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High Quality Factor 2D Photonic Crystal Based Pressure Sensor

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Abstract: This work presents the High Quality factor 2D photonic crystal based pressure sensor is proposed and designed with high quality factor. The sensor is created by the coupling of two photonic crystal based waveguides and one nanocavity. The photonic crystal with the rectangular structure having a triangular lattice which is composed of silicon material. Point defect is placed at the centre. Hole type crystal are created. Based on the optimization ,the resonant wavelength of the sensor have a linear shift as increasing the applied pressure in the range of 0GPa-5GPa and the quality factor is observed.

Keywords —Photonic crystal, Rectangular structure, Point defect, Refractive index, Quality factor, FDTD Solution.

I. INTRODUCTION

The Photonic crystal is a type of exploring the research direction in optical field. It is a structure and it has a property of appearing variation in refractive index as per the scale of light in different directions this is one, two, three directions. Photonic crystal is a periodic natural metallo dielectric nanostructure with low and high dielectric constant material. One of the very important properties of the photonic crystal is its light confinement and controlling property.

Sensor is device which senses physical and biological parameters. In past various electronics sensors are designed but these sensors have certain limitations and this limitations are overcome by optical sensors are classified as one dimensional, two dimensional and three dimensional.

In this work we design 2D photonic crystal with rectangular silicon material and triangular lattice, point defect is place at the centre and hole type of structure. The refractive index of silicon varies under pressure and the resonant wavelength shifts, the sensor properties such as quality factor, resonant wavelength and transmittance are investigated. The analysis of the sensor has been conducted by FDTD solution method.

II. PRESSURE EFFECT ANALYSIS

A. Pressure sensor

The sensor is related to change in refractive index of the silicon material. This change in refractive index will modify the resonant wavelength of the structure.

B. Sensing principle

Depending upon the parameters of lattice constant, ratio of radius to lattice constant and refractive index of material. The change in any geometry of the pressure may cause some changes in photonic band gap (PBG) which shifts the resonance wavelength of sensor.

The relationship between pressure and refractive index is given by

$$n = n_0 - (C_1 + 2C_2)\sigma$$

$$C_1 = n_0{}^3 \left(\frac{P_{11} - 2VP_{12}}{2E}\right)$$

$$C_2 = n_0{}^3 \left(\frac{P_{12} - V(P_{11} + P_{12})}{2E}\right)$$

Where, E is the Young's modulus, for silicon E is 190GPa. V is the Poisson's ration and it is 0.25. P11 and P12 are the strain constants. n0 the previous refractive index. For silicon P11 is -0.101 and P12 is -0.0094.

III. DESIGN AND ANALYSIS OF 2D PHOTONIC CRYSTAL

Design and analysis of 2D Photonic crystal

The structure of the 2D Photonic crystal is shown in below figure

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Fig.1.Schematic diagram 2D Photonic crystal *Based pressure sensor*

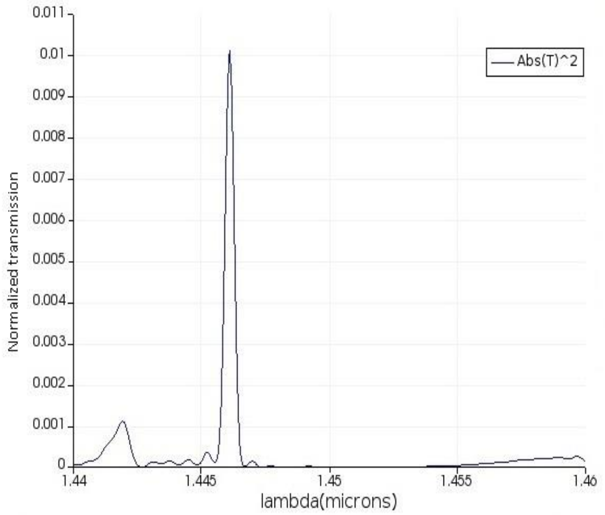

Fig.3. Normalized transmission with wavelength for case (a)

Two line defects are placed by removing holes in slab in order to form input and output waveguides as shown in Fig.1.The port which is marked input as input port and output as output port. The light which is a source placed at input. Photonic crystal inserted with source, monitor, and Quality analysis group and simulation region.

The design consists of rectangular slab having the thickness of 220nm, hole type circle is introduced at the Centre having the radius value, triangular lattice with 540nm, input source and monitor is used to create a structure.

Steps to create photonic crystal ring resonator

- A rectangular structure is chosen as a silicon slab which should be given the dimension as 15*30µm.
- Create holes in slab with hole radius 165nm and lattice constant 540nm to form a triangular lattice structure.
- Create two line defects that act as straight waveguides. It is created by removing holes in one complete row or by not creating holes.
- Set a source at the input port which should be of the Guassian mode source.
- Set a monitor at output ports to observe electric field, magnetic field and normalized transmission as a function and wavelength.
- Define simulation region.
- Run the simulation region to obtain the result.

