Numerical Investigation of Graphene-Gold SPR-Based Biosensor

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Abstract

This short study is aimed to investigate the graphene-gold surface plasmon resonance (SPR)-based biosensor by optimizing the graphene and gold layers respectively. Gold (Au) is used as a noble-metal material whereas graphene is used to avoid Au from oxidation and enhance the reflectance intensity of biosensor as well as increase molecular absorbance on the sensor surface for improving sensitivity. Numerical analysis is performed using finite-element method (FEM) by comparing the sensing performance such as reflectance intensity that explains the sensor sensitivity. The measurements are presented with various graphene thin film thicknesses in 3nm, 5nm, and 6nm with 800nm operating wavelength, and then considered the different gold thicknesses (10nm to 70nm). The proposed sensor shows that the five-layer graphene-40nm thick gold SPR-based sensor gave better performance with narrower plasmonic spectrum line width. The obtained results also indicate that the graphene-gold SPR-based sensor is suitable for medical diagnostics in immunoassays.

Keywords: Surface Plasmon Resonance; Biosensor; Graphene; Numerical Analysis

Abbreviations: SPR: Surface Plasmon Resonance; Au: Gold; Ti: Titanium; FEM: Finite-Element Method

Introduction

Sensitive detections of diseases – which relevant antigens, antibodies, or proteins were critical for many biomedical studies and diagnostics [1-3]. The assays based on SPR technique here increased dramatically and the number of reporting researchers has been quickly growing [4-6]. The technique of SPR is very sensitive to a refractive index variation in sensing medium. This variation occurs due to binding of analyte (in a liquid sample) to their affinity ligands (immobilized on the chip surface) when the liquid sample comes in contact to the sensor surface. Therefore, material which is in contact with the liquid sample (top layer of sensor), terms of the refractive index and the absorption of molecules, is very influential and important [7,8]. In the present study, to enhance the sensitivity of the SPR sensor for biomolecules, a number of graphene layers are generated onto an optimized gold thin film. To see the points of proposed structure, the numerical analysis is carried out for different graphene-gold SPR-based configurations. The most

advantages of the use graphene layers can be pointed to more efficient biomolecular absorbance compared with gold, passivation of the sensor surface against oxidation, highly hydrophilic layered material, and be able to control of the SPR response by manipulating the number of coated graphene layers [9-12]. Due to the specific nature of graphene, the refractive index of this material in the visible range was estimated to be 1. n = 3+iC /3, where is the wavelength in and the constant C equals 5.446 μm^{-1} .

Moreover, the thickness of the graphene layer can be obtained as tg = 0.34nm × N, where N is the number of graphene layers [13]. As noted in Table 1, the proposed SPR structure (Figure 1) is numerically analysed in the specified values of materials' refractive index and thickness at a free space wavelength of 800 nm. In the first step, the graphene thickness is considered (three, five, and six) and applied one by one in each analysis. As shown in Figure 2a, the reflected light is more close to zero with acceptable narrow

line width at five-layer graphene. Therefore, it is fixed the graphene layers and continued the study for finding an optimized thickness of gold. For this purpose, the gold thickness is swept from 10nm to 70nm in the presence of five layers of graphene. Figure 2b clearly shows the reflection is best resulted in 40nm gold thickness, whether in excellent subsidence and narrowing of its width.
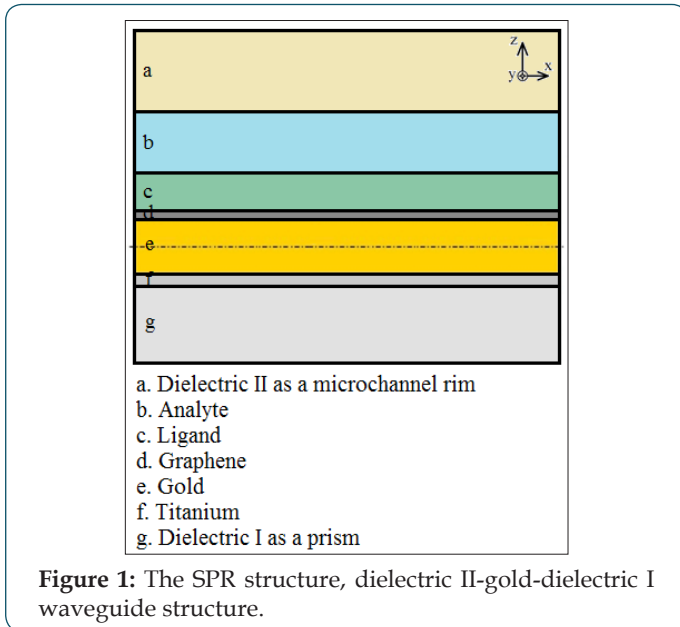

