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A Technical Review and Analysis of Surface Plasmon Resonance Based Optical Fiber Sensors for Exploiting Oxides Materials

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Abstract
The review focuses on the most important contributions of oxides materials in the field of surface plasmon resonance in modern years. Surface plasmon resonance (SPR) based fiber optic sensor with indium oxide (In_2O_3) layer covered on the center of the optical fiber is displayed and theoretical examined. The sensitivity of the SPR based fiber optic sensor has been also assessed numerically. It is indicated that the proposed SPR based fiber optic sensor with In_2O_3 layer has high sensitivity in the close to infrared area of range, which needs thoughtfulness regarding numerous natural and security applications and offers progressively precise and exceptionally reproducible estimations. Moreover, the sensitivity of the SPR based fiber optic sensor diminishes with the expansion in the thickness of In_2O_3 layer. The sensitivity of the sensor improves with the expansion in the thickness of ITO layer. With enhanced estimations of thickness of ITO layer and incident wavelength to be 50 nm and 1600 nm, individually, the proposed sensor offers high sensitivity of 164°/RIU.

***Keywords**: Surface plasmon resonance, indium oxide, sensitivity enhancement*

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INTRODUCTION

Surface plasmon resonance (SPR) emerges as a very effective tool for chemical sensing, bio sensing and food safety [1–3]. In recent times, conducting metal oxides (CMOs) is used to support surface plasmon wave [4]. An important aspect to use CMO as plasmonic material is that they keep several qualities like nonappearance of band to band transitions, chemically stable and have uniform thin layer. One of the most prevalent CMOs is indium tin oxide (ITO) [4–9]. ITO is translucent in UV and visible regions of spectrum and supports surface plasmon wave at ITO-dielectric interface [5]. ITO is n-type wide band gap semiconductor that has high electrical conductivity, high optical transparency towards visible light and refection spectra in IR region. Its charge density is typically around 1020–1022 conduction electrons per cm^3. Also, during formation of very thin layer of it, there are no island formations on dielectric surface i.e. thin films of ITO are highly continuous. Figure 1 shows the schematic diagram of SPR based fiber optic sensor.

The advanced sensitivity of ITO along with larger finding accuracy of Ag and report the fabrication and characterization of a SPR based fiber optic sensor utilizing bi-layers of ITO-Ag. It has been observed that method of wavelength interrogation is used for the characterization of the SPR sensor. Influences of thicknesses of ITO and Ag layers on the sensitivity of the sensor are seen earlier. For the better performance of the sensor, thickness of Ag layer need to be optimized. It has noticed that the sensitivity gets enhanced as the thickness of Ag layer is increased till 30 nm. By depositing an additional 30 nm thick Ag layer over 40 nm thick ITO layer, huge enhancement in sensitivity of the sensor is seen. 40 nm ITO-30 nm Ag based SPR sensor exhibits highest sensitivity [10].

In the study of TM polarized electric field of surface plasmon waves (SPW) decays exponentially in metal as well as dielectric medium. In order to excite surface plasmon waves at metal-dielectric interface, the propagation constant of SPW should match with that of the incident light, Kretschmann configuration method is generally used [11]. In addition, wavelength interrogation scheme is employed for the characterization of the SPR sensors, In the study of the ITO and ZnO layers related to sensitivity of SPR sensors, if the ZnO layer thickness gets increased up to 15 nm sensitivity increases and the highest sensitivity gets at the 15 nm thick ZnO-40 nm thick ITO layer based SPR sensor [12]. Prism based SPR sensors basically used three types interrogation techniques. First is the angular interrogation in which the SPR angle changes with respect to (w.r.t.) the change of refractive index as shown in Figure 2.

