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New Refractive Index Sensor Depend on Resonance Effect

Dalya H. Abbas*
College of Electrical and Electronic Engineering Techniques-Middle Technical University, Baghdad, Iraq

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Abstract:
In this paper, the new refractive index sensor depend on resonance effect is presents. By combine the fiber optic and radio frequency, the sensor could support the most important sensing applications with high accuracy. The optical fiber could be enhanced by side polished fiber to produce a passing filed sensing functions. The zinc oxide film generates high attenuation effect which allows highly sensitive index. By RF magnetron supporting technique, the zinc oxide has been prepared practically with the fiber sensing thickness of 75.1μm and zinc film of 70 nm has deposited on the polish surface. In refractive index range from 1.3 to 1.4, the achieved sensitivity is 3721.9 nm/RIU. Additionally, all situations were simulated in MATLAB imitation of refractive index to perform the near infrared and visible wavelength. The results show the sensor sensitivity is 0.899 nm for each salt unit.

***Keywords**: Refractive index, Resonance Effect.*

INTRODUCTION

The water refractive index discovery is the major matter in organic, ecological engineering, and chemical field. The numerous features of optical fiber sensor is involve small size, low interference with electromagnetic fields, fast response, and light weight [1-5]. In the direction of measuring the refractive index in fluid, numerous approaches has been suggested such as surface Plasmon [6], fiber Bragg grating [7], technology of interferometric [8]. Hence, the dynamic and sensitivity detection range of refractive index measured techniques are limited [9]. Therefore, new approaches require for refractive index sensing under new methods to overcome this limitations. The key parameters to measure the density of sea water is the salinity factor in determine a lot of aspects in water and soils chemistry [10-15]. The absolute salinity and density could be examine and evaluated under direct measurement of refractive index in theoretical aspects while in sea water it's difficult to measure directly [16-20]. The measurement of salt quantity in 1000g of water is the most commonly methods to examine the salinity referred to the parts per thousand [21]. Between 36% and 34%, the salinity of oceans is specific [22]. A number of techniques have been proposed to measure the salinity. The ultrasonic method under the measurement of travel time in the light is suggested by [23] to determine the salinity. The poly aniline matrix coated wire electrode from 0.010% to 75% has been proposed to measure the salinity by [24]. A refractive index sensor combined with Plasmon surface method to calculate the sea salinity is introduced by [25]. The simple intensity modulated displacement sensor to sodium solution detection has been reported by [26] with varying from zero to 12% under beam through methods. Based on salinity sensitivity hydrogel coating fiber Bragg grating, the fiber optic salinity sensor methods has been introduced by [27]. Fiber optic sensing structure containing FBG coat with different polymer is used to monitor the salinity is proposed by [28]. These approaches not provide enough effective techniques and compact design to easily fabricate. In different engineering fields, the optical fiber sensors are used to many wanted advantages [29]. As compare to conventional sensors, these techniques have better accuracy, reliability, and sensitivity [30]. The side polished fiber sensors is high sensitive in fiber based sensor [31], fiber sensor with thin film type [32], Bragg grating fiber sensors [33], and fiber sensor with long

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period grating [34]. The propagation of light in the ordinary optic fiber did not interact with surrounding of fiber medium [35]. To accomplish these dealings, the fleeting field is generated by diverse surface polish fiber technique [36]. Within microns, the fiber cladding is removed and evanescent field could be interacting in the ambient of refractive indices [37]. Hence, the D-shaped fiber could exist using to improve the magnitude of passing field and compassion [38]. On the shaped filament, the slim film was coating to construct a resonance base feeler of fiber [39]. Generally, two kind of resonance could be generated if the thin film deposited in the fiber optic of side polish surface the phenomena of resonance are caused by these two modes involved the sensor of SPR [40-45]. These two types are resonance of Plasmon surface and the other is resonance of nanowire mode [46-51]. By thin film absorbing, these techniques could be supported in refractive index sensing. In this paper, the gallium doped zinc oxide has been investigated to support the thin film materials which are widely used to fabricate many sensors. In case of ZO refractive index, the thin film has high sensitive to medium and the wavelength shift could be observed by LMR. The proposed technique demonstrates high performance in salinity and refraction index measurement which is helpful to the sensing process for many types of sensor fabrications.

