Designing of Lab-On Chip using Photonic Crystal Biosensor in the Detection of Glycerol and Glucose Concentration for Various Applications

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Abstract: The paper is all about the analysis of Glycerol and different concentrations of Glucose using Photonic Crystal (PhC) based sensor. These are the methods that can be used in the medical, pharmaceutical, bio technological fields. Photonic Crystal based sensing is so rapid and precise that it is going to be the technology of the near future. While conducting the tests for glycerol and glucose, experimental tests are conducted to determine based on a lot of molecular equations and iterations and the information about its concentration is done by mathematical calculations and plotting graphs. Most of the time there is a great possibility of inaccuracy. These methods are a lot time consuming and it often leads to misleading interpretation. This problem can be avoided by using Phc based sensor. This sensor is generally based on the RI of the sample and the result is obtained in a very few seconds. For analysis of samples we use the method of FDTD. The transmission range is obtained after simulation. From this spectrum, it is observed that there is a shift in output frequency and transmitted power. Hence the proposed PhC design can act as a sensor. A PhC based optical sensor has been designed and simulated by considering rods in air configuration. The small changes in dielectric constant of the samples can be measured using this sensor. This simulation is done by MEEP and MPB work, RI of 10% and 20% Glucose and glycerol is used as a sample.

Keywords: Phc sensor, MEEP**,** RI-refractive index.

Introduction

A photonic crystal is made of nanoscale structures that either allow or block individual wavelengths of light.

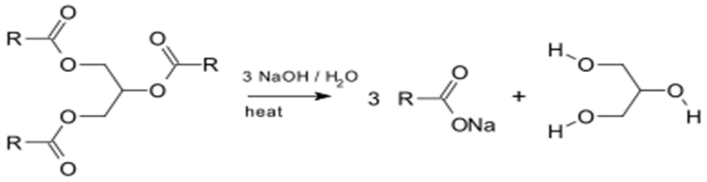
Analysis of the glycerol and the perfect concentrations of glucose are very much necessary as those are a key component in most of the surgeries especially in the bio-tech medical fields. In food and other beverages, the solution of certain concentration of glycerol serves as a sweetener, solvent, humectant, solvent and in may preserve foods. It is found in cough syrups, allergen immune therapies, elixirs, solid dosage form pharmaceutical tablets and expectorants, toothpaste, mouthwash and expectorants, skin care products having cream, hair care products like soaps, shampoo, serum.

When it comes to the case of glucose different concentration has unique applications for example 10% aqueous glucose solution is the chief component to supply carbohydrate as required during parenteral nutrition, rehydration in case of water loss and dehydration states in patients with high carbohydrate need, dilution of compatible medicinal products. A 20% aqueous glucose solution is frequently used adults and children to restore blood glucose concentrations in the treatment of the hypoglycaemia mostly resulting from the insulin excess. It is also used to provide temporary relief from the symptoms of cerebral oedema. Hyperosmotic glucose may correct hyperkalaemia in renal failure and also forms of hyponatramia.

The chemical equation for an aqueous solution of glucose is given by

$$C_6H_{12}O_6\ (S) + H_2O \longrightarrow C_6H_{12}O_6\ (aq)$$

The chemical equation for an aqueous solution of glycerol is given by



Photonic Crystal are the arrangement of refractive index of different samples (given here is the samples of Glycerol and concentration of Glucose) with Photonic band gaps which won't allow light to pass through a particular frequency range. Photonic Crystal Sensor makes use of the fact that property of light changes due to change in refractive indices. The technology behind PhC based sensing is the fact that each material has distinct permittivity 'ϵ' that is higher than that of air. This results in alteration of electromagnetic wave propagation when the same pass through the material.

Theory

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The photonic band gap can be comparable to solid state electronics. By introducing defect the property of sensing applications is utilized. The transmission spectrum is obtained for the specific analysis. The Photonic integrated circuit consists of light source, detectors and sensors. Photonic crystal sensors have the advantages of detecting the samples. Also we can obtain high sensitivity and selectivity [3].

Using the MEEP simulation tool on FDTD method to measure the shift in frequency of different samples we have proposed a two-dimension Phc sensor. The FDTD method uses Maxwell's equation. Using Maxwell's equations FDTD method can solve complicated problems. Important consequence of Maxwell's equation is the demonstration of how fluctuating electric and magnetic fields can propagate at the speed of light.

Maxwell's equation is used for modelling of time harmonic electromagnetic wave. We can express Time harmonic waves in the form of

