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Performance analysis of evanescent wave absorption plasmonic optical sensor with COMSOL FEM method simulation

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Abstract

We investigate the surface Plasmon resonance (SPR) based optical fiber sensor using COMSOL Multiphysics Finite Element Method (FEM) simulations. We evaluate the effects of two physical parameters of the sensor in an ichorous medium, i.e. the thickness of the nobel metal layer and the refractive index using numerical simulations. We have shown that a sharp dip in reflectance curve can be obtained by using appropriate physical parameters. From the biotechnology point of view, this SPR sensor structure can be utilized as an optical biosensor in ichorous environments for various biomedical application areas.

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Keywords- Surface Plasmon Resonance; Refractive index; Sensor; Plasmon; Sensitivity

1. Introduction

Surface Plasmon resonance (SPR) is a physical phenomenon concerning with the optical excitation of Surface

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Plasmon Wave (SPW) at the boundary between a metal and a dielectric. This phenomenon has been widely deployed as a detection standard for optical sensors. Optical sensors based on SPR are highly sensitive to variations in the refractive index of the neighbouring medium which enabled them to be highly proficient for sensing applications like in the fields of chemistry, environmental studies, and bio-logical systems. Optical fiber SPR sensors have been emerged from the fundamental SPR configuration based on Kretschmann configuration [1]. Basically, this configuration consists of optical fibre, thin metal layers of noble metals and the analyte or sensing medium (e.g. blood, tear). Since the prism-based SPR sensors have some drawbacks, for example, their bulky size and realization difficulties for far-flung sensing applications. To evade these shortcomings, the researchers have utilized optical fibers in SPR for the excitation of the surface plasmons wave.

Zhao et al. 2014 [2] Investigated the use of multi-layer modulation technique in SPR optical fiber sensor. They have shown that using multiple metal layer modulation procedure, sensitivity can be drastically enhanced. The sensitivity was found to be 1.73 x 10^{-4} RIUs in intensity interrogation and 1.74 x 10^{-6} RIUs in wavelength interrogation method of SPR sensing. Shukla et. al 2015 [3] theoretically analyzed highly sensitive surface plasmon resonance based fiber optic sensor with platinum (Pt) layer which is coated on the core of the optical fiber. Sensitivity of the sensor was found to increases enhances linearly with the increase in the refractive index of the medium, for all thicknesses of platinum layers. It was found that using 125 nm thick platinum layer, sensor provides maximum sensitivity of 17,500 nm/RIU. Suzuki et al. 2008 [4] investigated the effects of gold layer thickness and spectrum profile on sensor performance. They investigated that sensor with a gold layer of 65nm is sufficient for the accurate determination of resonance wavelength. The sensitivity of the sensor was found to be 1557nm/RIU in the RI from 1.333 to 1.3469. Mao et al. 2014[5] designed and simulated the D-shaped Multimode fiber sensor based on surface Plasmon resonance (SPR) technology. They investigated that when the residual fiber thickness approaches 75μm and the gold layer is 50nm, this multimode fiber SPR sensor has the greatest ability to work in a large dynamic ambient range from 1.33 to 1.39. In this range of refractive indices, the sensor gives the sensitivity of 4989nm/RIU. Wang et al. 2016 [6] designed and simulated the Compact and novel T-structure optical fiber RI sensor based on surface Plasmon resonance. They observed that SPR transmission spectrum shifts towards longer wavelength with the large increase in the sensing sample RI. They found that resolutions can be as high as up to 7.115 x 10^{-6} RIU and 3.525 x 10^{-6} RIU for the RI ranges of 1.333–1.36 and 1.37– 1.4 respectively. Mishra et al. [7] theoretically proposed SPR sensor with enhanced figure-of-merit and detection accuracy features using ITO and Silver metals. They found that 80 nm of ITO in connection with 40 nm of the silver has the maximum figure of merit (FOM).

2. Theory

The Basic Principle of SPR sensing is attenuated total reflection (ATR) which takes place in Kretschmann's configuration [8]. The general SPR sensor structure is shown in Figure.1

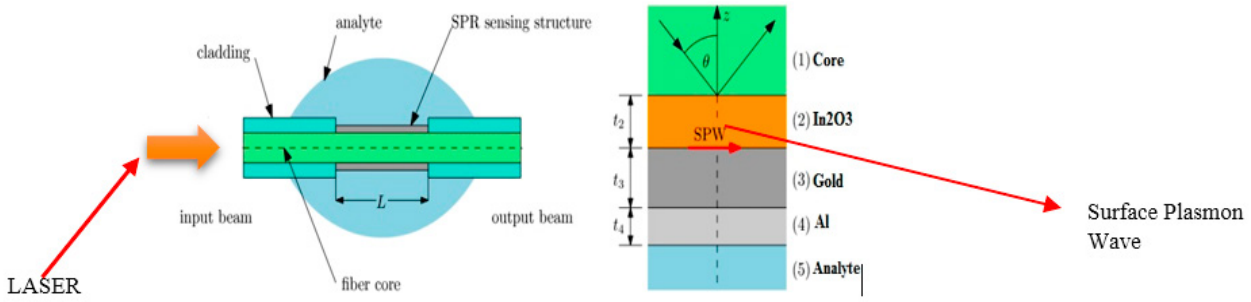

Figure 1: General SPR Sensor structure

The p-polarized light (TM-wave) at a particular wavelength, from the broadband source, is incident at one side of the optical fiber and the transmitted light is detected at the other side of the optical fiber. Plasmon wave is a transverse magnetic (TM) mode of electromagnetic field, which propagates along an interface between a plasmonic metal and a dielectric. Because here the fiber is acting as a dielectric medium so we can use the Sellmeier equation [9] to calculate the refractive index. According to the Sellmeier equation, we have