International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-6,June 2016
ISSN: 2395-3470
www.ijseas.com

Design and Modeling of Photonic Crystal based Pressure Sensor

Shruthi S V[1] and Mrs. Indira Bahaddur[2]

[1]M.Tech (DECS), Dept. of E&C, Malnad College of Engineering, Hassan, Karnataka, India

2Assistant Professor, Dept. of E&C, Malnad College of Engineering, Hassan, Karnataka, India

Abstract: In this paper, a photonic crystal based pressure sensor is proposed and designed. The sensor is based on two-dimensional photonic crystal. Here, the design of pressure sensor done by two methods, using ring resonator and with line defect. It is noticed that through simulation, the resonant wavelength of the sensor is shifted linearly towards the higher wavelength region, while increasing the applied pressure level. Similarly, photonic crystal with line defect also designed and variation of transmission power with respect to the change in pressure is observed. So by comparing both the designs, we can conclude that photonic crystal with ring resonator structure is more accurate than with line defect.

Keywords: Photonic Crystals (PhC), Ring Resonator, Line Defect, Photonic Sensor, Finite Difference Time Domain Method (Finite Difference Time Domain).

1. INTRODUCTION:

The photonic crystal explores a new research direction in optical sensing field. Photonic crystal is a periodic natural material in which periodicity of material is maintained by arranging different dielectric substrate in periodic manner. The important characteristics of photonic crystal are its light confinement and controlling property. These characteristics make the crystal to use in various sensing applications.

Photonic crystals are classified into one-dimensional photonic crystal (1DPC), two-dimensional photonic crystal photonic crystal (2DPC) and three-dimensional photonic crystal (3DPC). Here, the sensor is based on 2DPC. Compared to 1DPC and 3DPC, 2DPC is preferred, because it has relatively simple structure, small size, better confinement of light, accurate band gap calculation and easy integration [2].

Sensor is a device, which sense physical as well as biological parameters. The limitations of past electronics sensors are overcome by optical sensors. These optical sensors are designed by using optical fiber, photonic crystal fiber and photonic crystal.

In the literature, the pressure sensor using the photonic crystal was reported periodically. In the paper [3], author reported a pressure sensing based 2DPC microcavity structure and achieved a linear resonant wavelength shift according to the applied pressure. In the paper [4], author designed a pressure sensor based on a photonic crystal waveguide suspended over a silicon substrate. The photonic crystal waveguide is deflected toward the substrate under the applied pressure, causing a decrease in optical transmission due to the coupling of the waveguide field to the silicon substrate.

2. DESIGN

In this paper, we uses the two dimensional photonic crystal. First design a ring resonator. Line defect engineering is introduced by removing the rods in air.

MEEP is the tool used for design and simulation of a photonic crystal. MEEP stands for Maxwell’s Electromagnetic Equation Propagation. It is used in solving Maxwell’s equations. The transmission flux value can be obtained at each frequency. This is the integral of Poynting vector over a plane of the photonic crystal structure:

$$P(\omega) = \mathrm{Re}\hat{n}.\int E_{\omega}(x)^{*} \times H_{\omega}(x)d^{2}x$$

MEEP computes the flux at the specified regions, and the frequencies that we want to compute. By using the UNIX command ‘Grep’, the transmitted amplitude values can be extracted from the MEEP output file for corresponding frequency.

The Finite Difference Time Domain method is used to simulate operation of sensors in different pressures.

3. SIMULATION RESULTS

Here, we designed the pressure sensor by means of photonic crystal with ring resonator and photonic crystal with line defect.

Design 1: First we design a photonic crystal with ring resonator structure.

