Fiber Optic Surface Plasmon Resonance based Refractive Index Sensor

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ABSTRACT

In the present study, a surface plasmon resonance (SPR) based fiber optic sensor is proposed. The extreme sensitivity of SPR modes on the surrounding refractive index has been exploited to make the sensor. The optical fiber is coated with gold film which supports the propagation of surface plasmons. The SPR dip in the transmission spectrum is observed and its shift with varying refractive indices of different concentrations of sucrose solutions are obtained.

General Terms

Photonics, Fiber optic sensors

Keywords

Surface plasmon resonance, Plasmonic sensor, Optical fiber, Evanescent wave.

1. INTRODUCTION

In recent decades, the development of sensors based on surface plasmon resonances (SPR) for the detection of chemical and biological species has received considerable scientific attention. The physical phenomenon of surface plasmon resonance (SPR) has found its way into practical applications in sensitive detectors, capable of detecting sub-monomolecular coverage. [1,2] SPs are waves that propagate along the surface of a conductor, particularly along a metal-dielectric interface. It is generated when light interacts with the free electrons of the metal and they respond collectively by oscillating in resonance with the light wave. [3] The surface plasmons are accompanied by a longitudinal electric field which decays exponentially in metal as well as in dielectric medium. [4] The electric field has its maximum at metal-dielectric interface. Not all materials can be used as plasmonic materials, metals such as gold (Au), silver (Ag), copper (Cu), Aluminium (Al) and other alkali materials are the best choice. Among these all, Gold is a plasmonic material with proven chemical stability and consequently has been a favorable choice for most applications where the plasmon resonances of the material match with the spectral regions of interest.[5]Gold thin film modified optical fiber biosensors based on surface plasmon resonance has been proposed to enhance the SPR effect on biosensing.[6] The optical fiber SPR sensor has the advantages of being low cost, disposable, highly stable, immune to electromagnetic interference, suitable for remote sensing and real-time monitoring, which permits this sensor to be one of the most promising candidate for biochemical sensing.

In the present work, we propose an optical fiber based SPR sensor which exploits the phenomenon that thin film of gold coated on an uncladded portion of fiberis sensitive to the refractive index change in its environment.

2. THEORY

SPR based sensing systems these days are now being replaced with optical fibers instead of using prisms in Kretschmann configuration. The major benefit of using optical fibers is their size as compared to the prism and the sensing probe which will be made in the center of the uncladded fiber. The visible light is launched to the one end of the fiber using a tungsten halogen light source and the other end is connected to the spectrometer (Avantes). Through the coupling of light, the surface plasmons on the metal-dielectric surface gets excited with the phenomenon of total internal reflection (TIR). [7,8]When total internal reflection occurs inside the core of the fiber, an evanescent wave is produced. This evanescent wave penetrates into the adjacent medium and decays exponentially with distance from the interface. [9,10] Before decaying, it excites the surface plasmons at the gold coated surface of the optical fiber. It has already been demonstrated that surface plasmon modes are sensitive to the variations in the refractive index at the surface of the metal film supporting the surface Plasmon. [11] When the environment of the sensing region changes, for example, the gold coated portion of the fiber comes in contact with a liquid solution of specific refractive index, the SPR response of the fiber changes. It reflects as a change in the transmission spectrum.

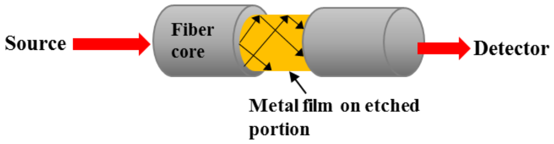

Fig 1: Schematic of a fiber sensor

3. EXPERIMENTAL METHODS

In this present work, we used a multimode optical fiber (400 μm core diameter). The cladding of the fiber is removed from the central portion (10 mm approx.) and the uncladded portion is etched by hydrofluoric acid treatment. The thin film of gold is deposited on the uncladded portion of fiber by the process of sputtering. A very thin layer of chromium is deposited prior to gold deposition to increase the adhesion of the gold filmon the fiber surface. The gold coated fiber is now connectedbetween the light source (tungsten halogen source) and the spectrometer detector (Ocean Optics spectrometer). When light is launched through the fiber, the SP modes are generated and the transmission spectra is recorded. Then solutions of sucrose of varying refractive indices are added onto the optical fiber surface and the transmission spectra is recorded for each case. With solution of different refractive index, there is a shift in the SPR wavelength and loss in the transmission spectra.