MATERIALS AND TECHNIQUE

In the first step the gallium oxide is prepared using radio frequency magnetron method with purity of 99% were used at the martial of coating. The coating substrate is used by silicon wafer, D-shaped fiber, and BK7 with 95mm distance between target and substrates. The diameter of target ZO is 50mm and 3mm thickness were powered by RF supply. Through the deposition of thin film, the power of ZO is kept at 80 W. As a supporting gas, the unadulterated argon gas by means of speed of 20 sccm is use and the stress is set at 0.2 Pa. An quality of optical instrument is evaluated by transmittance of optical. The measuring of film thickness is done by surface profile meter. By using spectrophotometer, the transmittance of optical was measured with wavelength from 300 nm to 24500 nm of Ltd Japan. By using the x-ray directory, the film structure has been evaluated and analyzed by high resolution scan microscopy.

The vital factor that influences the fiber sensor performance is by select the coating knowledge and thin film material. It could be regarded the waveguide design in case of deposit the thin film and side polished fiber to affects the light propagation. Hence, in case of the slim film real part permittivity's is harmful with high amount than its possess fantasy part, then the Plasmon resonance is arises. The coupling appears among the propagation of light via waveguide and Plasmon surface. In same time, the MR phenomena arise at the actual part of slim film permit is optimistic and advanced size than imaginary element. An important characteristic of LMR consequence could be generated by light polarization or by electric of transverse with multiple resonances that could produce without modifying the structure of optic fiber with wide material variety. In the wavelength location, the ZO thin film has been coating on the polished fiber and the real part of refraction index is more than D-shaped. Additionally, the surrounding medium indexing in salt is above than ZO film by 1.3.

RESULTS AND DISCUSSION

This work utilizes two spectrometers to investigate the near infrared and visible light of spectrum to reach the thinning single mode fiber with high sensitivity to generate new evanescent wave. These waves could be used to interact the surround medium inside the deepness of penetration. To generate flat outside and put ZO slim film, the shaped fiber have to polish precisely with high seal to the smooth facade of the fiber. The evanescence wave could be interacting with the analytic of surrounding when the D-shaped fiber is refined to be slim sufficient. The polishing part of shaped fiber has high sensitivity to the refraction index in medium surrounded. For about 72-77 µm of polishing thicknesses and 130v fiber mode have been polished under homemade fiber system. The cladding have been removed until the wave of evanescent was generated and the polishing surface reduction to overcome the loss of scattering. The remaining thickness of optical fiber has been measured by microscope of optical image that is found of about 75.1 µm and the 30mm of polished fiber length. Figure 1 show the scheme of suggested sensor based on shaped fiber.

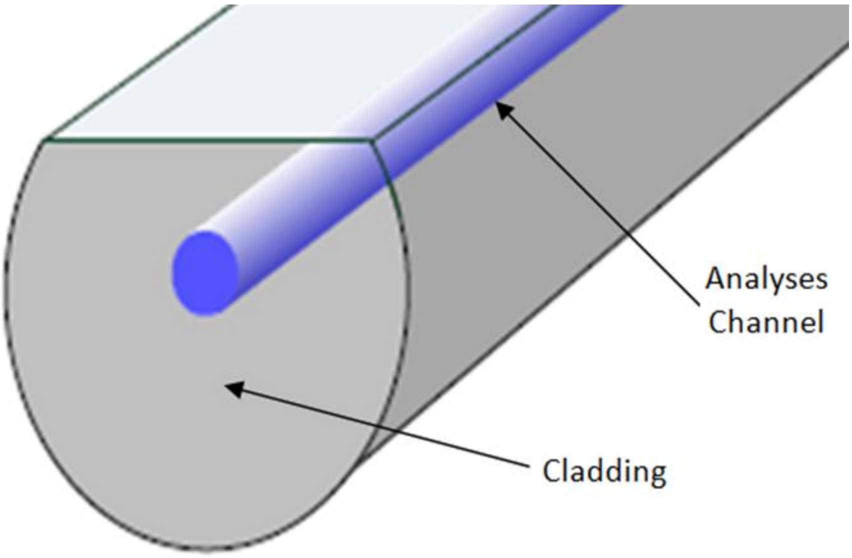

Fig. 1- suggested sensor based on shaped fiber.