Design parameters for ring resonator are given below:

a. Ring radius - 0.19 micrometer
b. Dielectric constant of ring – 12
c. With respect to the sample taken, hole in ring dielectric constant is changed
d. Ring height – infinity

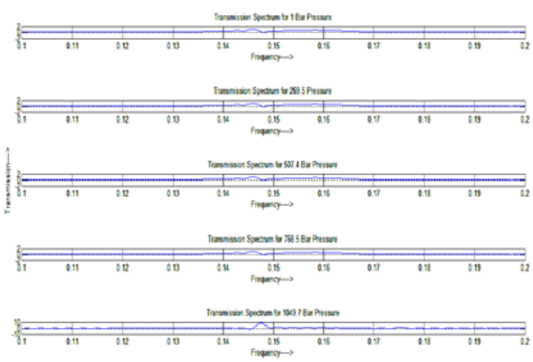

Fig-1: Transmission spectrum at 1.56 degree temperature

Here, fig-1 shows the transmission spectrum at 1.56 degree temperature and fig-2 shows the combined graph at 1.56 degree temperature, where we can observe the change in transmitted flux values with respect to the change in pressure values.

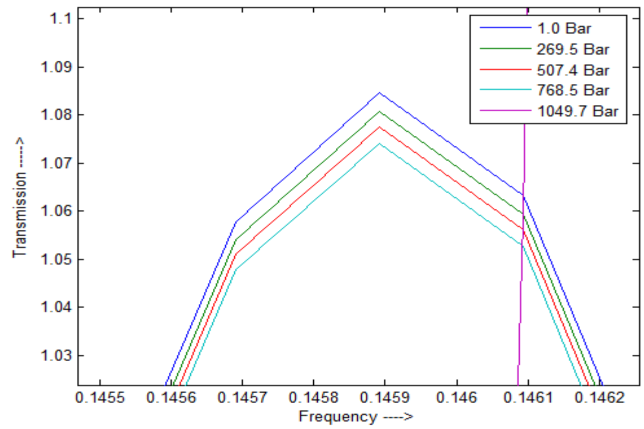

Fig-2: Combined graph at 1.56 degree temperature

Similarly below fig-3 and fig-4 shows the transmission spectrum and combined graph at 7.64 degree temperature respectively.

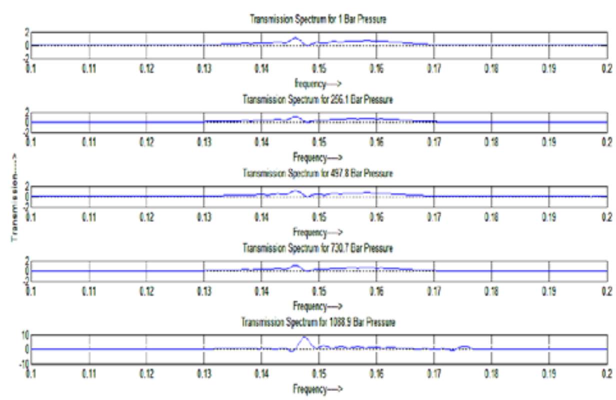

Fig-3: Transmission spectrum at 7.64 degree temperature

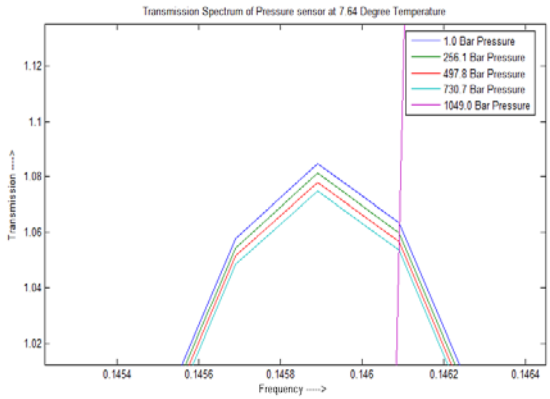

Fig-4: Combined graph at 7.64 degree temperature

Table 1 shows the distinct transmission power values for different pressure values at 1.56 degree temperature in ring resonator structure.

Table 1: Pressure v/s Output transmission flux value at 1.56 degree temperature in ring resonator structure

Pressure value (in bar)	Transmission flux value (in dB)
1	1.085
256.5	1.08
497.8	1.076
730.7	1.073
1049.7	1.065

Table 2 shows the different values of transmission flux for different pressure values.

