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Numerical analysis of graphene coated surface plasmon resonance biosensors for biomedical applications

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ABSTRACT

This paper describes the effect of adding graphene layers in prism and planar waveguide based surface plasmon resonance biosensors using angular interrogation mode. The proposed sensors are designed based on graphene material as biomolecular recognition elements (BRE) and the sharp SPR curve of gold (Au). Our calculations show that the proposed graphene in prism and planar waveguide based SPR biosensors have 1 + 0.40 L and 1+0.45 L; (where L is the number of graphene layers) times more sensitivity than the conventional SPR biosensor respectively. The enhanced sensitivity is due to increased SPR angle change about 40 L% and 45 L% by adding graphene layer and using the optical property of graphene. We also investigate the performance of proposed biosensors in terms of sensitivity using graphene sublayers. The compact size, prism and planar waveguide based design, and very high sensitive- these characteristics are expected to make these biosensors preferred choice for biomedical applications, as compared to other contemporary biosensors.

1. Introduction

In modern days, vast research area has been founded centering surface plasmon resonance (SPR) based biosensor making many researchers enthusiastic due to its fast growing field of applications such as analysis of biochemical substances like protein, DNA, different enzymes and so on. The SPR technique has gained uniqueness for its real time sensing and level free detection [1]. In case of SPR based biosensors, surface plasmon wave (SPW), a schematic representation of an electron density wave propagation or plasma oscillation is generated along metal-dielectric interface with resonant frequency simulated by incident light. That means, when light rays incident on the interface and matches with wave vector of surface plasmon (SP), resonance occurs at the surface [2].

Today, different types of SPR based biosensor has been investigated and developed on the basis of dielectric medium and types of metal layers coated over it. Among them prism-Au based SPR biosensor is conveniently used [1,3]. A p-polarized light falls into glass prism and reflected from gold coated prism facet [4]. In this case, deviation of reflected angle helps to detect the nature of biochemical substance got to keep on biosensor. But this type of biosensor would face complexity monitoring remote and distant species. Besides, large systems with costly projects can only suit this type of SPR based biosensor. Therefore it would be only suitable working at laboratory [4].

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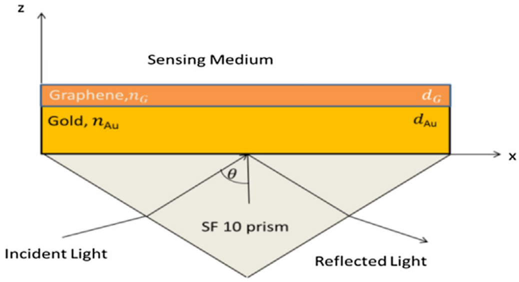

Fig. 1. proposed model of prism based SPR biosenso.

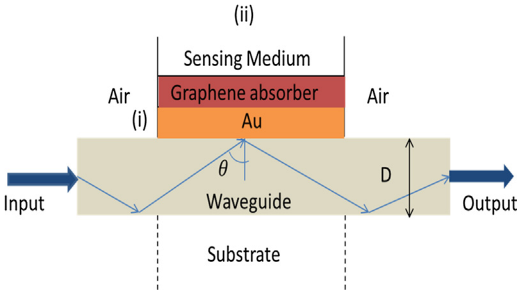

Fig. 2. proposed model of PWM based SPR biosensor.

On the other hand, waveguide based SPR can handle remote sensing and cost reduction in compared to prism based biosensor [5–7]. It ensures to produce multisensor devices with monolithic In this type of sensors, beam of light is thrown into a waveguide core and falls into accession between a fundamental core mode and a plasmon which spreads over a metal film deposited over waveguide [4]. Then resonance occurs at their interface.

It is a matter of fact that, improvement of performance of SPR based biosensor is a burning question. Experimental study reveals that performance of SPR based biosensor can be enhanced if graphene layer is added. Graphene aids a good resort for absorption of biomolecule as they have huge surface area and such structure containing π-configuration for which an excellent dielectric top layer is ensured [18]. A research shows that, graphene layer on gold layer gives a good platform for absorbing biomolecule, thus providing a large refractive index change at graphene-gold interface. Introduction of graphene layerpromotes the sensitivity of SPR sensing [8].

One of the most important constituents of any sensing device is the binding/adsorbing material with large surface area, and the recently developed 2D nanomaterials such as graphene have attracted a considerable amount of attention [9]. Graphene is emerging as an attractive material candidate for future electronics and optoelectronics due to its unique combination of several important characteristics, including high carrier mobility, high optical transparency, exceptional mechanical flexibility and strength. Recent studies have demonstrated the exciting potential of exploiting graphene for diverse optoelectronic devices including solar cells, touch panels, photodetectors, ultra-fast lasers, polarizers and optical modulators [10,11]. The wideband absorption, high carrier mobility and short carrier lifetime make graphene an ideal material for wideband, high-sensitive biosensors. Graphene and graphene oxide provide good support for biomolecule adsorption due to their large surface area and rich π conjugation structure, making them suitable dielectric top layers for SPR sensing [12]. However, graphene produces more damping in SPs due to large imaginary dielectric constant for higher graphene layers, and hence result in decreased detection accuracy [13].

In this paper, we investigate the numerical modeling of graphene coated SPR biosensors. Since graphene has prominent properties, a monolayer of graphene is sandwiched between metal films and sensing medium as biomolecular recognition elements (BRE). Numerical results show that compared to graphene in prism based SPR biosensor, graphene in planar waveguide based SPR biosensor offers 25% more sensitivity for five layers of graphene.

2. Design of the proposed biosensors

We introduce a numerical model of prism based biosensor [3] whose configuration

shown in Fig. 1. Here the first layer is a SF10 glass prism having RI $np = 1.723$ is [13], the second layer is formed of gold film having thickness and RI are $d_{Au} = 50$nmand $n_{Au} = 0.1726 + i3.4218$, respectively [19]). Third layer is graphene having thickness and RI are $d_G = 0.34$ nm and $n_G = 3 + i1.149106$, respectively [19]. Lastly, the final layer is water as a sensing medium whose RI is $n_S = 1.33$ [20].

Again, The cross-section view of proposed waveguide based SPR biosensor has been illustrated in Fig. 2 like following from [16]. Total design has been divided into two distinct areas. Among them, region (i) covers a lossless single-moded