

Photonic Crystal Fibres PCF for Different Sensors in Review

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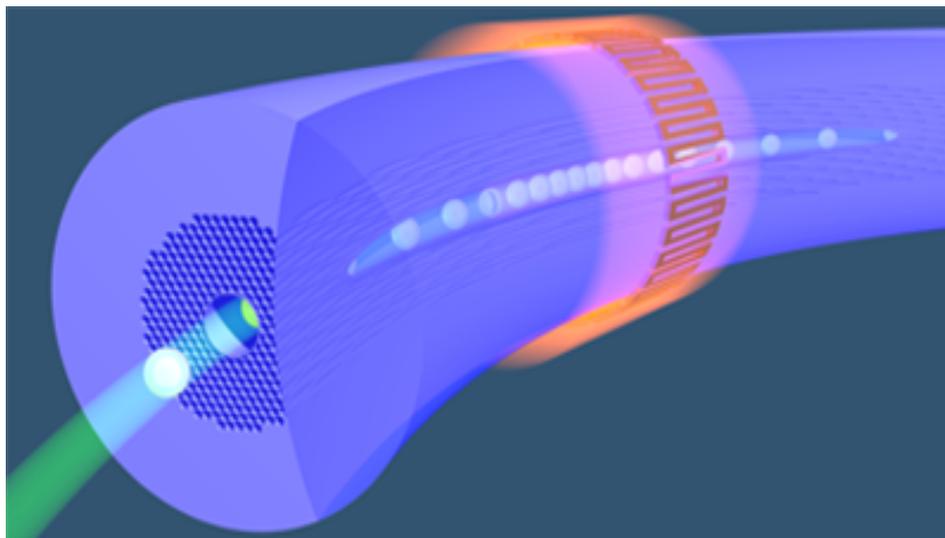
Abstract: In this work, we present the update results for using the PCF as a sensors application, where we have chosen a modern collection of manuscripts previously published in scientific journals in the field of optical, biological and chemical sensors. So we compared their presented results, in order to reach the best results previously published in the use PCF for optical, biological and chemical sensors.

Keywords: PCF; Photonic Crystal Fiber; Gass Sensors; Refractive Index Sensors; Sensors

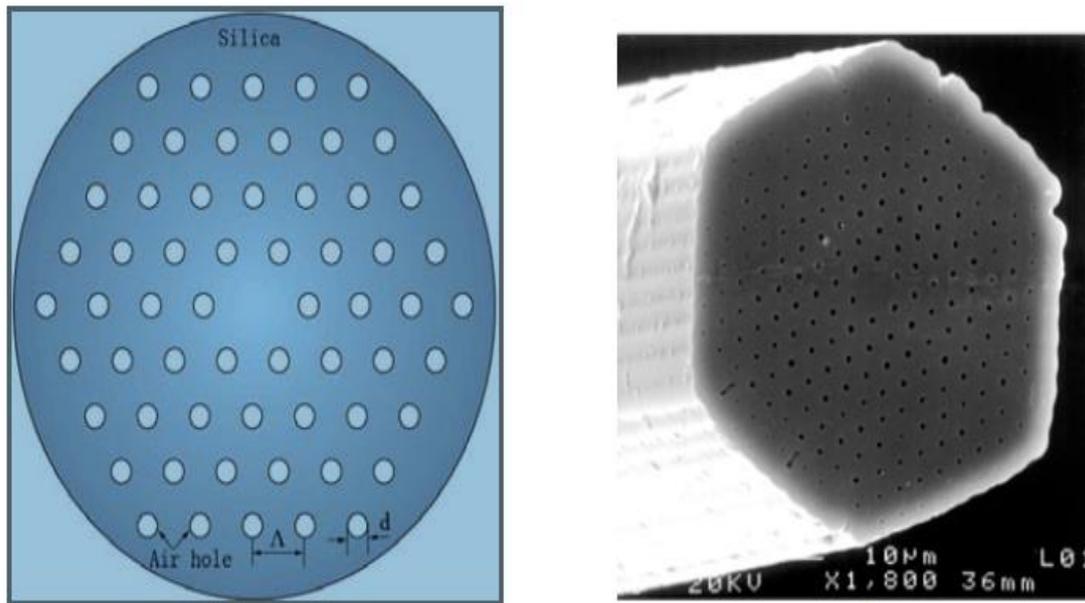
1. Introduction

A novel technology of the optical fiber, which uses the Photonic crystals is photonic crystal fiber (PCF) [1,2]. There is an important feature of this type of fibers which is the periodic array of air gaps [2]. There are two types of PCFs, they are Solid core (SC) and Hollow core (HC) as present on Fig. 1(a, and b) [3, 4], each one use different mechanism in the propagation of light [5].

There is a specific difference between conventional fiber and PCF which is the required refractive index, where PCF uses lower refractive index in the cladding layer [6]. PCFs are used in so many applications such as meteorology, bio-medicine, imaging, telecommunication, industrial machinery etc. [7].



(a)



(b)

Figure 1. (a) Hollow core photonic crystal Fiber, and (b) Solid core photonic crystal Fiber

2. Literature survey

Photonic Crystal Fibers used for sensing applications such as temperature [8] and refractive index Sensing [9], sensitive photonic crystal fiber interferometer (PCFI) for the external refractive index (ERI) sensing [8], the microstructure core and cladding (PCF) used in highly sensitive gas sensor [11], A refractive index sensor based on a D-shaped photonic crystal fiber with a nanoscale gold belt [12]. PCF provides potential effects in telecommunications such by filling the core with nematic liquid crystal where the light is confined this core center at all telecommunication bands with a very low losses of confinement [13], and also used in bio sensing [14] application depending on the Surface Plasmon Resonance [15] and chemical sensing such for ethanol detection [16].