A. DESIGN OF WAVEGUIDES AND NANOCAVITY

In this structure it consists of mainly rectangular structure with silicon material. Point defect is placed at the centre of the structure. Hole type circles are arrange

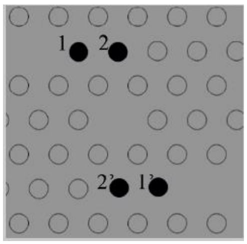

Fig.2. Representation of point defect and indicates the cases

In this representation the point defect is introduced by removing the single hole at the centre of the structure and there are three cases considered. In case (a) the holes numbered 1 and 1', and 2 and 2'are kept. In case (b), rods numbered 1 and 1' are removed and 2 and 2' are kept. In case (c) rods numbered 1 and 1', and 2 and 2' are removed. The normalized transmission of the sensor with different wavelengths is obtained after simulation.

IV. SIMULATION RESULTS

The simulation gives the highest quality factor and normalized transmission and resonant wavelength. After designing, the simulation is carried out using FDTD.

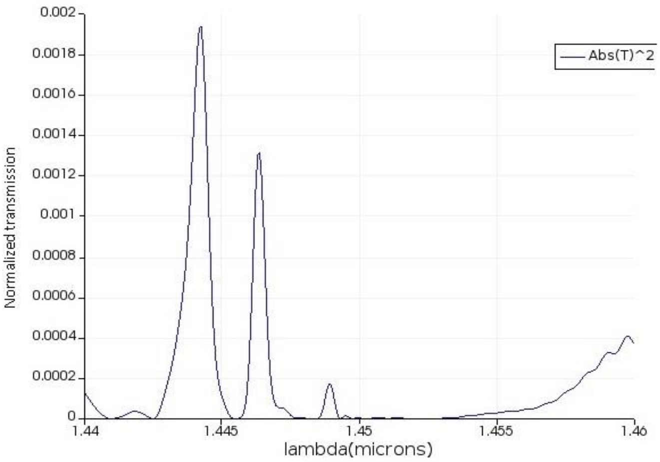

Fig.5. Normalized transmission with wavelength for case (c)

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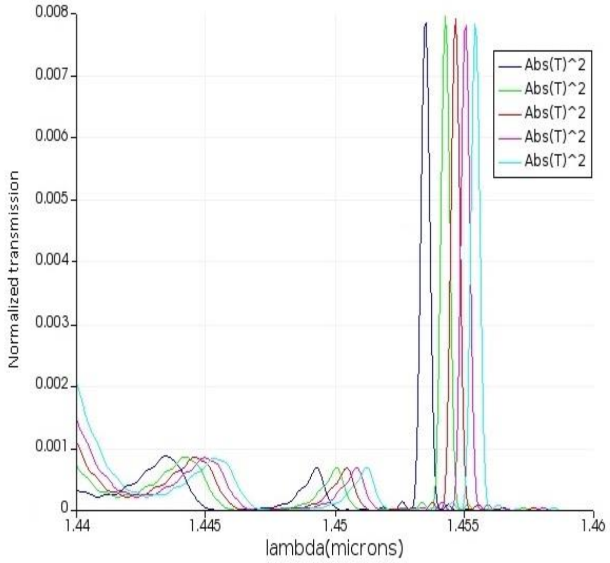

Fig.6 Normalized transmission for different pressure

Figure2, 3, 4 and 5 represents the normalized transmission with resonant wavelength. For case (a) this represents the High quality factor when compared case (b) and case (c).

Table 1 Parameters of resonant wavelength

SL.no	Resonant wavelength	Quality factor
1	1.4461	4382
2	1.44590	2728.49
3	1.44417	3139.5

This table represents the resonant wavelength and quality factor. In this case a, b, c the best quality factor is obtained.

High Quality factor:

A cavity is considered to be a High Q cavity for which the electromagnetic fields cannot completely decay from the simulation in a time that can be simulated by FDTD.

The best quality factor obtained is 4382 when compared to case (b) and case (c).

V. CONCLUSION

In this paper a 2dimensional photonic crystal which can work as pressure sensor has been designed. A quality factor is calculated by using the formula. The sensor is formed by rectangular slab with 220nm creating hole type with 165nm radius structure. The normalized transmission at input port and resonant wavelength is observed. Analysis of wavelength shift is done with the equations which relate applied pressure and refractive index. Comparison of case (b), case (c) the case (a) obtained a highest quality factor.

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