Table 2: Pressure v/s Output transmission flux value at 7.64 degree temperature in ring resonator structure

Pressure value (in bar)	Transmission flux value (in dB)
1	1.085
256.1	1.08
497.8	1.075
730.7	1.07
1049	1.065

So, from the above results, we can say that at particular frequency (f=0.1459), there is a distinct shift in the transmission power at 1.56 and 7.64 degree temperature. It shows that it acts as a micro-displacement pressure sensor and it is very highly accurate.

Design 2: Next we design a photonic crystal with line defect. The design parameters for line defect are:

a. Radius of rods – 0.19 micrometer
b. Dielectric constant of rods
c. Defect rods dielectric constant is changed with respect to the sample taken
d. Rods height – infinity
e. Lattice constant – 0.1 micrometer

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-6,June 2016
ISSN: 2395-3470
www.ijseas.com

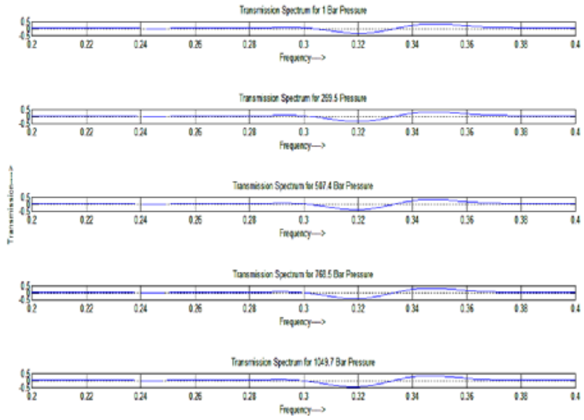

Fig-5: Transmission spectrum at 1.56 degree temperature in line defect

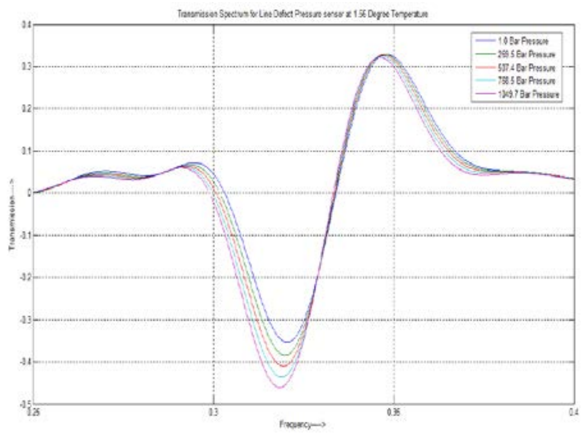

Fig-6: Combined graph at 1.56 degree temperature in line defect

Fig-5 and fig-6 shows the transmission spectrum and combined graph at 11.56 degree temperature in line defect respectively. Similarly fig-7 and fig-8 shows the transmission spectrum and combined graph at 7.64 degree temperature in line defect respectively.

