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طراحی و ساخت حسگر تشدید پلاسمون سطحی

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چکیده: امروزه حسگرهای تشدید پلاسمون سطحی به یک ابزار مهم برای مشخصه یابی و شناسایی اندرکنش بین مولکول های زیستی و دارویی تبدیل گشته است. در این مقاله ابتدا مراحل طراحی و ساخت یک حسگر پلاسمونیکی گزارش شده و سپس با استفاده از حسگر ساخته شده ضریب شکست سه محیط متفاوت به صورت تجربی اندازه گیری شده است. نتایج تجربی و شبیه سازی ما نشان میدهد که حسگر ساخته شده می تواندبرای اندازه گیری ضریب شکست محیط های مایع با حساسیت 8×10^{-4} RIU **ومحیط های گازی با حساسیت** 1.5×10^{-3} RIU **به کار رود.**

کلید واژه- تشدید پلاسمون سطحی، حسگر ضریب شکست، حسگر زیستی SPR

Design and Construction of Surface Plasmon Resonance Sensor

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Abstract: surface plasmon resonance (SPR) sensors have become a central tool for characterizing and quantifying bimolecular and drugs interactions. In this article first we have reported the processes of designing and manufacturing of our new homemade SPR sensor. Then by means of constructed sensor the refractive index of three mediums have been measured. Based on both experimental and simulated results, our SPR sensor can be used as refractive index sensor for liquid mediums (gas mediums) with sensitivity of 8×10^{-4} RIU (1.5×10^{-3} RIU).

Keywords: Surface Plasmon Resonance, refractive index sensor, SPR biosensor.

1. Introduction

Today Surface plasmon resonance (SPR) sensors have been demonstrated as a sensitive and label-free probe for the biomolecular interactions.

In a typical SPR sensor, a glass slide with a thin gold coating is colligated to a prism. In the attenuated total reflection method, when light is illuminated through the glass slide and onto the gold surface at angles and wavelengths near the so-called "surface plasmon resonance" condition, a drop in the reflectivity of the gold film is observed.

For a monochromatic light source, the angles where the SPR condition has been reached, depends very sensitively on refractive index changing of the adjacent medium to gold. This phenomena is used in SPR sensors for measuring the refractive index variation of different samples [1-3].

In this article we have reported the processes of designing, manufacturing and testing of our new homemade SPR sensor.

2. Materials and Methods

2-1. Simulation and Design method

In this work, the Transfer matrix method (TMM) is used to calculate reflectivity of designed SPR sensor in angular modulation.

The structure is considered as one-dimensional four layers that consists of prism, Titanium, Gold and medium. The manufactured chip consists of 5 nm titanium that coated on BK7 slide and 50 nm of Gold that was coated on the titanium. Then this chip is colligated to a BK7 prism by appropriate matching index oil. The Schematic of this structure are shown in fig 1. The refractive index of layers used in the present simulation are listed in Table 1. (The matching index oil and glass slide ignored in simulation because of their same refractive index as prism). The incident light is considered as a p-polarized plane wave with wavelength of 671 nm.

According to TMM method, the characteristics matrix for each layer can be expressed by:

$$M_i = \frac{1}{2\tilde{n}_{i+1}} \begin{bmatrix} (\tilde{n}_i + \tilde{n}_{i+1})e^{-j\varphi_i} & (\tilde{n}_i - \tilde{n}_{i+1})e^{+j\varphi_i} \\ (\tilde{n}_i - \tilde{n}_{i+1})e^{-j\varphi_i} & (\tilde{n}_i + \tilde{n}_{i+1})e^{+j\varphi_i} \end{bmatrix}$$

Where $\tilde{n}_i = n_i sec\theta_i$ and $\varphi_i = n_i k_0 d_1 cos\theta_i$ [4]. The resultant matrix is defined as the product of these characteristics matrices:

$$M_i = M_1 ´ M_2 ´ M_3 ´ M_4$$

From which the reflectivity is calculated as:

$$R = \left| M_{10} / M_{00} \right|^2$$

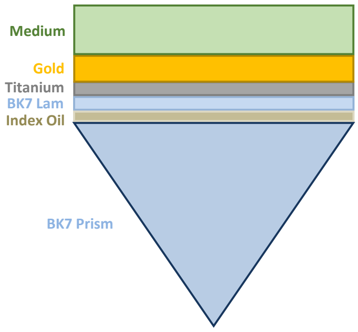

Figure 1. Schematic of our structure

Table 1. Optical properties of materials at 671 nm wavelength of light and 27.2°C [5].

Material		Refractive index	Thickness
BK7 Prism		1.62	Semi-infinite
Titanium		2.70+3.77i	5nm
Gold		0.18+3.44i	50nm
Medium (one of the fallowing materials)	Air	1.00	Semi-infinite
	Water	1.36	
	Ethanol	1.33	

2.2 Experimental Setup

We designed several optical elements to customizing our SPR sensor.