3.1 Results And Discussion

The different concentration solutions of sucrose were made and their corresponding refractive indices were measured using refractometer and are shown in Table 1.

Table 1. Different concentration of sucrose solutions with corresponding refractive indices.

S. No	Sucrose Concentration (%)	Refractive Index
1.	1	1.33388
2.	5	1.33876
3.	10	1.34665
4.	15	1.35378
5.	20	1.36016

The graph was plotted between the concentration of sucrose and their corresponding refractive indices, a continuous increase in refractive index was observed with increasing concentration of sucrose as in figure 2.

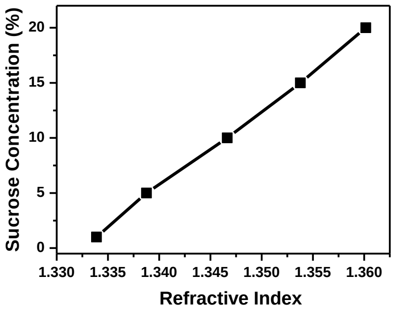

Fig 2: Sucrose concentration versus refractive index

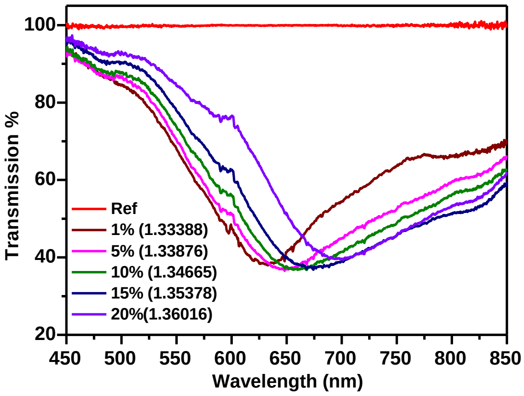

Fig 3: Shift in wavelength with varying refractive indices of sucrose solutions

Figure 3 shows the gold coated fiber in air as reference while the rest of curves are with sucrose solution of different concentration having different refractive index. From the figure, it is clear that the surfaceplasmons present on gold coated fiber are very sensitive to the change in refractive index; with varying refractive indices a visible shift in the wavelength can be seen. The shift in wavelength observed was very prominent, from 628 nm (for 1% solution of sucrose) to 692 nm (for 20 % solution of sucrose).

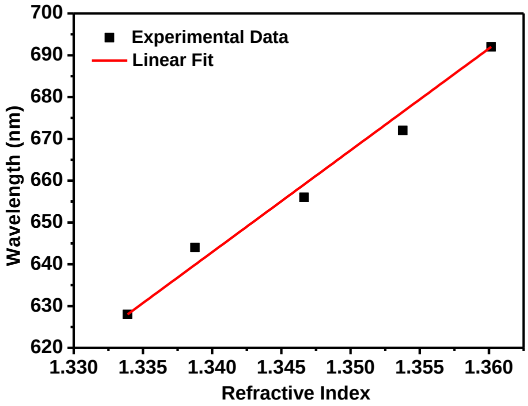

Fig 4: Wavelength versus refractive index.

The shift in wavelength versus refractive index was plotted in Fig. 4 and the sensitivity of the sensor was found to be 2435 nm/RIU (approx.).

We have shown that the chemically etched optical fiber sensor based on surface plasmon resonance as the transducer can be used as chemical sensor. The change in concentration of sucrose solution leads to a shift in plasmonic dip in the transmission spectra and a reasonable sensitivity is achieved.

4. CONCLUSION & FUTURE SCOPE

The work presented here demonstrated an optical fiber based SPR sensor which is very sensitive to the change in refractive index around its environment. The optical fiber SPR sensor has the advantages of being low cost, disposable, highly stable, linear, free of labelling.It has the potential for real-time detection of analytes which permits this sensor to be used in biochemical sensing - starting from disease diagnosis to environmental sensing and food toxin detection.

5. ACKNOWLEDGMENTS

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