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Design Nanocavity Coupled Biosensor Based On 2D Photonic Crystal

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Abstract- **in this paper we have presented a two dimensional photonic crystal based biosensor. The structure of biosensor consists a linear waveguide with nanocavity which is used for sensing purpose, their refractive index change according to sensing material. Plane wave expansion method use to find out a bandgap. For the purpose structure band gap is 1339 to 1981nm and input wavelength is 1550nm. The simulation results have analyzed by using the finite difference time domain (FDTD) method.**

Keywords— **Finite Difference Time Domain, Photonic Crystal; Plane Wave Expansion; Refractive Index.**

I. INTRODUCTION

The term "biosensor" is a biological sensor. Biosensor made a transducer and biological element like enzyme and antibody or a nucleic acid. Biosensor is sense a biological element connected to a transducer and converts a measureable signal. A biosensor is an analytical device, used for the detection of an analytes that combines a biological component with a physicochemical detector. Biosensor is many type like- electrochemical biosensor, blood glucose biosensor, potentiometric biosensors, conduct metric biosensor, thermometric biosensor, optical biosensor etc.

II. THEORY

Photonic crystals are periodic structures made of dielectric materials that are divided into three structures: 1D, 2D, and 3D based on their refractive index distribution functions [1].

Because 1D structures lack a complete band gap and it is too difficult to make 3D structures due to a small constant lattice [2], therefore, 2D structures are used because they have the complete band gap and easier to make the 2D structure rather than the 3D one. Usually, there are two modes in 2D structures: air holes in a dielectric substrate and dielectric cylindrical rods immersed in air. Photonic based bio sensor is new research direction in optical field. Photonic crystal is natural material and the periodicity of material is maintaining different background material. It is a periodic dielectric structure with lattice parameter based on order of wavelength of propagated electromagnetic wave. One of very important characteristics of photonic crystal is its light confinement and controlling property. These characteristics allowed the crystal to use in various sensing applications [3] . There are two types of design a biosensor: one is change a refractive index and sense the shift of wavelength, and the other method is change a thickness in the surface level and changes are measured [4] Recently S. H. Kwon *et al.* proposed a photonic crystal chemical sensor based on a cavity [5]. Also Wang *et al.* designed a refractive index sensor for bio layers and chemical sensing, consisting of a micro cavity and two waveguides [6]. In this paper, we design a linear waveguide based biosensor with nano cavities with FDTD tool. Finite-difference time-domain or Yee's method is a numerical analysis method used for modelling differential equation. FDTD is time domain method with wide frequency range and treat nonlinear material property .FDTD method based on Maxwell equation.

III. DESIGNING OF BIOSENSOR

The layout of photonics crystal biosensor based on linear waveguide with two nanocavity and 2D photonic crystals have a 21 silicon rod in Z-direction and 17 silicon rods in X-direction. For the propagation of light inside the structure 1550 nm wavelength is use. For the detection of wave at another end optical detector is used. The design of bio sensor structure is based on Si rods background wafer in air type with the square lattice shape. The refractive index of silicon material is 3.47 and air is 1. The radius is 110 nm and lattice constant of structure is a= 570 nm. In this paper, we design a two dimensional photonic crystal biosensor proposed by linear waveguide with nanocavity. We present a structure for bio sensing application. When sensing analytes is induced to nanocavity the refractive index of nanocavity is changed and transmission spectra is vary according to sensing analytes which can determine a property of sensing analytes. In this paper we design a ultra small novel biosensor for bio sensing application based on nanocavity. Fig 1 shows a 2D photonic crystal biosensor with linear waveguide and nanocavity.

