Highly Sensitive Surface Plasmon Resonance Fiber Sensor Based On Triangle Gold Nano-rod Array

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***Abstract*—In order to obtain a high sensitivity, linearity and large dynamic measuring range, A physical model for a novel surface plasmon resonance sensor coupled by side polished fiber and triangular nano-rod array is proposed and established. By using finite element method (FEM), the strong evanescent field escaped from the polished region of the fiber excites three kinds of plasmon resonances, which are propagating surface plasmon resonance (PSPR), intrinsic surface plasmon resonance (ISPR) of the triangular nano-rod, and the inter-rod surface plasmon resonance (IrSPR), and correspondingly results in three resonance valleys in the transmission spectra of the sensor. Both the ISPR and the IrSPR are of localized surface plasmon resonance (LSPR), presenting a relatively low sensitivity while yields in a high linearity to the change of the refractive index of the surrounding environment. On the contrary, the propagating surface plasmon resonance shows a high sensitivity but a nonlinear dependence to the change of refractive index. In the optimized design with a height of 100 nm for the triangular gold nano-rod, a sensitivity up to 12882 nm/RIU is achieved in the range of 1.38 ~ 1.42 RIU.**

Keywords—***Surface plamon resonance; Side-polished fiber; finite element method; triangular gold nano-rod array; sensitivity; dynamic measurement range***

I. INTRODUCTION

Surface plasmon resonance (SPR) is a kind of physical phenomena in the interface of the metal and dielectric. It is very sensitive to the dielectric refractive index adjacent to the metal, and it's playing an important role in biology, medicine and chemical detection [1-5]. The optical fiber SPR sensors have great applications in the food safety, water quality, environmental health due to it's good light transmission characteristic, such as small volume, low cost, remote transmission and so on.

In this paper, we mainly calculate a physical fiber SPR sensor coupled by side polished fiber and triangular nano-rod array,which not only can obtain a higher sensotivity than the traditional gold film sensor, but also can get a high linearity and a large measurement range.

SIMULATION MODEL

In simulation, The 3D(a) and 2D(b) schematic of side-polished fiber optic SPR sensor based on the gold triangle nano-rod array is proposed from Fig.1. The residual fiber thickness and the diameter of the fiber core are 125 µm and 8µm, the Refractive index were 1.4378 RIU (Refractive index unit) and 1.4457 RIU, respectively, the length of sensitive area is L. And the triangular nano-rod array is covering the polished area of the fiber, the altitude of the triangle is defined as D.

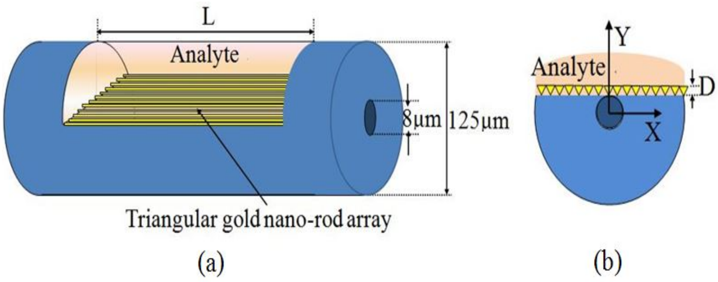


Fig.1 The 3D(a) and 2D(b) schematic of side-polished fiber optic SPR sensor based on the gold triangle nano-rod array

II. RESULTS AND DISCUSSIONS

A. For this part, we propose a gold triangular nano-rod to replace the gold film. There are seven different altitudes were simulated to calculate for this SPR sensor, 60nm, 70nm, 80nm, 90nm, 100nm, 110nm, and 120nm, respectively, which is marked by D in the Figure 2.

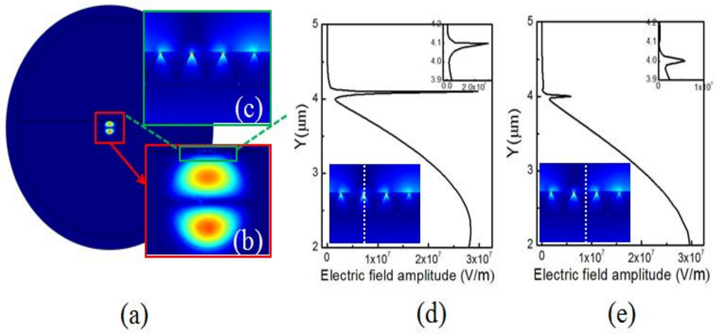
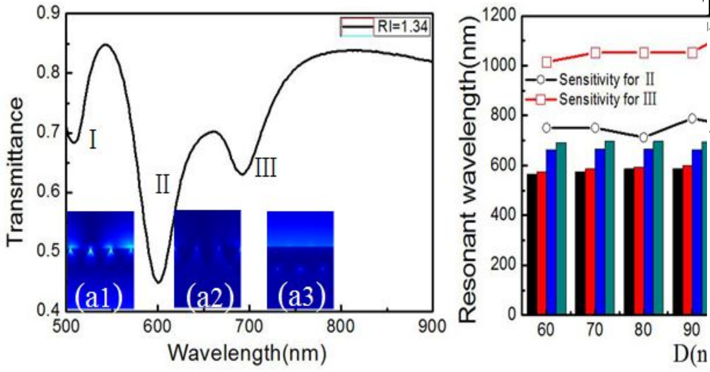


Figure 1 (a-c)Field distribution for fiber SPR sensor with RI = 1.34; Electric field density along the y-axis. When y=4.1µm(d); y = 4µm(e), at the height of the gold triangle nano-rod array surface, the decay of the field is interrupted and a strong peak occurs corresponding to the plasmonic mode

To verify the resonances, we quantify the electric field distribution for the case RIU = 1.34, as shown in Fig 2. The left image shows the field distribution when SPR occurs. Close to the center, the electric field density decreases roughly symmetrically with distance from the center. However, at y = 4µm, corresponding to the plane of the gold triangular nano-rod surface, a sharp peak in the electric field is apparent. This electric field enhancement is caused by surface plasmon resonance and has potential applications in surface-enhanced Raman scattering. As expected, the field decreases exponentially with distance above the surface.