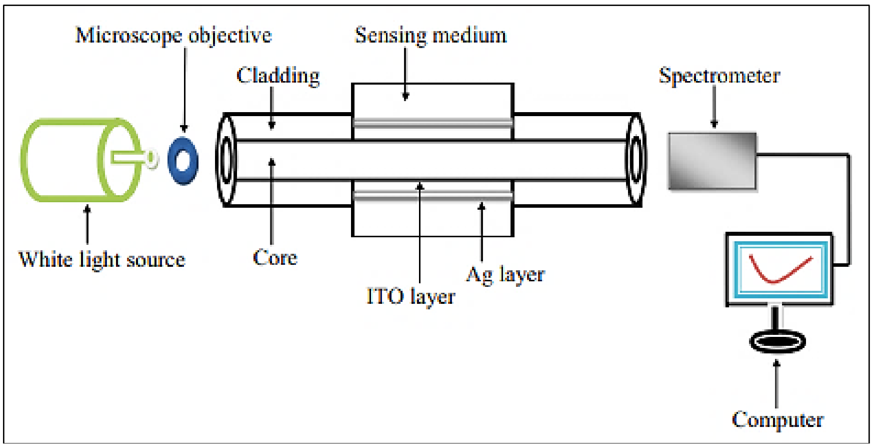

Fig. 1: *Schematic Diagram of SPR based Fiber Optic Sensor.*

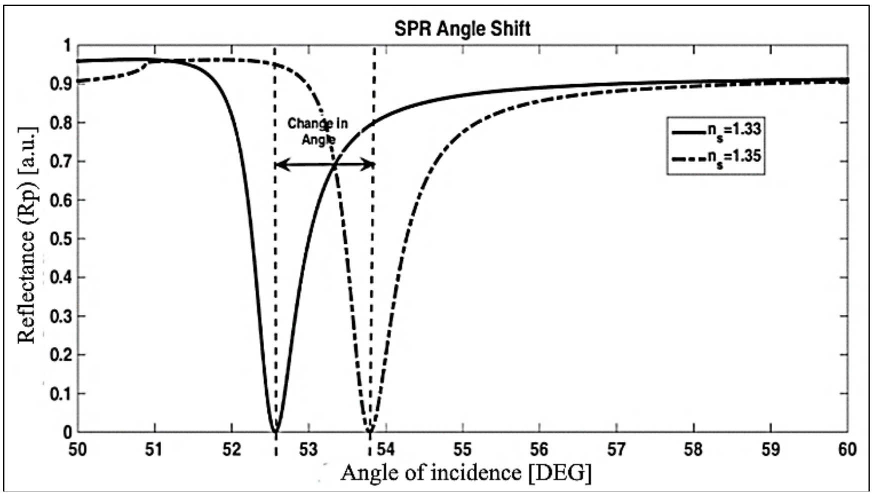

Fig. 2: *Angular Interrogation Technique of SPR.*

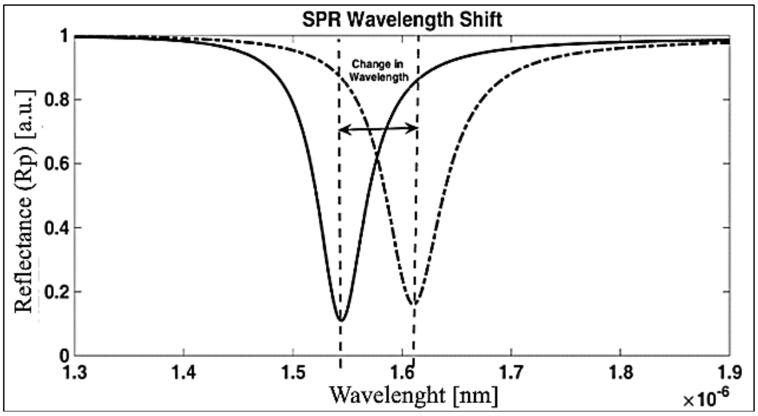

Fig. 3: *Wavelength Interrogation Technique of SPR.*

Second is the wavelength interrogation in which the wavelengths shift w.r.t. the refractive index of the sensing media as shown in Figure 3. Third is the phase interrogation in which the phase of the reflected light changes w.r.t. the refractive index of the sensing layer as shown in Figure 4.

THEORETICAL ANALYSIS

Sensitivity and figure of merit (FOM) of sensor gets increased with increase in Pt layer thickness for all thicknesses of ITO layers [13].

The dielectric constant of ITO is written according to Drude model as,

$$\varepsilon_m(\lambda) = \varepsilon_{mr} + i\,\varepsilon_{mi} = 3.8 - \frac{\lambda^2 \lambda c}{\lambda p^2 + (\lambda c + i\lambda)} \quad (1)$$

Here, λ_p and λ_c are plasma and collision wavelengths of ITO respectively. $\lambda_p = 5.649 \times 10^{-7}$ m and $\lambda_c = 11.121 \times 10^{-6}$ m for ITO. Figure 5 showing the schematic diagram of prism based SPR sensor.

