Design and Optimization of Surface Plasmon Resonance Fiber Sensor Based on Gold Nano-Column Array

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***Abstract*—In this paper, a surface plasmon resonance fiber sensor based on gold nano-column array instead of gold film is designed and optimized. The finite element method (FEM) is used to optimize the sensitivity, resonance wavelength and resonance intensity of the fiber sensor relate to the diameter of the nano-gold colunm. The optimized sensor has 70 nm gold nano-column coated on a D-shaped single mode fiber. The results show that the average sensitivity reaches 5318 nm/RIU when the environmental refractive index changing from 1.33 RIU to 1.39 RIU, which is much higher than that in conventional surface Plasmon resonance structure.**

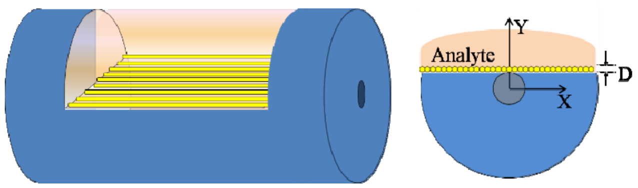
Keywords: Refractive index; single mode fiber; surface plasmon resonance; sensitivity

I. Introduction

In recent years, the optical fiber sensors have attracted considerable attention due to its high sensitivity and compact configuration [1-2]. Surface plasmons are charge density waves of free electrons which occur on a surface of a thin metal film interfacing with an adjacent dielectric and propagate along the interface [3-5]. In this paper, we simulate the SPR fiber sensor which gold film is replaced by gold nano-column array. We mainly calculate the sensitivity, resonance wavelength and resonance intensity of the SPR sensor relate to different size of gold nano-column to obtain the optimal performances.

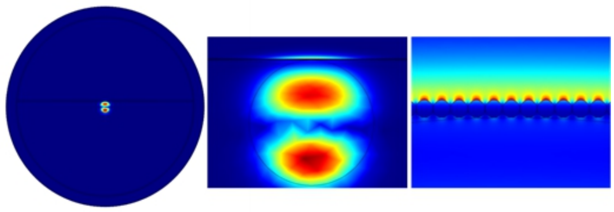
II. Simulation Model

The main parameter of the sensor includes the length of the sensor L, the radius (r_{core}) and refractive index (n_{core}) of the core are 10mm, 4 µm and 1.4378, respectively. The radius ($r_{cladding}$) and refractive index ($n_{cladding}$) of the cladding are 62.5µm and 1.4457, respectively, the residual fiber thickness d=75µm. The 3D and 2D model of the structure of fiber SPR sensor based on nano-columns array can be seen in Fig.1. D denotes the diameter of gold nano-column. From the analysis of the coupling mode theory, the light leak out from the "window" of the optical fiber polishing area, there will be a phenomenon of surface plasmon resonance(SPR), when it satisfies the resonance conditions. As we can see in Fig.2, significant electromagnetic field aggregating around the gold nano-column, its strength is higher than that of gold film. It is due to the mutual coupling between the gold nano-columns. So it is obvious that SPR occurs on the interface between the single mode fiber core and the gold nano-columns. Fig.2 (b) is the local amplification of the core Fig.2 (a), and Fig.2(c) is the local amplification of gold nano-columns array of Fig.2 (b).



(a) (b)

Fig.1 The model of the structure of fiber SPR sensor based on nano-columns array: (a) 3D; (b)2D.



(a) (b) (c)

Fig.2 cross section mode field of optical fiber coated gold nano-columns (λ =638.19, RI=1.33): (a) global mode field distribution; (b) mode field distribution of the core position and surrounding; (c) mode field distribution of gold nano-columns array.

III. Results And Discussions

This paper mainly calculates the influence of optical fiber sensor relate to different diameters of gold nano-columns (60 nm, 70 nm, 80 nm, 90 nm, 100 nm, 110 nm, 120 nm). Fig. 3 reflects the sensitivity of optical fiber sensor change with the diameter of gold nano-columns as well as the environmental refractive index changed from 1.33 RIU to 1.34 RIU. As the chart shows, in the same environment, the resonant wavelength increases with the increasing diameter of gold nano-columns. The sensitivity of SPR optical fiber sensor is minimum when the diameter is 60nm. When the diameter shifts from 70 nm to 120 nm, there is little influence of sensitivity of fiber sensor. But the larger the diameter of the column results in deeper resonance dips (Fig.4). Considering synthetically, the optimum diameter is 70nm.

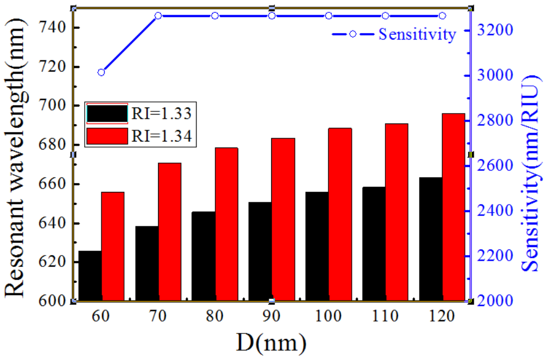


Fig. (3) Sensitivity and resonant wavelength of the SPR fiber sensor with different size of gold nano-columns in different environmental reftractive index

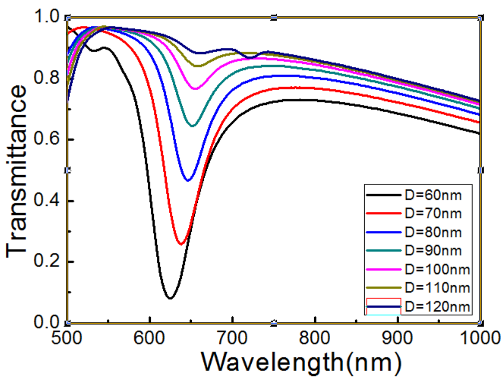
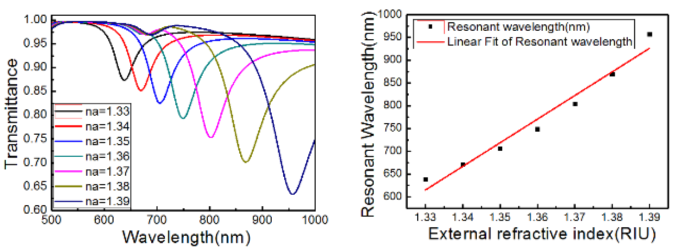


Fig.4 transmittance of fiber sensor relate to different size of gold nano-columns



(a) (b)

Fig.5 (a) transmittance change with environmental refractive index; (b) relationship between the resonant wavelength and external refractive index

Based on the above calculation, we choose the optimized parameter to evaluate the performance of sensors. When the environmental refractive index change from 1.33 RIU to 1.39 RIU, as shown in Fig.5 (a), the average sensitivity of the sensor can reach 5318 nm/RIU, and there is a good linear relationship between the resonance wavelength and the refractive index of the environment which is showed in Fig. 5 (b).

IV. Conclusion

In summary, simulation results shows that the thickness of gold nano-column D. It has great influence on the sensitivity, resonance wavelength and resonance intensity of SPR fiber sensor. When the thickness of gold nano-column approaches 70nm, this single mode fiber SPR sensor has ability to work in a large dynamic ambient range from 1.33 RIU to 1.39 RIU with high sensitivity of 5318nm/RIU.

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