Modeling of halloysite-nanotube modified surface plasmon resonance sensor

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Abstract— **In this paper, a numerical model of halloysite nano-tubes (HNTs) modified surface plasmon resonance sensor is established and optimized. The simulations investigate the effect of HNTs size parameters on the SPR sensor performance. From this study we can find that the optimal design for halloysite modified SPR sensor.**

Keywords-Surface plasmon resonance; sensitivity; halloysite nano-tube

I. INTRODUCTION

In recent years, many attentions have been attracted in the development of optical sensors with high sensitivity and excellent performance [1]. Surface plasmon resonance (SPR) has evolved from a fairly esoteric physical phenomenon to an optical tool that is widely used in physical, chemical and biological investigations where the characterization of an interface is of interest [2, 3]. However, the SPR sensors are insufficient sensitive for the direct detection of small molecules, ultralow concentration of analyte, or low affinity interactions [4, 5] Halloysite nano-tubes have recently been demonstrated to show excellent performances in various fields derive from their versatile properties, such as high aspect ratio, good biocompatibility, and high refractive index, which can potentially result in the improvement of sensor performance. In this paper, we establish the numerical model for the SPR sensor modified with a layer of halloysite nano-tubes on the top of the gold film. The effect of HNTs size parameters on the SPR sensor are analyzed and the optimized design is carried out.

I. SIMULATION MODEL

Figure 1 shows the simulation model for a Kretschmann SPR configuration. A gold film of tens nanometers in thickness is deposited on the prism, and a layer of HNTs is sprayed on the gold surface. The refractive indices of prism, gold, and HNTs are obtained from the database of Refractive Index website [6]. The system is operated in a wavelength modulation. The method we use in this work is transfer-matrix method (TMM). The sensitivity (S) is defined as the ratio of the wavelength shift (Δλ) to the change of refractive index (Δn).

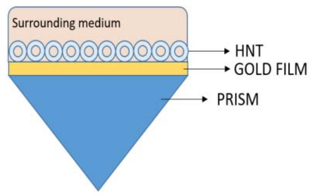

Fig.1 Structure of HNT modified SPR sensor

II. RESULTS AND DISCUSSIONS

A. The relation between the size of HNT and the SPR sensor sensitivity.

Figure 2 shows the sensitivity of SPR sensor modified with HNTs for inner diameters of 10 nm, 15 nm, 20 nm, and outer diameters of 40 nm, 50 nm , 60 nm and 70nm, respectively. We can find that the highest sensitivity is 5051 nm/RIU when the inner diameter is 10 nm and the outer diameter is 70 nm.

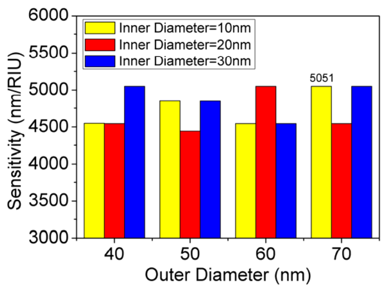

Fig.2 Sensitivity of the SPR sensor modified with different size of HNT.

B. Sensitivity under the optimal performance

Now, we pick out the optimal design, where the inner and outer diameter is 10 nm and 70 nm respectively, for further analysis of the sensor performance. The resonance dip shifts to longer wavelength when the ambient refractive index increase from 1.333 to 1.36 RIU and yields a linear coefficient up to 0.99384, as shown in Fig. 3. The sensitivity achieved here is 6313 nm/RIU, which is much higher than that of the conventional SPR sensor.

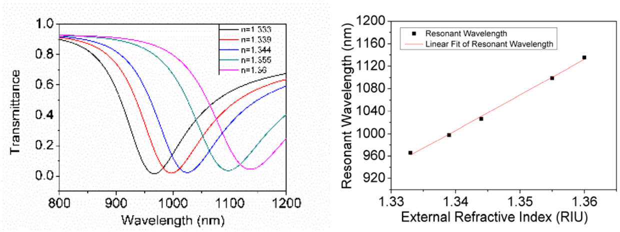

Fig.3 Simulation of transmittance of the sensor for different ambient refractive index, and linear fitting lines of the resonant wavelength versus ambient refractive index of 1.33-1.36 RIU.

To verify the simulation result, experimental measurement is performed on a SPR sensor modified with 2.5%, 5% HNTs concentration of the dispersion of HNT and ethanol. The experimental results shown in Fig. 4 demonstrate the practical sensor exhibit similar tendency to the simulated one. The sensitivity is measured to be 3140 nm/RIU and 8000 nm/RIU for HNTs 2.5% and 5%, respectively. It can be estimated that the HNTs concentration in the simulation should be approximately 4%.

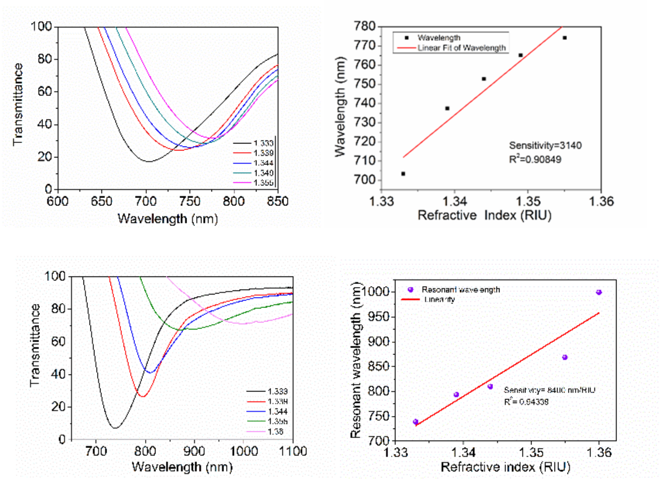

Fig.4 Experimental of transmittance of the sensor for different ambient refractive index, and linear fitting lines of the resonant wavelength versus ambient refractive index of 1.33-1.36 RIU.

III. CONCLUSIONS

A simulation model for the HNTs modified SPR sensor is established and the effect of inner and outer diameters of HNTs on the sensor performance is investigated as well. The optimized design achieve a sensitivity of 6313nm/RIU and a linearity of 0.99384.Experiments are performed and verify the numerical analysis. Thanks to the excellent properties of HNTs and the enhancement to the sensor performance, the proposed sensor might have a promising future in biochemical sensing.

IV. ACKNOWLEDGMENR

This work is supported by the National Natural Science Foundation of China (Nos. 61575084, 61505069, 61575084, 61177075, 61275046, 61675092, 61361166006, 61475066, 61405075, and 61401176), the Natural Science Foundation of Guangdong Province (Nos. 2016A030310098, 2014A030313377, 2014A030310205, 2015A030306046, 2015A030313320, 2016A030311019, and 2016A030313079), the Science and Technology Projects of Guangdong Province (Nos. 2012A032300016, 2014B010120002, 2014B010117002, 2015A020213006, 2015B010125007, 2016B010111003, and 2016A010101017), the Science & Technology Project of Guangzhou (201607010134, 201506010046, 201605030002).

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