In this manuscript we conducted a mini-study for employment the PCFs as a different sensors application, where we have selected a collection of manuscripts published in advance in a recent volume of the scientific journals under the jurisdiction of optical, biological and chemical sensors.

Refractive index (RI) and temperature sensing is an important process in so many applications. The development of sensing methods came from using sensors which based on optical fiber MZIs until the discovery of photonic crystal fiber sensors.

In 2014 a group of researchers [17] reported refractive index measuring method at low temperature this done by construction of open-cavity optical fiber Fabry-Pérot interferometer. In 2015, Ahmmed A. Rifat [18] proposed deposited PCF core based SPR sensor and got maximum refractive index (RI) sensitivity about 3000 nm/RIU at the range of 1.46–1.49. Yong (2015) [10], suggested and demonstrated a highly sensitive photonic crystal fiber interferometer (PCFI) which has RI sensitivity up to 252 nm/RIU in range of (1.333–1.379) refractive indices, PCFI has several advantages such as design simplicity, small size, low cost and low temperature sensitivity.

Luan (2015) [19], proposed a design of D-shaped photonic bandgap PCF that depending on the surface plasmon resonance sensor to examine the SPR sensing performance on a specific range of wavelength. This proposal has been modified by Wan Zhang and colleges (2017) [20] to allow the design to operate at wider range of refractive indices from 1.2 to 1.4 and maximum sensitivity at 3751.5 nm/RIU. Ying (2018) [21], suggested an interferometer model of two thin core fibers, RI sensitivity that obtained by this model about 48.9 nm/RIU within the range of (1.34 - 1.40), and temperature sensitivity of 1.7 pm/°C for the temperature and refractive index sensing applications.

The photonic band gap fiber type used as a sensor for the gas pressure measuring applications, this is done by Yingchun in 2014 [22], who got pressure sensitivity of 1.044×10^{-2} rad/(Pa·m) that induced because of the refractive index difference.

Morshed and colleges (2015) [9], designed a gas sensor based on the microstructure core and cladding (PCF) which operate within the range (1.3 -2.2 μm) of wavelengths, the proposed PCF allows one to get highest sensitivity of about 42.27% at 1.33 μm wavelength during methane and hydrogen fluoride gases absorption.

In 2017, Wenlin [6] designed a hydrogen sulfide gas sensor based on graphene-coated tapered photonic crystal fiber (GTPCF) Mach-Zehnder interferometer (MZI), the GTPCF-MZI was presented and clarified experimently, this design showed sensitivity of 0.03143 nm/ppm within a range from 0 to 45 ppm which represents a good linear performance of a sensor.

Zeonex-based (PCF) represents a novel ethanol in terahertz frequency range detection method has designed and analysed in 2018 by Jakeya Sultana and partners has been modeled and analyzed for detection in terahertz frequency range where the PCF sensor simulation presents sensitivity of 68.87% at 1 THz frequency. [16]

The best RI sensor sensitivity obtained by Zhang and colleagues proposal, where the highest sensitivity is achieved, as shown in table (1)

Table 1. Sensitivity of refractive index sensor

Sensor sensitivity nm/RIU	Refractive index	Cause of getting high and low sensitivity
3000 ^a	1.46-1.49	The use of graphene layer and the filled cores with a high RI liquid improved the sensor performance.
252 ^b	1.333–1.379	The sensitivity increased as the PCF diameter decreases.
3751.5 ^c	1.2 to 1.4	The sensitivity improved by both width and distance from the fiber center to the polished surface.
48.9 pm/°C ^d	1.34 - 1.40	The sensitivity increased by filling the PCF air-holes with matching liquid oil.

^aAhmed A. Rifat (2015) [16], ^bYong (2015) [8], ^cWan Zhang (2017) [18], ^dYing (2018) [19]

The best gas sensor sensitivity obtained by Jakeya Sultana and partner's model, where the highest sensitivity is obtained, as shown in table (2).

Table 2. The sensitivity of gas sensor

Sensor sensitivity	Cause of getting high and low sensitivity
$1.044 \times 10^{-2} \text{ rad / (pa. m)}$ ^e	The difference in refractive index air inside the HC.
42.27% ^f at wavelength of 1.33 μm .	microstructure core and cladding PCF.
0.03143 ^g nm/ppm	RI of cladding layer increases as the hydrogen sulfide gas contacts with the sensing layer of graphene of GTPCF.
68.87% ^h at 1 THz frequency	The best sensitivity can be achieved in the X-polarization mode than the one in the Y-polarization mode.

^eYingchun in 2014 [22], ^fMorshed (2015) [11], ^gWenlin (2017) [8], ^hJakeya Sultana (2018) [16]

3. Conclusion

Photonic Crystal Fibers PCF based of different sensing applications such as refractive index, and gas sensors, the presented work shows the higher sensitivity for the refractive index was found by Zhang, et al. and its about 3751.5 nm/RIU for the value of refractive index 1.2- 1.4, and the best gas sensor sensitivity eas obtained by Jakeya Sultana at the value of sensitivity of 68.87 % at 1 THz.

4. References

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