Before coating of ZO, the glass substrate, silicon wafer, and shaped fiber were cleaned by ultrasonic device. The shaped fiber has been embedded and glued to substrate of coating and the thin film is coated to the polished fiber surface under RF magnetron techniques. The ZO film thickness was found 67nm that measured by profile meter and the micro structure have been analyzed by electron microscope. The micro picture of wrought fiber covered by means of ZO slim film shows enough observation of this sensor. To overcome the contamination error, the distilled water has been used and the solution was measured the sodium chloride and prepare probably. The experiment type was conducted in dilute solution include the refractive indices detection and the second experiment type is the salinity measuring. In these two experiments, the refraction index was found from 1.3 to 1.4 and salinity from 0 to 250% respectively. These results are larger than existing works for the measurement of salinity. In addition, these results of fiber optic sensing locations has been engrossed keen on sense solution and the broadcast spectrum time have examine by software programming in processor device. The ZO film spectrum variation was deposited on the polished fiber with salinity solution and measured correctly. The virtual diagram of project experiment with halogen light is illustrated in Figure 2.

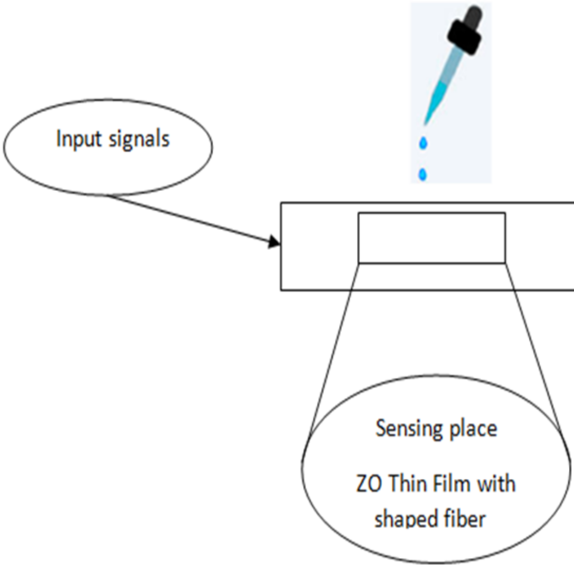

Fig. 2 - virtual diagram of refractive index and salinity sensing Experiment setup

In this experiment, the source of white light is linked to the fiber optic feeler and the further two ends were attaching to the spectra meters. The spectrometer output spectrum has been experiential by a range of wavelength beginning by 370 to 1600 nm. To examine the change of wavelength in the amalgamation peak, the section of polish within 35 mm is measured in the dissimilar solutions. In the experiment of salinity detection, the sensing locations of sensor were immersed into solution of saline at diverse salinity from zero to 250%. The solution of sensing has been changed and analyzed the measured information by mean of spectrometer of optical. Here, the observation of wavelength shift variety with diverse in every measurement. The sensing device of transmission spectrum after and before ZO thin film coating is illustrated in Figure 3 and Figure 4. The light transmitted concentration of created fiber was decreased following ZO slim film covering with the composite refractive index calculation by ellipso meter. To provide all situations, the MATLAB imitation of refractive index is performed in the near infrared and visible wavelength.