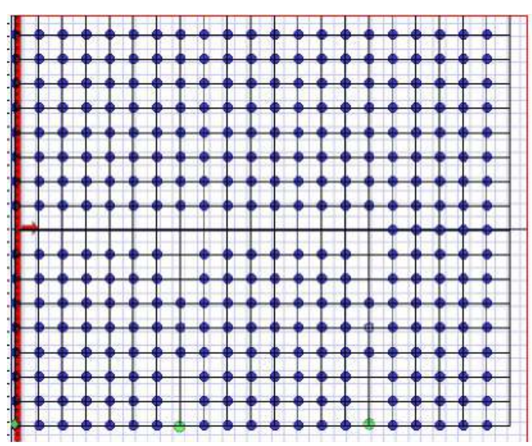

Fig.1 2D Photonic crystal based biosensor layout

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In the Fig. 2, the band diagram of Sensor structure has shown which gives the Photonic Band Gap for Transverse Electric modes. The complete structure has one band gaps. The PBG is in the range between the wavelength 1339 nm and 1981 nm. The Plane wave expansion (PWE) method is used, to estimate the band gap and propagation modes of the PC structure without and with defects.

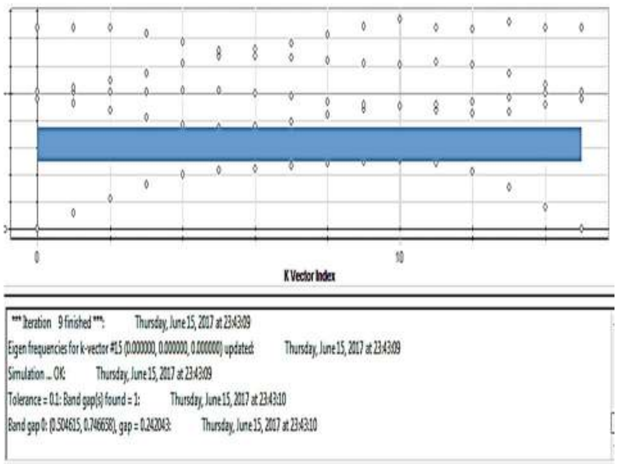

Fig.2 TE band diagram square lattice

Table 1. Design Parameter and its value used in biosensor

S.No.	Name of Parameter	Values
1.	Radius of Si(rod)	110nm
2.	Lattice constant	570nm
3.	Refractive index of Si	3.47
4.	Refractive index of wafer (air)	1
5.	PBG range	1339-1981
6.	Polarization	TE

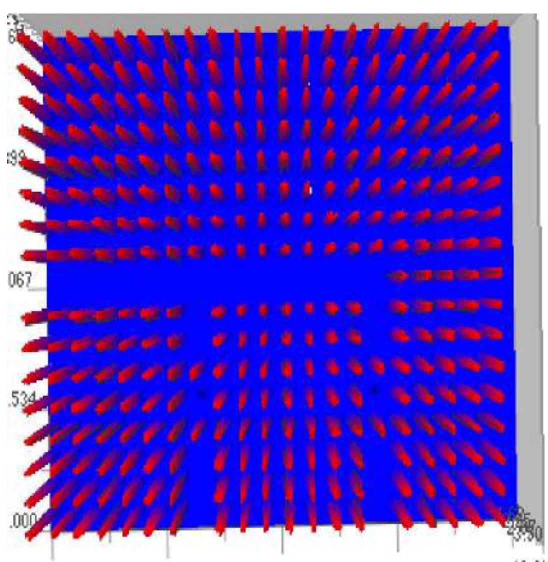

Fig. 3 Refractive index of structure

IV. SIMULATION AND RESULT

The performance of sensor has measured by 2D finite-difference time-domain (FDTD) method. When we observe that the refractive index (RI) of the nano-cavities has been changed, it means that the sensing molecules flow in an aqueous medium. The presence of target molecules varies the ERI. The change in the ERI is utilized to calculate the presence of target molecules. This sensing mechanism is based on homogenous sensing. So the output spectrum is changed. In this section, we suppose $n1$=1.42, $n2$=1.49. With the variation of the nano-cavities size 110 nm to 100 nm, the transmission spectra changes with respect to the RI variation as shown in Fig. 4(a). Fig shows a transmission 94 % with 1550 nm wavelength and 1.42 refractive index.