(a) (b

B. *Sensing properties*

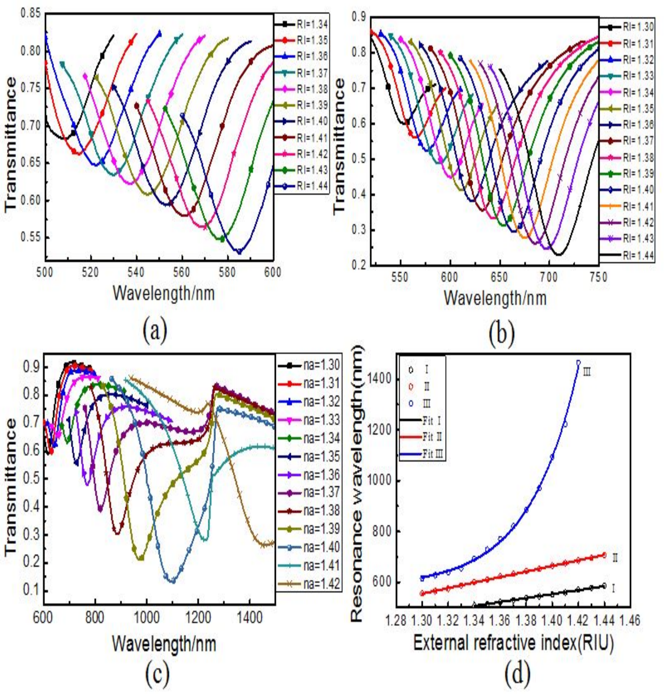


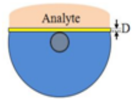
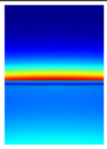
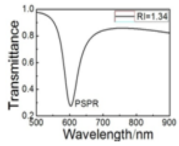
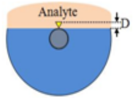
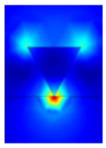
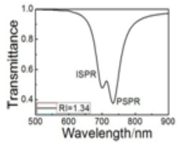
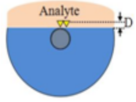
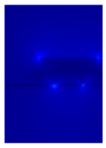
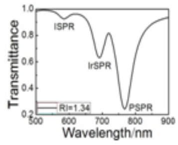
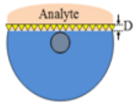
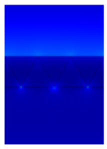
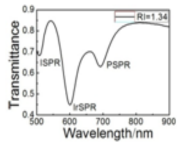
Fig.3(a-c) The wavelength shifts with the different RIU in a range of 1.30-1.43RIU; (d)The linearity of those three resonance dips.

We analyze the transmittance curves of different gold film thickness (30, 40, 50, 60, and 70nm). Fig.3 shows that the resonant valley becomes shallower with the increase of gold film thickness, and the FWHM become wider. And the highest sensitivity is 2920 nm/RIU when the gold film thickness is 50nm and 70nm. However, the FOM of the 50nm is higher than 70nm. Therefore, to obtain the better performance, the selected thickness of gold film is 50nm.

C. *The characteristics of different sensing structure*

In order to explain the reason of three resonance dips, we simulate the different cover methods of SPR sensor. the optimum thickness of gold film is 50nm , while the hight of triangle is 100nm. when the refractive index of surrounding environment is changed from 1.33RIU to 1.34RIU, the resonance wavelength will be calculated for these four different structures sensors. and the sensitivities of them can be obtained from the formula(2).

Table 1 The characteristics of different sensing structure

Model	Electric field (PSPR)	Resonance spectrum	Sensitivity(nm/RIU) PSPR	ISPR	IrSPR
 Gold nano film			2764		
 Single triangular gold nano-rod			1003	1003	
 Double triangular gold nano-rod			1253	1003	501
 Triangular gold nano-rod array			3759	1253	752

III. CONCLUSIONS

According to the simulation, we can find that using the gold triangular nano-rod array instead of the gold film will enhance the sensitivity of a single mode fiber SPR sensor. when the refractive index of surrounding environment is changed from 1.30RIU to 1.33RIU, the sensitivity of 1337 nm/RIU is lower than the traditional optical fiber SPR sensor based on the structure of gold film, which is 2167 nm/RIU. While the refractive index of surrounding environment is changed from 1.33RIU to 1.38RIU and from 1.38RIU to 1.42RIU respectively, it can achieve an average sensitivity of 4094 nm/RIU and 12882 nm/RIU, respectively, which all are higher than the average sensitivity of 3900nm/RIU and 10010 nm/RIU of the traditional optical fiber SPR sensor based on the structure of nanostructured gold film. Therefore, according to the different measurement requirements, we present a SPR sensor based on gold triangular nano-rod. This sensor not only can obtain a higher sensotivity than the traditional gold film sensor, but also can get a high linearity and a large measurement range.

Acknowledgment

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