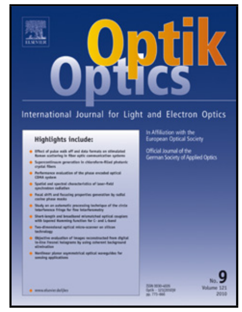

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PII: S0030-4026(17)31370-0
DOI: https://doi.org/10.1016/j.ijleo.2017.10.157
Reference: IJLEO 59893

To appear in:

Received date: 18-9-2017
Accepted date: 26-10-2017

A Highly Sensitive Surface Plasmon Resonance Biosensor using Photonic Crystal Fiber filled with Gold nanowire encircled by Silicon lining

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Abstract— **The proposed photonic crystal fiber structure senses small deviations in the refractive index of liquids by surface plasmon resonance phenomenon. The coupling of core guided mode to surface plasmon polariton modes is modulated by the analyte placed between the central core and gold nanowire. Numerical study on the sensor performance is executed using finite element method. A sensitivity of 2000 nm/RIU is achievable for detection of liquids with refractive index greater than 1.37 and the sensor covers a wide sensing range from 1.37 to 1.45. Loss factors as high as 187.76 dB/cm is achievable. The analysis on the influence of structural modifications such as increase and decrease of gold nanowire diameter on the sensing action is also carried out. Numerical results depict an increase in confinement loss factor as the gold diameter gets reduced and a shift towards longer wavelength. The analysis of the sensor performance is performed when the gold nanowire is coated with silicon and it reveals that the loss factor gets enhanced by three fold, from 115.88 to 360.81 dB/cm for analyte refractive index of 1.4, as compared to without silicon coating due to the enhanced energy coupling between plasmon and core modes. The increased silicon thickness improves the sensitivity factor to 4000 nm/RIU.**

Keywords— **Photonic crystal fibers, surface plasmon resonance, Biosensor, Finite element method**

I. INTRODUCTION

Surface plasmon resonance (SPR) is recently being implemented in increasingly large number of sensing applications due to its higher sensitivity towards the refractive index (RI) of the material in contact with plasmonic material. This surface sensitive optical technique is efficient in detecting small RI changes of liquids thereby finding potential applications [1-3] in the field of biochemical technology, medicine and food safety sectors. Among the various sensing structures like waveguides, prisms, etc. [4-9], the optical fibers are more advantageous as they are very compact, allow easy integration and offer remote sensing capabilities. The introduction of Photonic crystal fibers (PCFs) has overcome the limitations of conventional optical fibers [10-12] and moreover opens up novel characteristics such as tunable non-linear effects, birefringence, better light confinement and even enables guiding of light inside vacuum [13-15]. These unusual characteristics of PCFs have kindled growing interest in their deployment as sensors in widespread applications.

The PCF can be facilitated to function as SPR sensor when the light confined to the central solid core region by index guiding principle is capable of propagating outside the core to reach the metal-dielectric junction. The electromagnetic wave transfers its energy to the electrons in the metal exciting surface plasmons and the energy transfer is maximum at the peak resonance wavelength, as a match occurs between the wavenumber and energy of light photons and induced plasmons. The plasmon material and analyte are filled into some of the air holes of PCF which comprises of a regularly arranged pattern of air holes. The transmission characteristics of the fiber are greatly influenced by the RI of the analyte under investigation. The maximum energy transfer from the fundamental core mode occurs at different peak resonance wavelengths for different RI variations of the analyte thus accomplishing the role of a biosensor.

In this paper, we present a solid core PCF based on the principle of SPR which can detect small RI variations in analyte having RI greater than 1.37. The comprehensive numerical characterizations of the key performance parameters of proposed sensor such as sensitivity, confinement loss, sensor length are performed using the finite element method. The impact of dielectric silicon coating, deposited on the nanowire filled with the plasmonic material, on the sensing parameters is discussed.

II. DESIGN AND THEORY

The schematic diagram of the proposed PCF sensor structure is depicted in Fig 1. The air holes are arranged in hexagonal lattice having pitch value p, distance between the centers of successive air holes, of 1.63 µm while the diameter d1 of smaller air holes is 0.35*p/1.3.

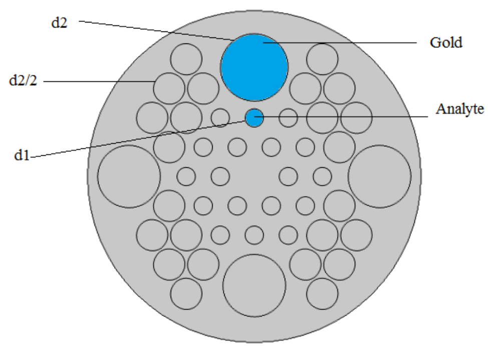

Fig 1 Schematic diagram of PCF based sensor based on SPR

The smaller air holes are enclosed by medium sized air holes with diameter d2/2 and are replaced by larger air holes of diameter d2 of 1.5 µm in 4 primary directions such that the remaining air holes resemble a butterfly shape simultaneously achieving high birefringence. The shaded