$(x, t) = \{(x)^{(jwt)}\}$

$\nabla xE = jwH$

$\nabla xH = -jwE$

$\nabla.D=0$

$\nabla.B=0$

Where,

E= Electric field vector

H=magnetic field

$\mu = \mu_0 \mu_r$=permeability of E

$\in = \in_0 \in_r$ =permittivity of E

D=electric flux density

B=magnetic flux density

Where,

$D = \in_0 \in_r E$

$B = \mu_0 H$

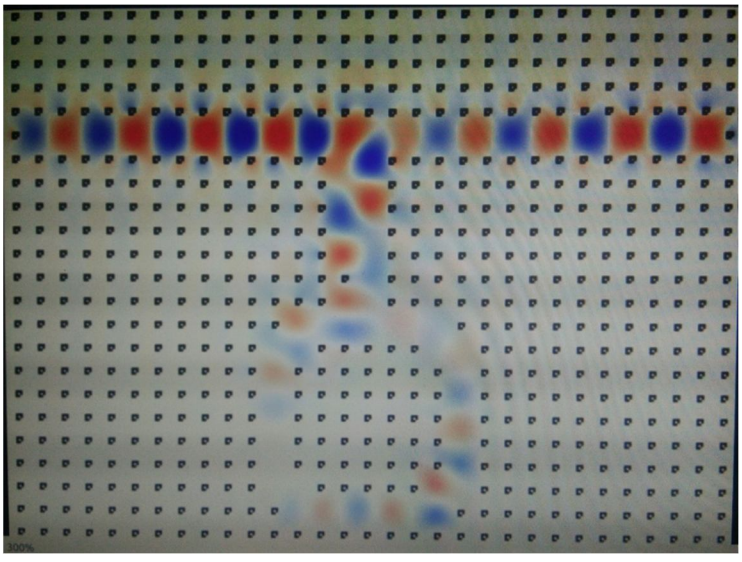
By equating equations 3 and 4, we obtain a single equation

$\nabla \times 1/\in \nabla \times H = \omega 2/C2H$

This equation is known as Wave equation for magnetic field. It also describes that ω is inversely proportional to $\in$.

Sensor Design

In this paper MEEP tool is used for sensor design and simulation. We have designed a Phc sensor which will help us in the detection of the materials in the advanced way. It consists of 2-dimensional square arrangement. Here glycerol and glucose samples are sited in rods-in-air sensor. The lattice is periodically uniform in x-y plane. The light passed from one end and will interact with the samples and gets detected from another end. As concentration in the components varies, the refractive index also varies and so they will be transmission of light in the Phc.



Basic specification of sensor design
1) Rods in air configuration
2) Square lattice structure
3) Lattice constant 'a'=1
4) Radius of rods 'r'=0.199μm
5) Dielectric constant of silicon rods =12
6) Height of rods= 0.65
7) Wavelength= 500nm
8) Defect= Line Defect
9) Lattice size 29x27
10) Light source= Gaussian Pulse

Simulation Result

MEEP tool provides both the frequency and the output transmission flux values. Number of frequencies where output flux had to be evaluate was 500 (nfreq=500).
All 500 values which we obtained through MEEP are imported to an excel sheet. The values in the excel sheet are first imported to MATLAB and are plotted through MATLAB.

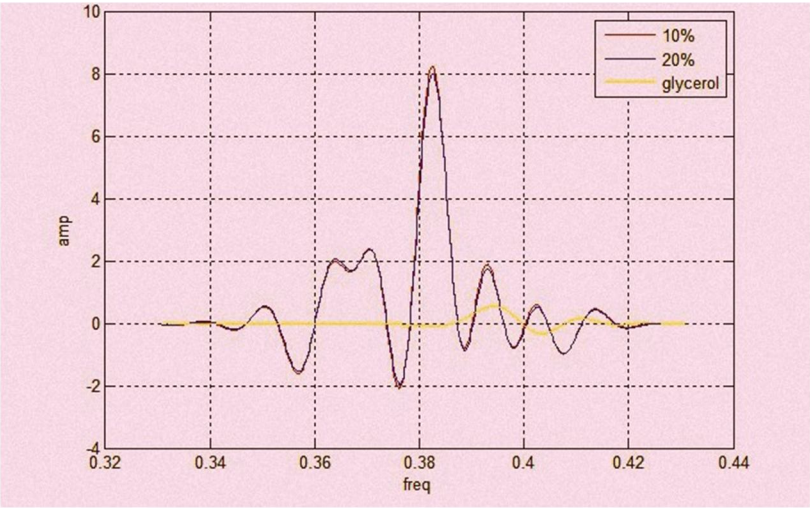


Fig 2: Transmission spectrum of glycerol and 10% and 20% glucose solutions

Fig 3: Enlarged Graph of 10% and 20% glucose solutions

Above Fig 2 shows the transmission spectrum of glycerol and 10% and 20% glucose solutions. The transmission spectrum is frequency versus amplitude. In this red colour indicates spectrum of 10% glucose solution. Blue colour indicates spectrum of 20% glucose solution. And yellow indicates spectrum of glycerol. By observing this spectrum we can see the frequency and amplitude shift in spectrum of glucose concentration and glycerol. Frequency shift occurs when there is small change in R.I values of glucose and glycerol.

Table 1 Result of sensor design for Glucose and Glycerol

Samples	R.I Values	Centre Frequency	Quality Factor
10% Glucose	1.3477	0.38089	4443
20% Glucose	1.3635	0.3799	22034
Glycerol	1.4729	0.29789	4532

Conclusion

In this paper, We have designed and developed a sensor which can be fictional as a Lab-on-chip. The output transmission flux was obtained when were used in 10% glucose, 20% glucose and glycerol background. MEEP tool is the software that is used to design and simulate the Photonic Crystal. The amplitude and frequency shift in the frequency spectrum has been observed and recorded by plotting the so obtained flux values in the MATLAB software. The sensor that is designed by all this process is highly sensitive with the Quality factor. The designed sensor can be helpful in the medical, food industries, bio-technology field and skin-care products application. This designed sensor gives more accurate result than other method.

Acknowledgment

It's been an immense pleasure to thank our guide Dr. Preeta Sharan (head of RND Dept TOCE) to provide us with a great opportunity to work alongside with her on a very interesting topic. And I specially thank our PRINCIPAL and HOD for their constant encouragement .Last but not the least I extend my heartfelt gratitude to our parents and all my friends for their encouragement, moral support and affection throughout our dissertation.

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