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

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***Abstract*—Using finite element method (FEM), a D-shaped surface plasmon resonance (SPR) fiber sensor based on square gold nano-rod array was designed and optimized. Here the core radius of single mode fiber is 8μm. The simulations show that the resonant wavelengths of 45th~50th propagation modes and their wavelength redshifts due to the ambient refractive index change are all the same. Among the SPR spectrums for different modes, higher order mode will induce deeper notch and larger extinction ratio. By tracing the wavelength shift of the 45th mode, the sensor was optimized. The optimized sensor has 70nm square gold nano-rods thickness and 50nm distance between square nano-rods coated on D-shaped single mode fiber. Its average sensitivity of 6266 nm/RIU can be attained, which is much higher than 3150 nm/RIU of the single mode SPR fiber sensor in the ref. [1].**

Keywords—Refractive index; singlemode fiber sensor; 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 In this paper, we simulate the SPR fiber sensor which gold film has been replaced by square gold nano-rod array. We mainly calculate the impact of different size of square gold nano-rods and the distance between the nano-rods on the D-shape SPR fiber sensor sensitivity to obtain the optimal performances.

II. SIMULATION MODEL

In simulation, the main design performances of the sensor included the length of the sensor L (10mm), the radius and refractive index of the core ($r_{core}=8\mu m$ and $n_{core}=1.4457$, respectively) and of the cladding ($r_{cladding}=62.5\mu m$ and $n_{cladding}=1.4378$, respectively), the residual fiber thickness $d=66.5\mu m$, the thickness of square gold nano-rods D, their distance Λ and the refractive index of the environ ambient medium n_a. The maximum element size and the minimum element size of the mesh are 2.8μm and 0.1μm. And we determine the optimum performances according to the sensitivity [6].

Fig.1(a) Structure of the SPR fiber sensor. Gold nano-rods are put on the D-shape area in parallel with the fiber. Fig.1 (b)Sectional view of the D-shape area. The cross section of the gold nano-rods is square. Fig.1 (c) shows that the full view of the electric field amplitude distribution, and electrical field amplitude 1D across the fiber core. Fig.1 (d) shows that the electric field and the electrical field will be changed by the gold nano-rods. Fig1(e) As we can see the electric field and electrical field across the fiber core couples with that on the nano-rod array.

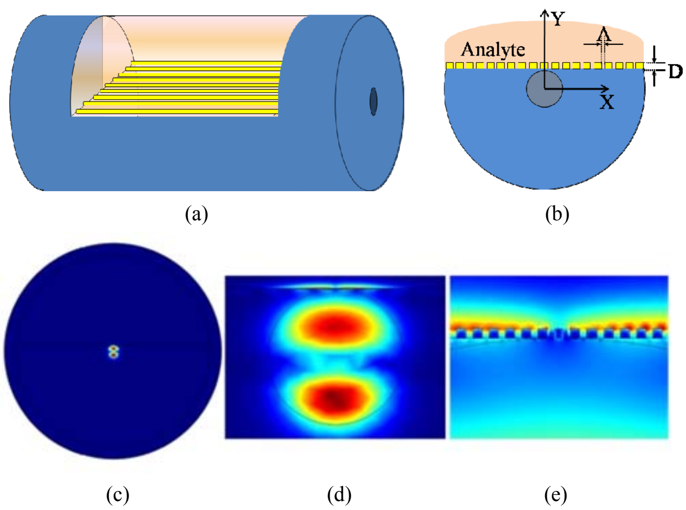


Fig.1 (a) (b)Structure of the surface plasmon resonance fiber sensor based on square gold nano-rod array.(c) Full view of the electric field amplitude distribution, and electrical field amplitude 1D across the fiber core.(d) Partial view of the electric field amplitude distribution, and electrical field amplitude near the fiber core.(e) Partial view of the electric field amplitude distribution, and electrical field amplitude near the square gold nano-rod array.

III. Results And Discussions

A. The relation between the thickness of square gold nano-rods D*, the distance between them Λ and the SPR sensor sensitivity.*

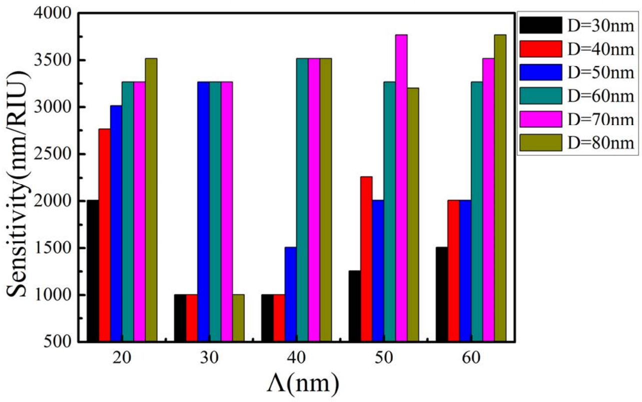
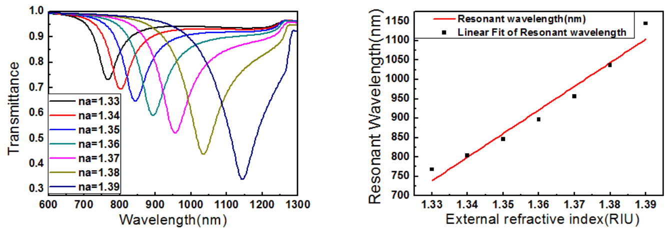


Fig.2 Sensitivity of the SPR fiber sensor with different size of square gold nano-rods D and the distance between them Λ.

When the refractive index of the environ ambient medium changes from 1.33 to 1.34, we depict the sensitivity of the SPR fiber sensor for 5 distances Λ, i.e., 20, 30, 40, 50, 60nm and the 6 thickness of square gold nano-rods *D*, i.e., 30, 40, 50, 60, 70, 80nm. We can find that the highest sensitivity is 3769 nm/RIU when Λ=50nm, D=70nm.

B. Sensitivity under the optimal performance

Through the above analysis, we get the optimal performance for SPR fiber sensor based on square gold nano-rod Array which the thickness of square gold nano-rods D is 70nm, the distance between them Λ is 50nm.



(a) (b)

Fig.3 Simulation of transmittance of the sensor for different ambient refractive index(a), and(b) linear fitting lines of the fiftieth mode resonant wavelength versus ambient refractive index of 1.33-1.39

In the case of the optimal performances, we calculate the location of the resonance wavelength under different ambient refractive index (1.33-1.39) and point out the linear fitting lines of the resonant wavelength versus ambient refractive index of 1.33-1.39. Fig.3 (a) shows the resonant wavelength obviously moves toward longer wavelength as the refractive index of the ambient increases, and the resonant peak becomes deeper. We have an average sensitivity of 6266nm/RIU, and have high linearity.

IV. Conclusions

Simulation results shows that the thickness of square gold nano-rods *D*, the distance between them Λ both have a great influence on the sensitivity of SPR fiber sensor. When the thickness of square gold nano-rods approaches 70nm and the distance between them is close to 50nm, this single mode SPR fiber sensor has ability to work in a large dynamic ambient range from 1.33 to 1.39 with high sensitivity of 6266 nm/RIU and linearity.

V. Acknowledgment

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