A diode laser with wavelength of 671 nm has been used as light source. the light was p-polarized by a linear polarizer. To change incidence angle, we used two XY-axis servomotors drive controller with 0.08° of each step. A neutral density filter (ND filter) was used to reduce power of the incident light because high intensities of light cannot be detected by photodetector. A Plano-convex lens was used to collimate light to a spot on the SPR surface. The intensity of reflected light was measured with a pin diode detector.

Figure 2. Experimental Setup a) schematic, b) 3D Figure, c) Laboratory view

We have made a series of experiments with three different mediums of Air, Water and Ethanol, to test the performance of our sensor.

3. Results and Discussion

The simulation results of our study are shown in Fig. 3. These simulations are calculated for three different mediums (Air, ethanol, water). Also the experimental results of these mediums are brought in Fig. 4.

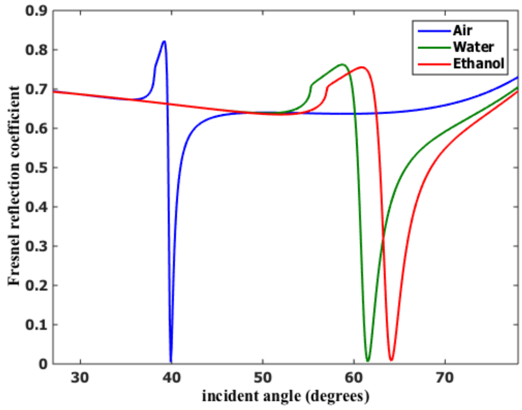

Figure 3. Simulation result of Air, Water and Ethanol

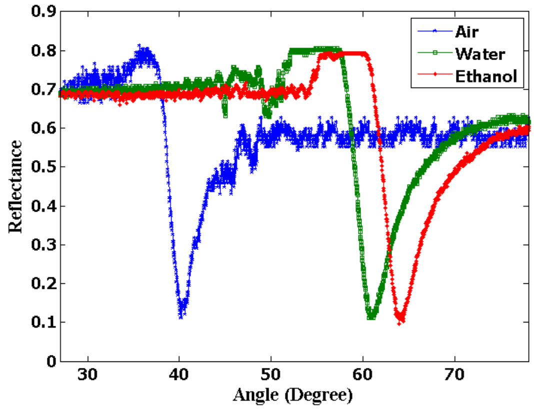

Figure 4. Experimental results of Air, Water and Ethanol

It can be seen that numerical results and experimental data are in excellent agreement. According to these results a change in refractive index of the sample medium leads to a measurable shift in the angular position of the deep of the reflectivity. It shows that this apparatus can be used as a refractive index sensor.

To calculate the sensitivity of this sensor, it's necessary to calculate calibration curve. In this order we made a simulation where the medium refractive index has been varied in the range of 0.8 to 1.5 and calculate SPR angle.

The calculated results have been shown in Fig. 5. In this figure the experimentally measured value of SPR angle for three different sample mediums are also presented.

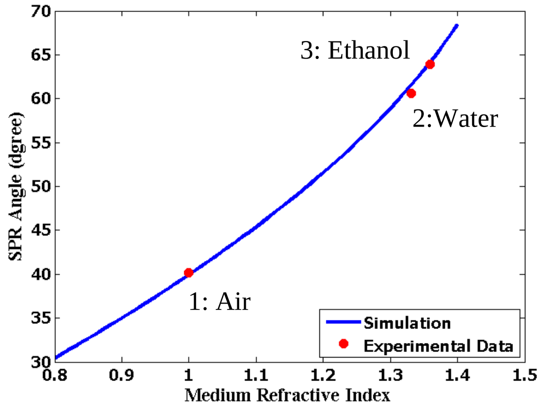

Figure 5. Experimental and simulation data of results of calibration curve

The value of line slope of calibration curve between points 2 and 3 is $m = \frac{\Delta n}{\Delta\theta} = 0.01$. Reminding this fact that our rotation stage accuracy is $\Delta\theta_{min} = 0.08°$, the minimum refractive index which can be measured with our SPR sensor is:

$$\Delta n_{min} = m * \Delta\theta_{min} = 8 \times 10^{-4}$$

The minimum detectable refractive index change may be used to describe the sensitivity. This means that the sensitivity of our homemade SPR sensor for liquid mediums is 8×10^{-4} RIU.

Depends on line slope of calibration curve at point 1, the sensitivity of our sensor is 1.5×10^{-3} RIU for gas mediums.

4. Conclusion

In this article we have reported the processes of designing, manufacturing and testing of our new homemade SPR sensor.

Both experimental and simulated results show that our SPR sensor can be used as refractive index sensor for liquid mediums (gas mediums) with sensitivity of 8×10^{-4} RIU ($1.5 \times 10^{-3} RIU$).

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