a. Dielectric II as a microchannel rim
b. Analyte
c. Ligand
d. Graphene
e. Gold
f. Titanium
g. Dielectric I as a prism

Figure 1: The SPR structure, dielectric II-gold-dielectric I waveguide structure.
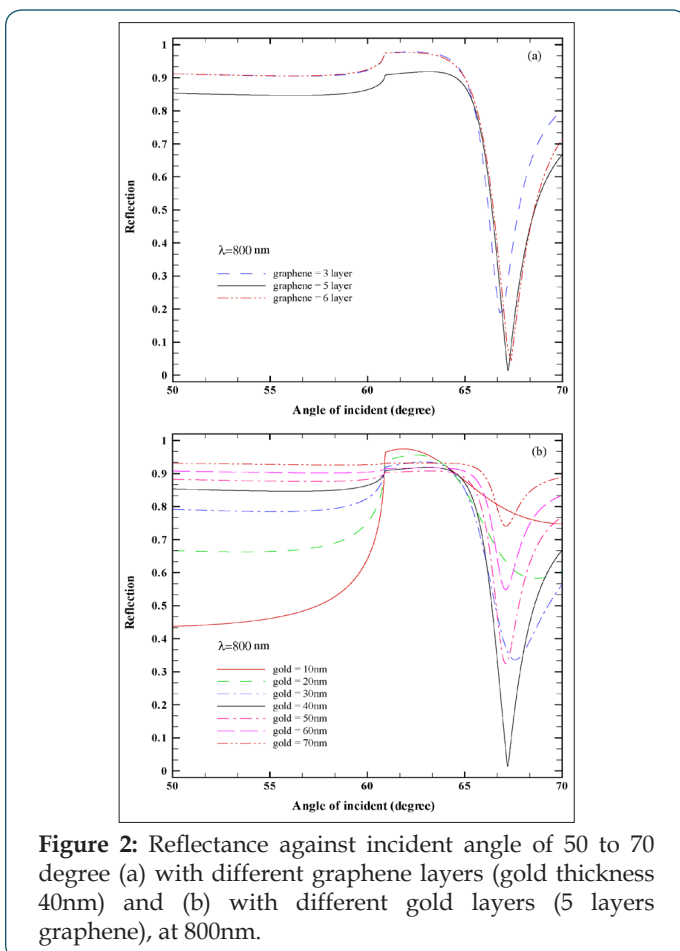

Figure 2: Reflectance against incident angle of 50 to 70 degree (a) with different graphene layers (gold thickness 40nm) and (b) with different gold layers (5 layers graphene), at 800nm.

Table 1: The values of materials refractive index and thickness at a free space wavelength of 800 nm.

Material	Refractive Index (RI)	Thickness (nm)
Microchannel rim	1.52	1000
Analyte	1.329	1250
Ligand	1.333	100
Graphene	$3 + i(5.446[\mu m-1]/3)\lambda$	$0.34 \times N$ (N=3, 5, and 6)
Gold	0.16 + i4.84	10 - 70
Titanium	3.14 + i4.01	2
Prism	1.51	1000

Conclusion

Performance of graphene and gold thin film thicknesses in our proposed configuration has been numerically investigated. It was found that the optimal number of graphene layer (five-layer) based on the reflectance intensity which is proportional to sensor performance enhancement. For better functionality of our structure, the thickness of gold layer was investigated as well and best chosen in value of 40nm. Since the graphene acts as the bio-recognition element so the proposed graphene-gold SPR-based biosensor provides a promising potential for using in medical rapid diagnostic approaches and intelligent biomedical manufacturing systems.

Acknowledgement

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