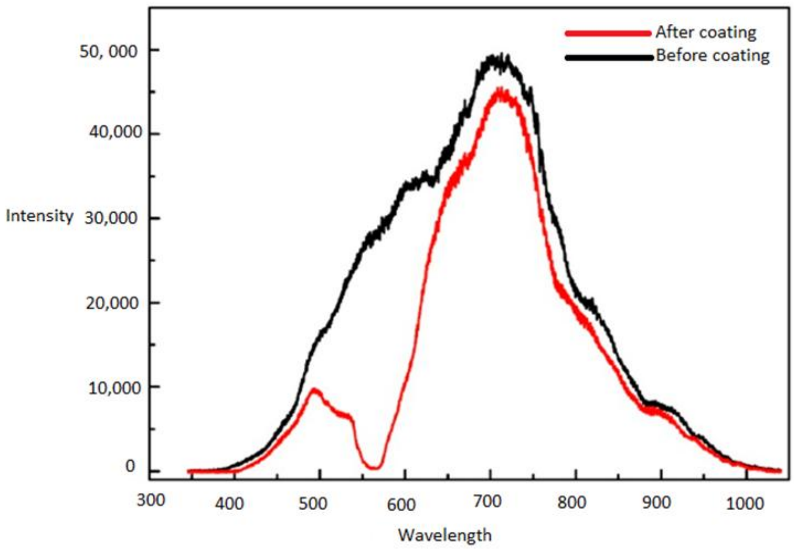

Fig. 3- transmission spectrum after and before ZO thin film coating

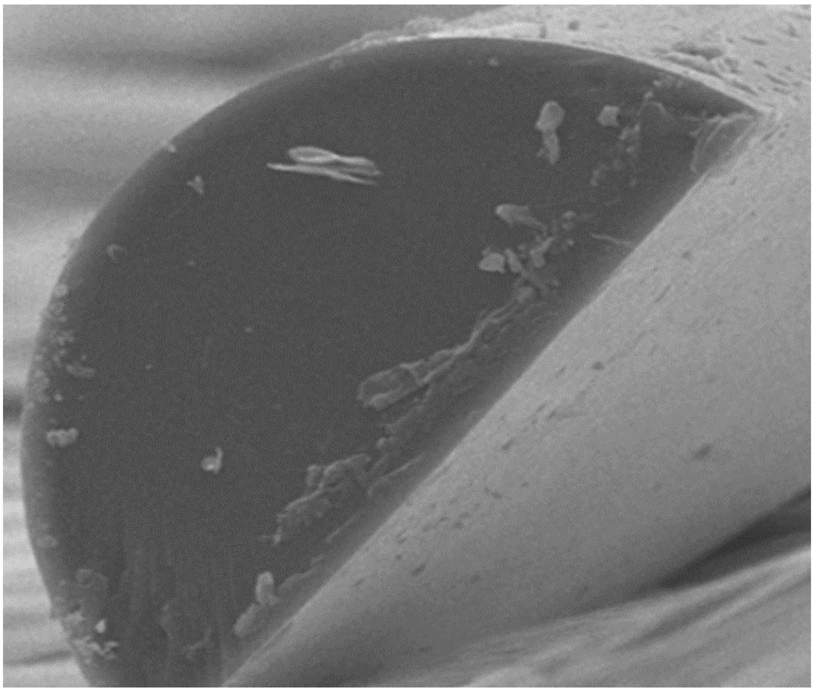

Fig. 4 - proposed fiber coat image with ZO film.

Extinction coefficient and refractive index of ZO thin film simulation results are illustrated in Figure 5 which indicates that the ZO film meet the generation conditions. From these results, one could observe that the refraction index is about 2.000 and the extraction coefficient is 0.00029.

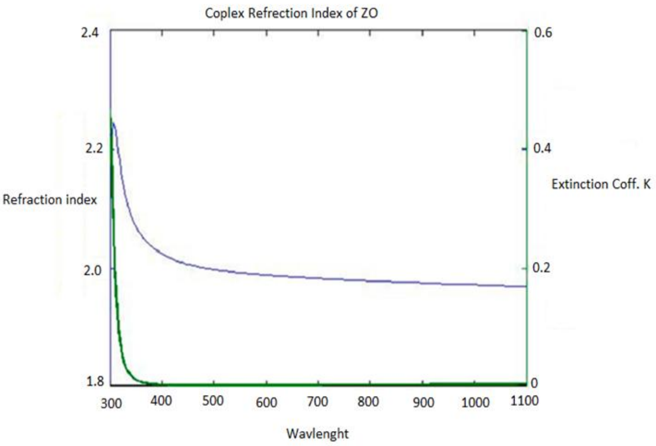

Fig. 5 - refractive index of ZO thin film simulation results.