It is studied that the increase in thickness of ZnO layer increases the sensitivity of SPR sensor for all thicknesses of ITO layers. In addition, 50 nm thick ITO and 30 nm thick ZnO layers based SPR sensor shows greatest sensitivity. 50 nm ITO-30 nm ZnO based SPR sensor possesses sensitivity of 2202 nm/RIU [14]. The optimized value of thickness of InN layer is found to be 70 nm. Possessing high sensitivity of 4493 nm/RIU, the 70 nm thick InN layer based fiber optic SPR sensor illustrates good sensing behaviour [15].

Also, various incident wavelengths (1500–1800 nm) and thickness values (30–50 nm) of ITO layer are considered. The sensitivity of the sensor enhances with the increase in the thickness of ITO layer [16], the SPR sensors with a metallic layer have their SPR wavelengths in the visible range and accordingly not permitting the sensing in the infrared spectral region.

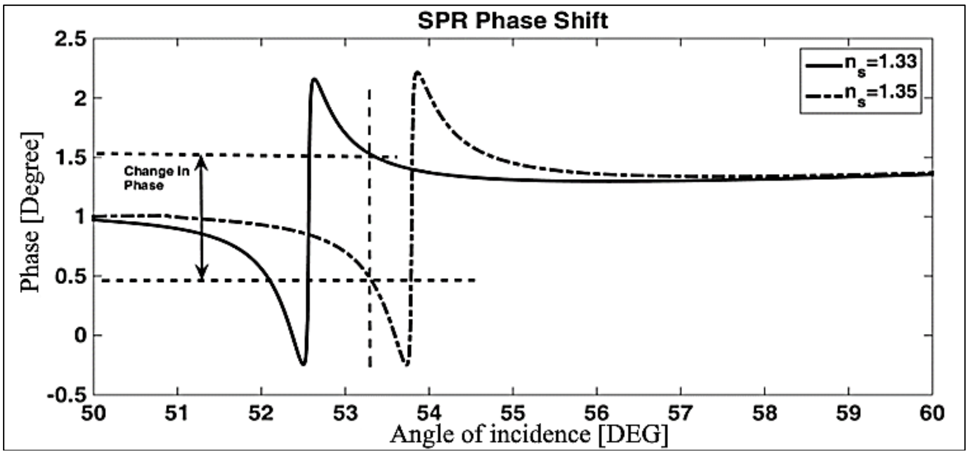

Fig. 4: *Phase Interrogation Technique of SPR.*

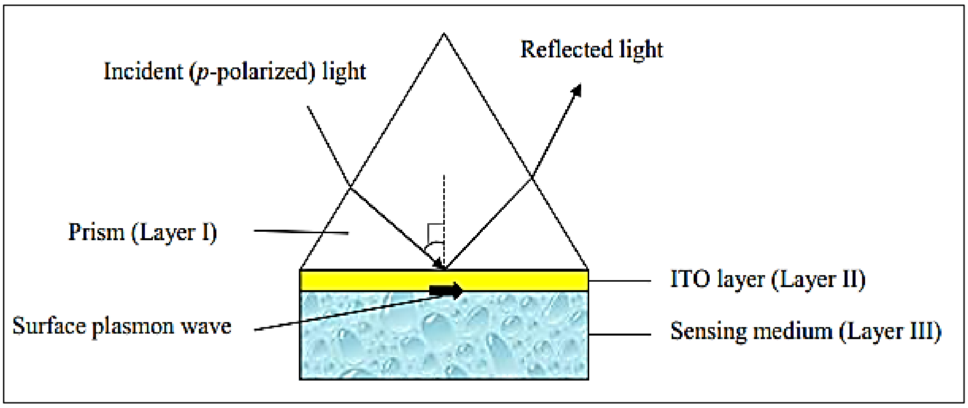

Fig. 5: *Schematic Diagram of Prism Based SPR Sensor.*

Sufficient research work has been carried out on transparent conducting metal oxides. In recent times, utilization of ITO thin films in SPR based fiber optic sensing is studied theoretically as well as experimentally in many research explorations[17–20].

CONCLUSION

It has turned out to be feasible to achieve surface resonance by utilizing straightforward foremost metal oxide thin films. Further, highest accessible transmissivity for visible light, lowest electrical resistivity, reflection spectra in infrared region and wide band gap semiconductor, makes indium tin oxide (ITO) as one of the most extensively used transparent conducting metal oxides. Besides, ITO thin films are continuous and no immersion of band to band transitions. Prism based SPR sensors basically used three types interrogation techniques.

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