Active Plasmonic Biosensors

Active plasmonic nanostructures in organic electroluminescent biosensors

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***Abstract*—We have demonstrated the phenomenon of active plasmonic grating structure for active surface plasmon polaritons propagating along 2-D grating at an organic/metal interface via Surface Plasmon Grating Coupled Emission (SPGCE) for enhancing and tuning far-field light emission. Our results showed that strong coupling resonances in SP-coupled emission from the interactions of organic/metal and metal/air symmetric mode lead to the enhanced optical properties of directional emission. Such scattering taking place through a metal film has an important bearing on the generation of useful light. Further investigations will be performed on SPPs with the integration of optimized organic electroluminescent plasmonic for active biosensor devices in biochemical analysis and immunoassay.**

Keywords- Surface plasmon resonance; nano-grating; band-gap; bioplasmonics.

I. INTRODUCTION

Surface Plasmon Resonance (SPR) phenomenon was described in 1980 and has been used for sensing for the past three decades [1][2]. SPR biosensors are optical sensors using polarized Surface Electromagnetic Waves (SEW) to probe molecular interactions between metal film surface and dielectric medium. SPR sensors have the advantages of high sensitivity, label-free and real-time detection [3]. In this paper, the coupling Surface Plasmon Polaritons (SPPs) on the nano-grating, the active plasmonics band-gap structure for bio-plasmonics are demonstrated. The presented results show that the enhanced performance of plasmonic on nano-grating, the active plasmonics band-gap structure is important for the structure design of novel optical biosensors.

The motivation of this research is to develop an accurate, integrated SPR sensor system chip using existing organic electroluminescent plasmonic technology due to its sensitivity and label-free advantage. We will propose a novel design of SPR device without using external light source and polarizer to have the same features of SPR, i.e., high sensitivity and real time. We can then observe the signal changes due to the presence of surface molecule or specific absorption wavelength of multiple samples. An all-in-one SPR sensor system chip with the capability of sensing applications in drug discovery, drug development testing or different kind of viruses and poison will be realized to eliminate large casualties in wars, terrorist activities or virus infections.

II. EXPERIMENT PROCEDURES

The excitation of organic semiconductor molecules by Surface Plasmon Grating Coupled Emission (SPGCE) is intended to demonstrate the effect of coupled active SPPs on the plasmonics response of a grating nanostructure with organic material on the surface. Our fabricated different pitch grating device consists of coupled organic/metal nanostructure with specific width and symmetric and asymmetric dielectric plasmonic band-gap structure. In particular, it is found that emission is significantly inhibited in the vicinity of the gap, and that the modified emission spectrum is determined by the wavelength dependence of the density of SPP states. We present recent experimental results discuss potential applications of such active plasmonic biosensor with enhanced resonance energy emission due to interactions on the organic/metal nano-grating. We report the design and development of organic semiconductor devices for chemical and biological sensing. A plasmonics-based biosensor was demonstrated using an organic SPGCE as an excitation source. In addition, the possibility of biological immunoassay for sensors based on active SPGCE was explored, as shown in Figures 1(a-c).

The interaction of SPR on a periodic grating of metal and polymer were investigated in theory and experiments [4]-[14]. In addition, we proposed a novel design of plasmonic biosensor without using the conventional external light source and polarizer to produce SPR having the same features, i.e., high sensitivity and real time. It can induce SPR wave on the metallic surface when proper resonant condition is matched by nano-grating coupled emission [4]-[7].

III. RESULTS AND DISCUSSION

We have shown experimentally that strong coupling between electronic and photonic resonances in metal grating and polymer grating really exist. Resonance angle plots of reflectivity of a metal nano-grating sensor, demonstrates the sensitivity of a refractmetric experiment, $\Delta\theta/\Delta n=36.4$ ($\lambda=643$ nm) and $\Delta\theta/\Delta n=69.7$ ($\lambda=833$ nm). In active plasmonic, our fabricated grating device of various pitches consists of coupled Au (gold) and polymer nanostructure with specific width and symmetric/asymmetric dielectric SP band-gap structure. In pitch modulation, results showed that grating at different pitch can match a linear shifting of momentum of about $\Delta k = 4.79\ \mu m^{-1}$ and $\Delta\theta = 11$ degree per 100 nm pitch size. In layer modulation, the resultant emission intensity can achieve a maximum enhancement of 6 times for the 4-Layer device and the Full-Width Half-Maximum (FWHM) was less than 50 nm. We can then observe the emission signal changes due to the presence of surface molecule or specific absorption wavelength of multiple samples. This phenomenon gives rise to a selective spectral response and a local field enhancement, which can be used for modulation in the nano-optics. The Alq_3/Au interface reciprocal interactions that the optical absorption, emission and scattering properties of metal nanostructures can be used to control the decay rates, intensity and FWHM and direction of luminescence emission.