The different sensor type performance could be provided under curve fitting to calculate the sensitivity regarding to ZO film width. Figure 6 shows the sensitivity of the suggested sensor as a meaning of slim film width as a very important factor to affect the performance of sensors.

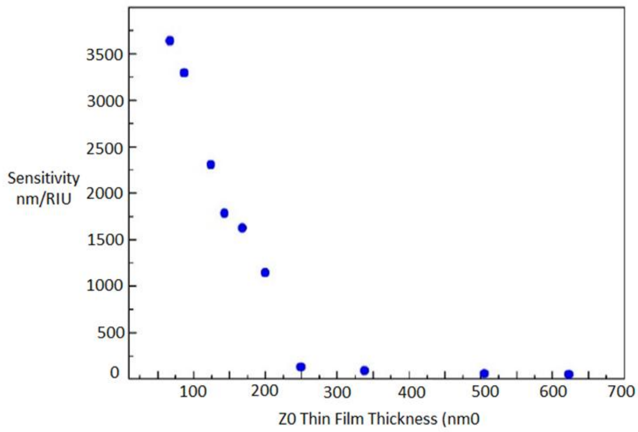

Figure 6: the relationship between sensors sensitivity and film thickness.

CONCLUSION

This paper introduces the salinity sensor and refractive index under thin film coating and polishing fiber methods. The ZO thin film has been putted on the surface of polishing with shaped fiber to generate efficient techniques for sensing. The thickness of about 74 µm of optic fiber and 67 nm thickness of thin film have been used in this

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approach. The coating of thin film on the facade of polished formed fiber could be improved for fluid sensor such as salinity and refraction index sensors. In refraction index, the sensitivity was achieved of about 3600 nm/RIU. In addition, the sensitivity of salinity sensor was provides of about 0.99 nm/SU. Hence, high sensitivity in salinity and refraction index measurement compared with existing approaches. Moreover, the suggested design of the sensors could be ready to adapt via thin film coating modification in order to detect the chemical class.

REFERENCES

1. Ishaq, M.; Quintela, A.; James, S.W.; Ashwell, G.J.; Lopez-Higuera, J.M.; Tatam, R.P. Modification of the refractive index response of long period gratings using thin film overlays. Sens. Actuators B Chem., 107, 738–741(2005).
2. Espejo, R.J.; Dyer, S.D. Practical spatial resolution limits of high-resolution fibre Bragg grating sensors using layer peeling. Meas. Sci. Technol., 18, 1661–1666 (2007).
3. Suhadolnik, A. An optical fibreinterferometricrefractometer. Meas. Sci. Technol., 18, 1205–1208(2007).
4. Cheng, Y.C.; Chang, Y.J.; Chuang, Y.C.; Huang, B.Z.; Chen, C.C. A plasmonic refractive index sensor with an ultrabroad dynamic sensing range. Sci. Rep., 9, 5134(2019)
5. Rahman, H.A.; Harun, S.W.; Yasin, M.; Ahmad, H. Fiber optic salinity sensor using beam-through technique. Optik, 124, 679–681(2013)
6. Cong, J.; Zhang, X.M.; Chen, K.S.; Xu, J. Fiber optic Bragg grating sensor based on hydrogels for measuring salinity. Sens. Actuators. B Chem., 87, 487–490(2002)
7. Men, L.; Lu, P.; Chen, Q. A multiplexed fiber Bragg grating sensor for simultaneous salinity and temperature measurement. J. Appl. Phys., 103, 053107(2008).
8. Andreev, A.T. et al., Highly sensitive refractometers based on a side-polished single-mode fibre coupled with a metal oxide thin-film planar waveguide. J. Opt. A Pure Appl. Opt., 10, 035303(2008).
9. Tien, C.L. et al., Hydrogen sensor based on side-polished fiber Bragg gratings coated with thin palladium film. Thin Solid Films, 516, 5360–5363(2008).
10. Cusano, A.; et al., Mode transition in high refractive index coated long period gratings. Opt. Express, 14, 19–34(2006).
11. Homola, J. Surface Plasmon Resonance Based Sensors; Springer: New York, NY, USA, (2006).
12. Wang, T.; et al., Ultrabroad band terahertz conductivity of highly doped ZnO and ITO. Opt. Mater. Express, 5, 566–575(2015).
13. Kim, J.; et al., Optical properties of gallium-doped zinc oxide—A low-loss plasmonic material: First-principles theory and experiment. Phys. Rev. X, 3, 041037(2013).
14. Kim, J.S.; et al., Optical analysis of doped ZnO thin films using nonparabolic conduction-band parameters. J. Appl. Phys., 111, 123507(2012).
15. Kim, Y.H.; et al., Effect of composition and deposition temperature on the characteristics of Ga doped ZnO thin films. Appl. Surf. Sci., 257, 109–115(2010)
16. Rana, A.U.; et al., High-Power Microwave-Assisted Ga Doping, an E_ective Method to Tailor n-ZnO/p-Si Heterostructure Optoelectronic Characteristics. Phys. Status Solidi A, 215, 1700763(2018).
17. Rana, A.S. and Kim, H.S. NH4OH Treatment for an optimum morphological trade-o_ to hydrothermal Ga-doped n-ZnO/p-Si heterostructure characteristics. Materials, 11, 37(2018).
18. Ko, H.J.; et al., Ga-doped ZnO films grown on GaN templates by plasma-assisted molecular-beam epitaxy. Appl. Phys. Lett.,