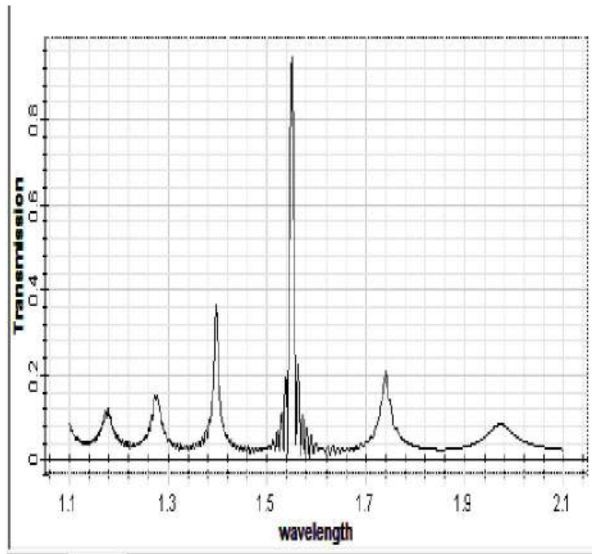

Fig 4: Transmission spectrum with refractive index (1.42)

Fig 5 shows transmission spectra with wavelength 1550 nm and refractive index 1.49. In this wavelength and refractive index transmission is 52%

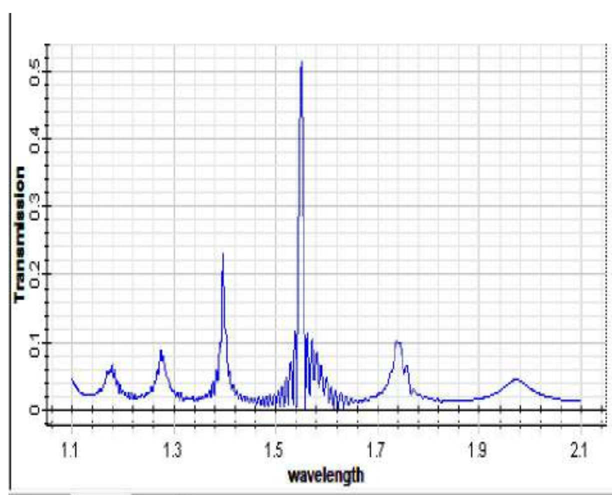

Fig. 5 Transmitted spectrum with refractive index (1.49)

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TABLE 2. Analysis of transmission spectrum according to Refractive Index.

S.No.	REFRACTIVE INDEX	TRANSMISSION
1.	1.42	94 %
2.	1.49	52 %

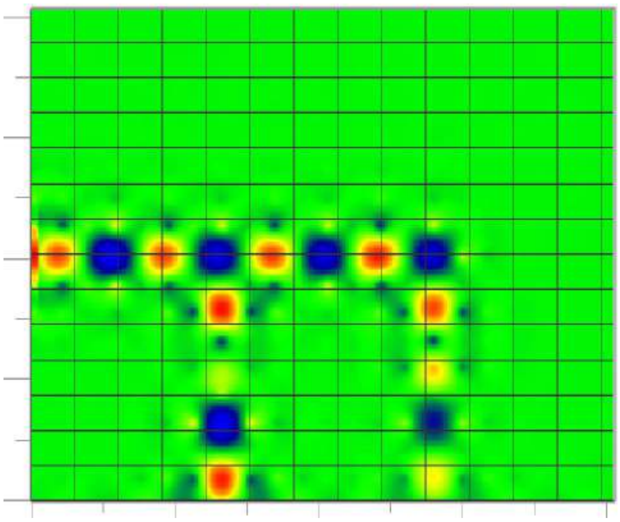

Fig. 6 Electric field distribution of the sensor

Fig 6 shows an electric field distribution at 1550nm .at this wavelength the waveguide is fully coupled and reached at the output port. Outputs were achieved with the good transmission efficiency which could make detection of bio-chemicals easy and possible.

V. CONCLUSION

In conclusion, a novel compact linear waveguide two channel biosensor has been designed. The channels of this sensor can measure two different refractive indices in a special time. The biosensing mechanism is based on the effective refractive index change of the sensing rods . The bio-molecules have been filled within the nano-cavities and transmission spectrum studied the output terminal. The structure has been optimized in good transmission. By filling an analyte into the nanocavity, the transmission shifted, and this process was utilized for determining the properties of the analyte.

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