, security in a burnable and hazardous environment, assurance from electromagnetic impedances, snappy reaction and the separated web based detecting capacity. Photonic gems (PhC) are occasional dielectric components with the capacity to screen and control light age and stream. The periodicity can be shaped by embedded and punctured openings in a dielectric component, making a photonic band hole (PBG) area [1–2]. PhC have been utilized in few applications, as in twist waveguides, channels, sensitizers, lasers, amplifiers, and resonators. Among those optical innovations, receptive photonic precious stone (PhC) built sensors have gotten a lot of consideration because of their microcosmic size, their high affectability, negligible model preparing denied of fluorescence classifying and the chance of participate in MEMS (Micro Electro-Mechanical Systems) [3]. More often than not, it is about physical and compound/biochemical challenges, the PhC sensors offer an incredibly solid narrow mindedness inside the substance to be broke down, because of the effect of the photonic taboo band [4]. The light can be packed in an extremely little volume, communicating with a colossal fluid light [5]. This wonder leaves the sensors to be very sensitive to minor refractive list (IR) factors that are shaped by the natural medium, with limits on the dividers of the PhC test. The examination is completed continuously and doesn't require the utilization of markers.

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The acquired discoveries can be improved via doing advancements in the sensor frameworks, for instance a warmth balance, the movement of the coupling and the topological streamlining of the geometry (shape, opening size, thickness and Si level). At this premise, an assortment of IR sensor proposition have been broken down and acknowledged by means of various sorts of PhC structures, for example, smaller scale depressions [6-7-8], waveguides [9-10], Slotted waveguides [11-12-13-14], hetero-structures [15], from which critical advancements in detecting stages have been arranged. A large portion of these arranged sensors work as a solitary thought or sensor and the quantity of brands that can be veiled on one event is very little. So, as to ease this lack, the fundamental thought is to build up a framework to permit blending a few research thoughts on a colossal substrate. That is the reason PhC-based sensors have been imagined and tried. A few photonic gem topologies have been proposed in the writing for structure of biosensors, contrasted and photonic precious stone smaller scale hole which has more deformity modes and optical restriction impact. So, as to improve the affectability of photonic precious stone miniaturized scale hole sensor, it is important to propose a sensor structure with colossal optical confinement impact [16-17-18-19].

In this paper, we depict the system and the reproduction procedure of the proposed PhC biosensor that is speculatively utilized for evaluating the glucose’s focus. Considering the silicon-on-encasing (SOI) innovation, the planned structure is molded by two waveguides with ring-formed openings pit framework. The detecting standard depends on the move of reverberation frequency $\lambda_0$, which occurs because of the adjustment in RI of the sensor when the PhC’s air gaps are involved by a homogenous demonized water ($n = 1.33$) or other fluid (distilled water $n = 1.3147$, methanol $n = 1.316$, acetone $n = 1.3445$, isopropyl alcohol $n = 1.363$ [20]). For the glucose recognition, it has been affirmed that the resounding frequency design changes its unearthly position following a direct demonstration when the glucose fixation somewhere in the range of 0% and 60% is applied. The properties of the sensor are reproduced utilizing the limited distinction time-space (FDTD) calculation (RSoft CAD). In theory and statistics, light concentration in photonic crystals is estimated by resolving Maxwell’s calculations in a varied dielectric medium, stated in equations (1) and (2); $E$ and $H$ are the electric and magnetic field intensities.

$$\nabla \times E(r, t) = \mu_0 \frac{\partial}{\partial t} [\varepsilon \varepsilon_0(r) \cdot E(r, t)]$$

$$\nabla \times H(r, t) = \frac{\mu_0}{\varepsilon_0(r)} [\varepsilon \cdot e_0(r) \cdot E(r, t)]$$

$\mu$ is the permeability which equals to $\mu_0$ as the measured material is non-magnetic, $\varepsilon$ symbolizes the permittivity which is habitually written as $\varepsilon = \varepsilon_0(r)$, where $\varepsilon_0$ is the permittivity of vacuum and $\varepsilon(r)$ is the relative permittivity of the material.

Equation (3) is obtained by solving Equation (1) and inserting it into the time derivative of Equation (2):

$$\nabla \times \left( \frac{1}{\varepsilon_0(r)} \nabla \times H(r, t) \right) = -\frac{\varepsilon_0}{\varepsilon} \big[ \mu_0 H(r, t) \big]$$

Assuming harmonic time dependence for the magnetic field with angular frequency $\omega$.

$H(r, t) = H(\vec{r}) e^{i\omega t}$; we obtain the master equation for the magnetic field:

$$\nabla \times \left( \frac{1}{\varepsilon_0(r)} \nabla \times H(\vec{r}) \right) = \left( \frac{\omega}{c} \right)^2 \vec{H}(\vec{r})$$

The spatial and temporal steps are related through this equation:

$$\Delta t \leq \frac{c}{\Delta x^2 + \Delta y^2}$$

Where $c$ is the speed of light in vacuum.
Δx and Δy are spatial stages in the x and y directions, respectively.