77, 3761–3763(2000).
19. Park, S.M.; et al., Effects of substrate temperature on the properties of Ga-doped ZnO by pulsed laser deposition. Thin Solid Films, 513, 90–94(2006).
20. Usha, S. et al., Fiber optic hydrogen sulfide gas sensors utilizing ZnO thin film/ZnO nanoparticles: A comparison of surface plasmon resonance and lossy mode resonance. Sens. Actuators B Chem., 218, 196–204(2015).
21. Gupta, B.D. and Verma, R.K. Surface Plasmon resonance-based fiber optic sensors: Principle, probe designs, and some applications. J. Sens., 979761–979772(2009).
22. Villar, I.D.; et al., I.R. Design rules for lossy mode resonance based sensors. Appl. Opt., 51, 4298–4307(2012).
23. Zamarreño, C.R.; et al., Tunable humidity sensor based on ITO coated optical fiber. Sens. Actuators B Chem., 146, 414–417(2010).
24. Hernaez, M.; et al., Optical fiber refractometers based on lossy mode resonances supported by TiO2 coatings. Appl. Opt., 49, 3980–3985(2010)
25. Villar, I.D.; et al., Generation of lossy mode resonances by deposition of high-refractive-index coatings on uncladded multimode optical fibers. J. Opt., 12, 095503(2010).
26. Sehmi, H.S.; et al., Optimizing the Drude-Lorentz model for material permittivity: Method, program, and examples for gold, silver, and copper. Phys. Rev. B, 95, 11544(2017).
27. Look, D.C.; et al., Near-infrared (1 to 4 _m) control of plasmonic resonance wavelength in Ga-doped ZnO. Opt. Eng., 56, 057109(2017).
28. Kumar, A.; et al., Integrated optic TE/TM pass polarizers using resonant coupling between ITO thin film lossy modes and dielectric waveguides modes. Opt. Commun., 291, 247–252(2012).
29. Tien, C.L.; et al., Double-sided polishing long period fiber grating sensors for measuring liquid refractive index. Proc. SPIE, 7634, 76341A (2009).
30. Usha, S.P.; Gupta, B.D. Performance analysis of zinc oxide-implemented lossy mode resonance-based optical fiber refractive index sensor utilizing thin film/nanostructure. Appl. Opt., 56, 5716–5725 (2017).
31. A. A. Rifat et al., “Highly sensitive multi-core flat fiber surface plasmon resonance refractive index sensor,” Opt. Express 24(3), 2485–2495 (2016).
32. M. Y. Azab, M. F. O. Hameed, and S. S. A. Obayya, “Multi-functional optical sensor based on plasmonic photonic liquid crystal fibers,” Opt. Quantum Electron. 49(2), 49 (2017).
33. S. I. Azzam et al., “Multichannel photonic crystal fiber surface plasmon resonance based sensor,” Opt. Quantum Electron. 48(2), 142 (2016).
34. T.Wieduwilt et al., “Ultrathin niobium nanofilms on fiber optical tapersa new route towards low-loss hybrid plasmonic modes,” Sci. Rep. 5, 17060 (2015).
35. W. Qin et al., “Analyte-filled core self-calibration microstructured optical fiber based plasmonic sensor for detecting high refractive index aqueous analyte,” Opt. Lasers Eng. 58, 1–8 (2014).
36. B. Shuai et al., “A multi-core holey fiber based plasmonic sensor with large detection range and high linearity,” Opt. Express 20(6), 5974– 5986 (2012).
37. X. Yang et al., “Analysis of graphene-based photonic crystal fiber sensor using birefringence and surface plasmon resonance,” Plasmonics 12(2), 489–496 (2017).
38. Z. Tan et al., “Improving the sensitivity of fiber surface plasmon resonance sensor by

