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Design of D shaped plasmon–photonic crystal fiber for bio sensing application

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ABSTRACT

This article proposes D-shaped plasmon photonic crystals for bio sensing applications. It reports the enhanced sensitivity of 7000 nm/RIU. The sensing mechanism is attained by following coupled mode theory property. It is then calculated by obtaining the wavelength shift in the output transmittance spectra. The overall analysis of device is followed by the finite element method (FEM).

Introduction

Photonic crystal fiber (PCF) devices are attracted in many sensing applications [1–4]. Upon that, plasmon based photonic crystal fiber in sensing property is reached through in many sensing applications [5] was proposed where the various types of metal is layered over the samples to be sensed. Many types of plasmon-PCF in hexagonal [6], circular [7], spiral [8] is used to optimize for better sensitivity. In this article, the D-shaped plasmonic PCF is proposed for bio sensing applications and reported the sensitivity of 7000 nm/RIU.

Structural design and its result analysis

The cross sectional view of the structure is shown in Fig. 1. The background of the fiber is filled by fuse silica [8] and its top layer is coated by gold material [8] followed by the samples to be analyzed. The dimensions include for big air holes (3 μm), smaller cladding air holes (2.2 μm) and pitch constant (3.5 μm). The thickness of the gold layer will be 50 nm and samples refractive index varies from 1.45 to 1.47.

The mode propagation of the D shaped plasmon PCF is calculated by FEM. For the incident wavelength, the corresponding electric field is emerged. Due to the presence of big air holes, the property of bi-refringence is induced and also caused for *x*- and *y*-polarization of silica and plasmon modes. The interaction point of both the modes is show in Fig. 1(b) which shows that initially fundamental core mode gets the propagation at shorter wavelength. While increasing the wavelength region, mode energy gradually moves to the plasmon mode region and it is coupled at some instance where the loss will be as high as possible. Finally, the entire mode energy gets penetrated on the metal layer. As shown in Fig. 2, the sharp peak values indicate that phase matching condition is satisfied. Such that the energy propagation is uniformed between plasmon and silica modes. The wavelength at the sharp peak point is known as resonance wavelength. For the variation of each analytes, the shift in loss spectra as well as resonance wavelength is changed. It is noted that the energy gets deviation while increasing peak wavelength.

The consolidation of peak wavelength and wavelength shift with respect to the analyte is calculated and plotted as shown in Fig. 3(a) and (b).

Using the loss spectra, the output transmittance can also be calculated using $\frac{P_0}{P_i} = \exp\left(-\frac{\alpha l}{4.343}\right)$. The variation of both peak wavelength and wavelength shift gets increased with increasing of samples refractive index. It is mainly due to the presence wavelength region from blue shift to red shift. The sensitivity of the proposed sensor device is calculated by expression, $S = \frac{\Delta\lambda_{peak}}{\Delta_n}$ and the maximum sensitivity is obtained as 7000 nm/RIU.

Conclusion

The work describes the principle of sensing mechanism using D-shaped plasmon photonic crystal fiber by finite element method. The proposed structure shows wavelength sensitivity 7000 nm/RIU with detection limit of 0.01. Moreover, it exhibited low loss transmission. D shape PCF can be also extended for various chemical analytes

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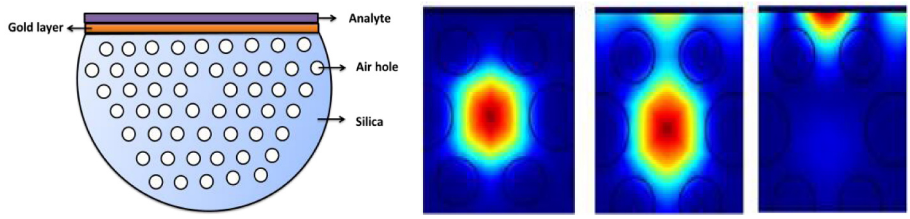

(a) (b)

Fig. 1. . (a) Cross section view of the proposed D-shaped PCF & (b) Mode propagation for silica and plasmon modes.

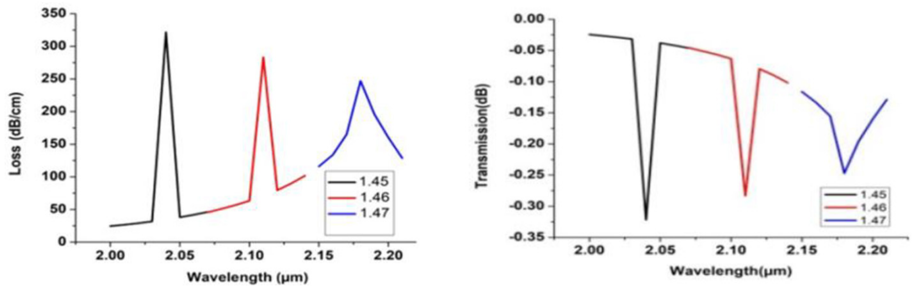

Fig. 2. . (a) Variation of loss spectra with function of wavelength & (b) Transmittance spectra.

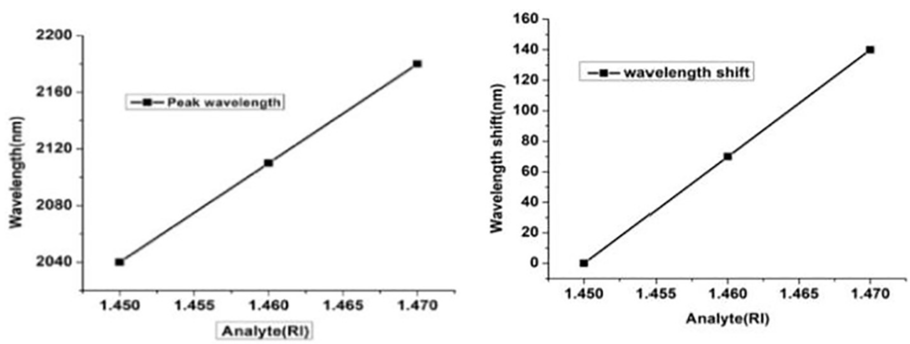

Fig. 3. . (a) Peak wavelength and wavelength shift for the given analyte.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rinp.2018.08.020.

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