In order to terminate the computational field, the perfectly matched layers (PMLs) are employed [21].

2. Materials and theoretical model

The proposed plan depends on a 2D-PhC structure. It comprises of a periodical triangular grid of air-expanded gaps punctured in a silicon (Si) piece (refractive list \(n_{si}=3.45\)). The range of the air openings is \(r=0.38a\), with a cross section steady \(a=550\) nm, the thickness of the PhC chunk is set as \(h=230\) nm. The Silicon dioxide (SiO\(_2\)) layer with a thickness of 1500 nm and low refractive record is utilized as a supporting layer to the high filed Silicon based chunk to keep light to the pit center, forestalling optical misfortunes in the lower substrate, and the light detainment in the vertical course is then protected by full interior reflection. So as to diminish the computational time which may happen in 3D structures, the PhC is changed into a 2D framework with the dielectric medium having the viable refractive file of 2.868, which relates to the powerful file of the focal guided TE mode. For the accompanied numerical reenactments, we have applied the powerful file approach given in [22], in blend with two different techniques specifically the 2D-PWE and the 2D-FDTD from the RSoft programming bundle. The dispersal properties of the deliberate PhC structure have been investigated utilizing the 2D-PWE technique in Band SOLVE programming. For the TE polarization, the photonic band hole (PBG) covers the scope of \(\omega_1=0.278 (a/\lambda)\) to \(\omega_2=0.4 (a/\lambda)\) comparing to the wide frequency goes of \(1323.7 > \lambda > 1908.1\) nm.

Subsequently, the viable working frequency extend is adequate to satisfy the detecting need, where the full mode creates a wide frequency move. Figure 1 shows the schematic of the planned biosensor. This last comprises of two waveguide couplers and one cavity. The two waveguides are acquired by expelling one column of air-expanded gaps in the x course, to couple light source in and out the Silicon section punctured ring-molded gaps PhC depression.

![Figure 1](image.png)

Figure 1. (a) Schematic diagram of the proposed rhombus-shaped photonic crystal cavity coupled to an input and output the PC waveguides.
(b) Schematic side and sectional view of the proposed PC biosensor structure in SOI substrate.

It is important to note that the ring-formed gaps arrangement doesn't just give greater adaptability as far as planning new structures in correlation with to roundabout molded ones, but also to improve the optical field containment, thus light-liquid cooperation inside the ring of low-dielectric material territory [23-24].
The ring-formed gap parameters are characterized by their internal and external range $R_{in}=121\text{nm}$ (0.22$a$) and $R_{out}=247.5\text{ nm}$ (0.45$a$) individually. In this manner the ringed air-expanded district is given by $R_{out}-R_{in}=126.5\text{ nm}$. The entire depression framework is isolated from the info and yield waveguides by three PhC gaps.

Two-dimensional limited contrast time-area (2D-FDTD) technique is utilized to gauge the structure's usefulness, considering the Perfect Matched Layers (PML) conditions in computations, to guarantee no back appearance in the broken down locale's breaking point.

In reproduction process, a TE energized Gaussian optical heartbeat, covering the entire recurrence scope of intrigue, is propelled at the information port to energize the hole modes. A force screen was put toward the finish of the yield waveguide to gauge the transmitted sign, and to improve the reproduction's precision, FDTD investigation is completed with a lattice size of 0.01 nm.

3. Sensing properties of the designed structure

So, for showing the working head of the PhC pit based RI biosensor, a progression of FDTD reproductions have been led. The starter detecting examination is finished by assuming the neighborhood penetration of de-ionized (DI) water in the hole detecting zone, this compares to the change in refractive file (RI) of the ring molded gaps from 1.33 (DI-water) to 1.332305450 of (0 g/l to 60 g/l).

The relation between both the glucose’s RI $n$ and concentration $C$ can be expressed as follows [25]:

$$n = 0.00011889.C + 1.33230545$$  \hspace{1cm} (6)

For a neighborhood invasion, an exact system dependent on small scale penetration innovation by means of empty submicron size pipettes has been tentatively shown in [26]. This strategy permits to control a fluid affidavit inside an ideal PhC gap, and not influencing the nearby ones.

For assessing the usefulness of the structure, for instance fluid, should be in contact with the sensor, and the reproduction is done by changing the RI of the gaps from 1.3147 (refined water) to 1.363 (isopropyl liquor). This prompts a move in the yield transmission range that relates to an adjustment in the RI.

Figure 2. Specific layouts of defected holes.
Figure 2 presents the specific layouts of defected holes. As can be seen from figure 3, the quality factor, sensitivity and transmission spectrum of resonant mode will change with N of (Design-A, Design-B, Design-C and Design-D).