filling liquid in a hollow core photonic crystal fiber," Plasmonics 9(1), 167–173 (2014).

39. R. K. Gangwar and V. K. Singh, "Highly sensitive surface plasmon resonance based D-shaped photonic crystal fiber refractive index sensor," Plasmonics 1–6 (2016).
40. M. F. O. Hameed, Y. K. A. Alrayk, and S. S. A. Obayya, "Self-calibration highly sensitive photonic crystal fiber biosensor," IEEE Photonics J. 8(3), 6802912 (2016).
41. M. F. O. Hameed et al., "Design of highly sensitive multichannel bimetallic photonic crystal fiber biosensor," J. Nanophotonics 10(4), 046016 (2016).
42. D. Gao et al., "Multi-hole fiber based surface plasmon resonance sensor operated at near-infrared wavelengths," Opt. Commun. 313, 94–98 (2014).
43. W. Sellmeier, "Zurerklärung der abnormenfarbenfolgeim spectrum einigersubstanzen," Ann. Phys. Chem. 219(6), 272–282 (1871).
44. A. Vial et al., "Improved analytical fit of gold dispersion: application to the modeling of extinction spectra with a finite-difference time-domain method," Phys. Rev. B 71(8), 085416 (2005).
45. P. J. A. Sazio, "Microstructured optical fibers as high-pressure microfluidic reactors," Science 311(5767), 1583–1586 (2006).
46. M. B. E. Griffiths et al., "Atomic layer deposition of gold metal," Chem. Mater. 28(1), 44–46 (2016).
47. F. Sequeira et al., "Refractive index sensing with d-shaped plastic optical fibers for chemical and biochemical applications," Sensors 16, 2119 (2016).
48. E. K. Akowuah et al., "A highly sensitive photonic crystal fibre (PCF) surface plasmon resonance (SPR) sensor based on a bimetallic structure of gold and silver," in Proc. IEEE 4th Int. Conf. on Adaptive Science and Technology, pp. 121–125 (2012).
49. X. Yang et al., "Analysis of graphene-based photonic crystal fiber sensor using birefringence and surface Plasmon resonance," Plasmonics 12(2), 489–496, (2017).
50. M. Y. Azab, M. F. O. Hameed, and S. S. A. Obayya, "Multi-functional optical sensor based on Plasmon photonic liquid crystal fibers," Opt. Quantum Electron. 49(2), 49, (2017).
51. A. K. Pathak, et al., "Sensitivity Enhancement of a Concave Shaped Optical Fiber Refractive Index Sensor Covered with Multiple Au Nanowires", Sensors v.19(19);(2019).