The preliminary results of these prototypical systems based on active plasmonics look very promising. The use of active plasmonics may lead to new biosensors that are small, portable, inexpensive, fast, without the need of label-free or any chemical modifications, and biosensors that are capable of detecting low concentrations of specific analytes with high sensitivity, as well as selectivity, as shown in Figure 2 (a-c). We will optimize the active plasmonics and sensing component, which will have the benefit of expanding its application in various fields, including biochemical and antibody/antigen analyses, as well as enhancing its dynamic range due to the higher sensitivity. Such scattering taking place through a metal film has an important bearing on the generation of useful light. Further investigations will be performed on SPPs with the integration of optimized organic electroluminescent plasmonic for active biosensor devices in biochemical analysis and immunoassay. In our calculation, the grating pitch is set at 400 nm. Here, ε_d of air is 1, alcohol (1%) is 1.329, DNA (0.1mM) is 1.405, and Ethanol (1%) is 1.363 in our calculation. Figure 3 shows the calculation results from the SPR parameters given above. With an increasing value of ε_d, one can see a right shift of the ω-k curves, which correspond to an increase in momentum space.

IV. CONCLUSION

We demonstrated the SPGCE from excited organic layer on different metal grating in organic/metal structure. Our results showed that strong coupling resonances in SP-coupled emission from the interactions of Alq3/Au and Au/air symmetric mode leads to the enhanced optical properties of directional emission, intensity and FWHM for active plasmon devices. Such scattering taking place through a metal film has an important bearing on the generation of useful light. Further investigations will be performed on SPPs with the integration of optimized organic electroluminescent plasmonic for active biosensor devices in biochemical analysis and immunoassay. This indicated a potential application of disposable and point-of-care biosensor.

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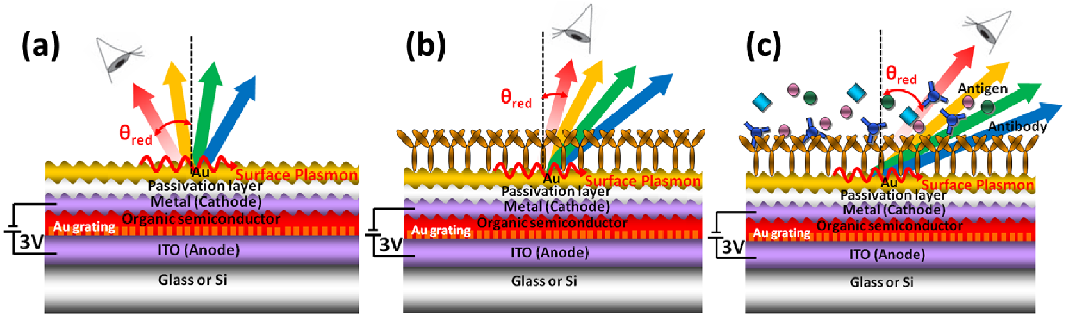

Figure 1. Light control in organic electroluminescence devices by SPGCE for biosensing application. The emission angle is dependent upon the index of refraction at the organic/metal/dielectric interface, which means that the index of refraction can be determined by measuring the shift in the emission angle.

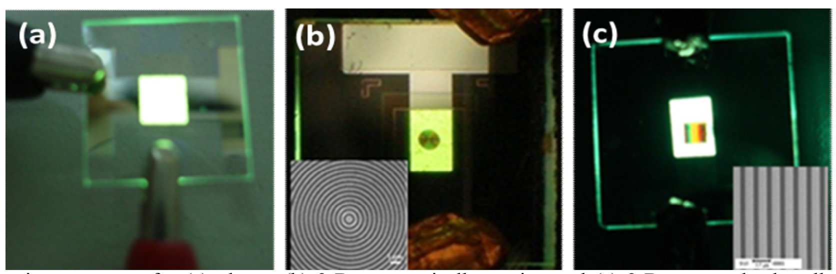

Figure 2. Active plasmonic grating structures for (a) planer, (b) 2-D concentrically grating and (c) 2-D rectangular lamellar grating in an organic/metal interface via surface plasmon coupled emission for enhancing and tuning far-field light emission of the active plasmonics biosensor based on novel electro-excitation method.

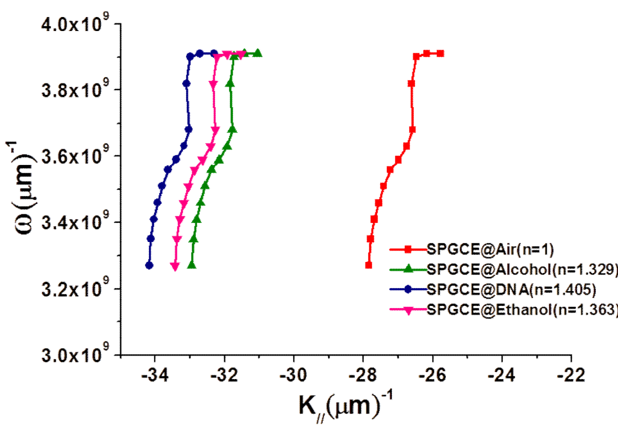

Figure 3.Experimental results for 2-D concentrically grating at pitch size of 400 nm. The dispersion relation between frequency ω and wave number $k_{//}$ for different species contacting the top side of the sample, the calibration dispersion curve for the determination of air and in alcohol (1%), DNA (0.1mM), and Ethanol (1%) solutions for the sample.

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