Normalized transmission spectrum of the PC cavity as a function of wavelength for different numbers N (DesignA, DesignB, DesignC and DesignD) is also illustrated in figure 3. According to 0g/l to 60 g/l with different numbers of functionalized circular, we can find that the normalized transmittance remains the same and can reach to 84.5. It can be seen in this figure that when the number of functionalized holes increases, the resonant wavelength shifts toward larger amounts. Figure 3 is in their lower values, which can explain the choice of the local infiltration instead of the total infiltration.

![Figure 3. Transmission spectra.](image)

**Figure 3.** Transmission spectra.

![Figure 4.](image)

**Figure 4.** (a) The resonant wavelength variations according to the change in the glucose concentration. (b) The quality factor variations according to the change of the glucose concentration. (c) Resonant wavelength shift as a function of the refractive index n.
As it tends to be found in figure 4(a), when the glucose fixation changes as per various quantities of N (Design A, Design B, Design C and Design D) there is a particular field at frequencies 1519.11nm to 1575.39nm, individually.

As indicated by figure 4(b) the best quality factor has a place with the structure N=0 by a position of 106. It is seen in the bend that affectability in all structures has significant and Figure 4(c) shows the frequency move of the plans A-D as a component of progress in RI. Great qualities from the relating estimations of sensitivities are 520, 537, 589, 604 nm/RIU for Design-A, Design-B, Design-C and Design-D, individually.

Reproduction results have been outlined in table 1. It is clear that the movements in resounding frequencies have been gotten in any event, for the slightest change in the example RI, subsequently; unique glucose concentrations in the infiltrated test could be all around identified. It can likewise be noted that the quality factor esteem increments relatively to its underlying worth before the tests invasion. This is because of the expansion in the surrounding refractive file, which diminishes the PhC differentiate [30]. In this manner, we can reason that the glucose biosensor based PhC-RSH pit presents high exactness and it is exceptionally touchy to the arrangement RI variations. A 0.2% RIU change in the RI arrangement may prompt the resonance top moving almost 1.1 nm. Moreover, high sensor exhibitions require additionally a low estimation of as far as possible (DL) which is conversely relative to Q and S. The identification breaking point of refractive record change can be communicated as follows [27-28]:

\[ DL = \frac{\Delta n}{10.08} \]  

Table 1. Comparison of performance’s parameters of the proposed biosensor with various similar PC-based designs.

| Sensing structure | Sensitivity (nm/RIU) | Q factor | detection limit (RIU) |
|-------------------|----------------------|----------|----------------------|
| [28] RI biosensor formed by two waveguide and one micro-cavity. | 330 | 3.82×10^3 | - |
| [23] RI biosensor consists of H2-type nano-cavity and broadband W1 waveguide. | 131.70 | 2.96×10^3 | - |
| [25] RI sensor based on a ring–slot cavity coupled to an input and output waveguides. | 160 | 10^7 | 8.75×10^-5 |
| [29] RI sensor consists of ring resonant cavity coupled to an in and out line defect PhCstructure. | 330 | 8.2×10^6 | 1.24×10^-5 |
| [30] RI sensor consists of ring cavity coupled to an opt fluidic slow-light waveguide in a PhC platform. | 293 | 950 | - |
| [31] RI biosensor based ring-shaped holes cavity coupled to an input and output waveguides. This work for design A | 462.61 | 1.112×10^5 | 3.03×10^-6 |
| B | 494.15 | 5739.5 | 5.52×10^-5 |
| C | 445.79 | 1.17×10^4 | 2.84×10^-5 |
| D | 482.24 | 8.7×10^4 | 3.67×10^-6 |

The table displays the performance parameters such as sensitivity, quality factor and detection limit of the designed biosensors based on PC-RSH cavity and also shows a comparison with several previously reported PC-based biosensors. The proposed biosensor exhibited significantly higher sensitivity due to the increase in light matter interaction.
within the sensing area. Additionally, the quality factor value and the detection limit of the designed device were favorably comparable to the reported works.

4. Conclusions
In this paper, we have proposed a novel design of refractive index optical sensor based on 2D photonic crystal. The structure consists of a 2D triangular array of silicon substrate. The proposed sensor is formed with a glucose concentration width modulated line-defect microcavity. In order to enhance the sensitivity of our sensor, we have tuned some structural parameters, such as the position, diameter of holes and introducing an air-slot. The principle of detection is based on the measurement of wavelength due to change in RI. In the present work, the variation in the analyte glucose concentration is analyzed by using FDTD simulations. Various sensitivities and high Quality factor have been attained, concluding very small detection limit respectively. These four structures are considered as basic structures for the performance of the detection process. In this case, the sensitivity is achieved to 482.82 nm/RIU with a detection limit of 3.67×10\(^{-6}\) RIU. Which can be important in many applications and be widely used in the detection of organisms, nanoscale sensors and explosive environmental.

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