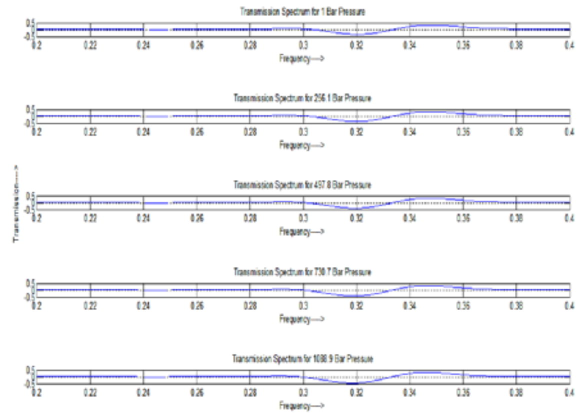

Fig-7: Transmission spectrum at 7.64 degree temperature

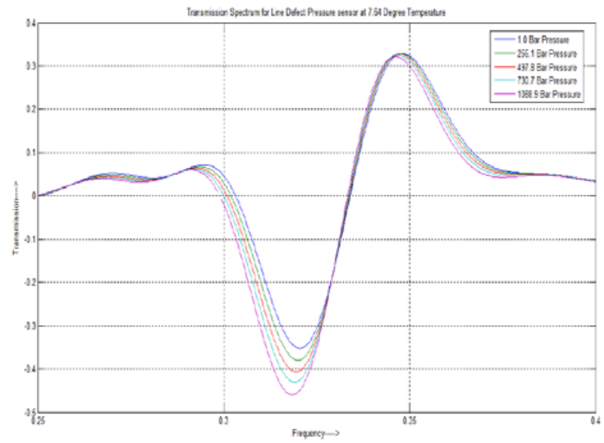

Fig-8: Combined graph at 7.64 degree temperature

Table 3 and table 4 show the variation in transmission flux value with respect to the different pressure values.

Table 3: Pressure v/s Transmission power value at 1.56 degree temperature in line defect

Pressure value (in bar)	Transmission flux value (in dB)
1	-0.35
256.5	-0.38
507.4	-0.41
768.5	-0.44
1049.7	-0.47

Table 4: Pressure v/s transmission power value at 7.64 degree temperature in line defect

Pressure value (in bar)	Transmission flux value (in dB)
1	-0.35
256.1	-0.38
497.8	-0.41
730.7	-0.43
1088.9	-0.46

From the above graphs (as shown in fig. 6 & 8), it is clear that, for two or more values of frequency there is a distinct variation in the transmission power for different values of pressure.

4. Conclusion

In this paper, a 2D photonic crystal based pressure sensor is designed. The designed sensor has ring resonator type structure and photonic crystal with line defect structure. It is observed that applied pressure shift the resonance wavelength of the sensor. By observing the transmitted flux values in both the designs, we can conclude that ring resonator structure is more accurate, when compared to line defect structure.

References

[1] D. Biallo, M De Vittorio et.al, “High sensitivity photonic crystal pressure sensors” [ISSN 1990-2573].

[2] Krishnan VIJAYA SHANTHI, Savarimuthu ROBINSON. “Modeling and simulation of optical pressure sensor for detection of Acoustic signals in Sub-micron range” [photonic sensors, 2014, 4(3): 248-253].

[3] C. Lee, J. Thillaigovindan, and R. Radhakrishnan, “Design and modeling of nanomechanical sensors using silicon 2-D photonic crystals,” Journal of Lightware Technology, 2008, 26(7): 839-846.

[4] A. Bakhtazad, J. Sabarinathan, and J. L. Hutter, “Mechanical sensitivity enhancement of silicon based photonic crystal micro-pressure sensor,” in

International Symposium on Optomechatronic Technologies (ISOT), Toronto, October 25-27, pp. 1-5, 2010.

[5] S. Robinson. "Photonic Crystal based Optical Sensor for Refractive Index Sensing", [ISSN 2394-3777, IJARTET, Vol. II, Special Issue XXIV, March 2015].

[6] S. Robinson and R. Nakkeeran, "PC based optical salinity sensor for different temperatures," Photonic Sensors, 2012, 2(2):187-192.

[7] Y. Lu and A. Lal, "Photonic crystal based all-optical pressure sensor," in IEEE 24th International Conference on Micro Electro Mechanical Systems (MEMS), Cancun, January 24-27, pp. 621-624, 2011.

[8] X. Xiong, P. Lu, and D. Liu, "Modeling of pressure sensors based on two-dimensional photonic crystals," Optoelectronics, 2009, 2(2): 219-221.

[9] 'Sensor Device', by Mitsuro Sugita, US patent number US7391945, 2008.

[10] R. V. Nair, R. Vijaya, Photonic crystal sensors, Vol. 34, Issue 3, May 2010, pp. 89-134.