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Research Article

Fabrications of Surface Plasmon Resonance (SPR) on Tapered Fiber Structure for Optical Sensor[#]

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Abstract: Improvement of tapered fiber sensor by introducing gold thin layer for facilitating surface plasmon resonance (SPR) generation has been studied. The particular interest in this problem is the conditions that determine the formation of evanescent field and the interrogation of the transmission intensity change due to the evanescent field absorption. The fabrication of the tapered fiber was conducted by a technique based on flame brushing using a homemade fiber tapering rig. The heat source comes from an oxy-butane torch. The gold nanolayer was then deposited onto the surface of tapered fiber by sputtering technique. The results suggest that a compact sensor based on this structure may be useful for biochemical sensors.

1. Introduction

Surface Plasmon Resonance (SPR) is a common method for the analysis of biomolecular interaction. SPR is sensitive to the changes in the refractive index occurring at the interface between a thin metal film and a dielectric medium. Binding events are detected as changes in the solute concentration in proximity to the sensor surface, e.g. for binding to a surface immobilized protein. Surface plasmon resonance takes place if the wave vector of the incident light parallel to the conductor surface k_x matches the wave vector of the surface plasmon k_{sp}, whereas the wave vector of the surface plasmon k_{sp} is sensitive to the refractive index of the dielectric medium in contact with the sensor surface[1]. Therefore the wave vector of the light k_x can be approximated by

$$K_{SP} = \frac{\omega}{c}\left(\frac{\varepsilon_m \varepsilon_s}{\varepsilon_m + \varepsilon_s}\right)^{1/2} \quad (1)$$

where ε_s is the dielectric constants of the dielectric medium, whereas ε_m is the real part of the dielectric permittivity of the metal. If excitation of surface plasmons occurs, it will resulting a dip in the intensity of the reflected light. Therefore, this dip varies approximately with the refractive index of the dielectric medium in contact with the sensor surface. When molecules in the sample binding to the sensor surface, the concentration, and therefore the refractive index, at the surface changes and the shift of the SPR dip suited to provide information is detected.

In the past few years, the collaboration of optical fiber technology and SPR has been a subject of intensive research. Importantly, the sensitivity enhancement has been a critical research issue in the area of fiber optic SPR based sensor. Several theoretical as well as experimental studies have been carried out. Tapered fiber offer an advantage of the ease of integration with conventional single mode fiber (SMF) as well as the access to the evanescent field provided by tapering since the light is guided by the boundary between the taper and the external environment. Also its because fast, highly sensitive and low cost tapered optical fiber biosensor that enables the label free detection of biomolecules[2]. This is owing to their unique optical guidance properties that include a relatively low loss, strong evanescent fields, tight optical confinement, and controllable waveguide dispersion. They possess large refractive index contrast which is able to provide tight field confinement that makes tapered fibers particularly suitable for nonlinear optical applications[3].

In the present instrument the dip is detected by the use of a convergent light from Reflectometry System (Nanocalc

2000 Ocean optics). What the SPR instrument actually measures is reflected light intensity that corresponds to the energy gets adsorbed by the plasmons.

2. Experimental Details

Tapered fiber fabrications have been demonstrated by using a wide range of techniques, in this paper we use the flame heating technique which has proven to be one of the most versatile, which can fabricate tapered fiber with good physical properties. The fabrication employs an oxy-butane torch. Fiber optic heated while being pulled slowly. Since borosilicate glass melts at a high temperature we are using oxy-butane torch at 800℃.

Figure 1. *Tapered fiber.*

Figure 1 shows a picture of tapered fiber produced by this method taken with Dino capture 2.0 microscope. Next we try to give metal layer of thickness 50 nm to the tapered fiber. We try using sputtering methods. Sputtering is a process where particles are ejected from a solid target material because of bombardment of the target by high-energy particles.

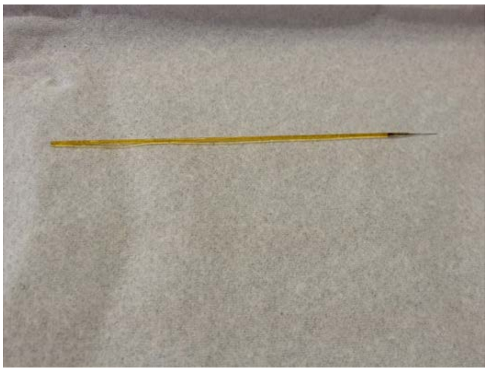

Figure 2. *Tapered fiber with 50 nm gold layer.*

Figure 2 shows tapered fiber made by flame brushing technique and metal layer deposited using sputtering technique.

The Reflectometry System (Nanocalc 2000 Ocean optics) was used to excite light into one end of the tapered fiber sensor and monitor the reflection spectrum from the same end of the tapered fiber. For a typical test, air was used to evaluate the performance of the tapered fiber. The intensity of light reflected internally from the metal film was measured. Experimental SPR set-up can be seen in Figure 3. The reflection spectrum of air was recorded for comparison.

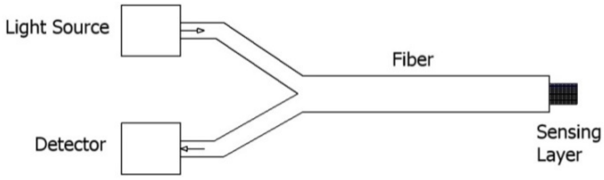

Figure 3. *Experimental SPR set-up.*

The comparison between the initial reflection spectrum on air (red), reflection spectrum dipped in ethanol (blue), and reflection spectrum dipped in sugar solution (black) was shown in figure 4. There was an obvious shift. A change in refractive index at the surface of the gold layer causes the shift. At 589 nm standard refractive index measurements taken, refractive index of water is 1.00, refractive index of 10% glucose solution in water is 1.33, and refractive index of ethanol is 1.36. It was found experimentally that the bigger the refractive index could shift reflection spectrum to the right and it matches our experiment result.

However, the experimental result showed small changes in profile and intensity. There might be some reasons for this. First, the tested tapered fiber sensor was not as ideal as we hoped for. Second, there might be physically adsorbed solution which also changed the properties of the tapered waveguide.

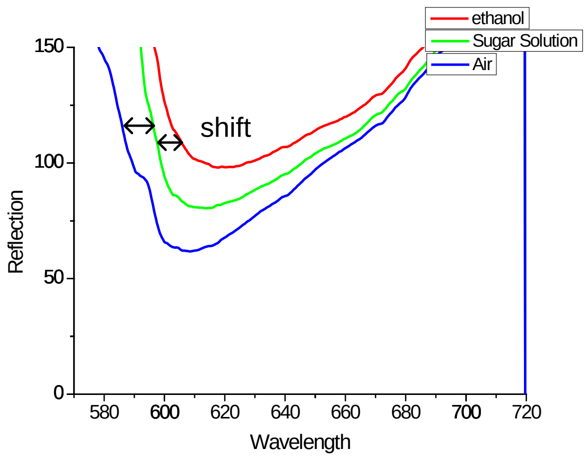

Figure 4. *A shift in SPR dip caused by changes in refractive index.*

3. Conclusion

The excitation of surface plasmon waves in the gold metal-air interface was examined, and a dip in reflected intensity was observed. The performance of SPR refractive index sensor was investigated by using air, ethanol, and sugar solutions. It is noted that the SPR reflectance curve shifts. It is inferred that if the SPR dip in the reflectance is used as a basis for the detection of variation in solution, a reasonably high sensitivity is achieved over a wide range of refractive index measurement.

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