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Performance of Graphene on Copper SPR sensor using InN

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Abstract. This report demonstrates that the influence of various semiconductors like wurtzite nitrides on the overall performance of a Cu-film based optical sensor. The theoretical simulation shows that the sensitivity enhances due to the introduction of various optimized semiconductors by a factor of 2.38, 2.22, 2.33, 1.73, and 2.28 for InN, AlN, GaN, Ge, and Si respectively. The electric field enhancement factor has been studied separately for each semiconductor and found highest factor for InN. The investigation shows that overall performance is attained maximum for the optimized thickness of InN (13nm), Cu(32nm) and graphene (0.34nm). This study recommends that introduction of InN would be a new roadmap for fabrication of highly sensitive and accurate SPR sensor.

Keywords: Overall performance, Sensitivity, EFIEF, SPR, Sensor

INTRODUCTION

The surface plasmon resonance method is used to investigate the biomolecular interaction at the interface between metal and dielectrics [1, 2]. The benefits of this method are label free method, real time and less time factor. In order to monitor the biomolecular interactions at the interface in a stable and very sensitive way, the sensor must be highly sensitive to biomolecular interactions, the SPR curve should have a thin FWHM and a stable noble metal film under any lethal surrounding conditions [3]. Due to various properties of specific thin metal films, it is very difficult to realize the above three conditions for a conventional SPR sensor. Most frequently the researchers are using two noble metals like Ag and Au in the SPR sensor development [4]. But another metal like Copper (Cu) can be used for the development of a new SPR sensor instead of Silver and Gold [5]. The potential drawback with copper metal is that it is highly vulnerable to oxidation and poor adsorbent of bio-molecules. However, Cu would be a promising candidate if a few layers of Graphene on the surface of copper are coated. A few research groups have reported that introduction of semiconductor layer between metal and graphene layer improves the overall performance of a G-SPR configuration [6]. The basic reason of improvement is high index of refraction of the semiconductor. High refractive index also rises the electric field intensity at the interface leading to strong penetration of field into the analyte. Thus, it is required to investigate the high index semiconductor material like wurtzite nitrides (ie. InN, GaN, AlN). These materials are nontoxic, bio-friendly. Also, these materials are combined with graphene layer easily due to its hexagonal structure. In this report, we have theoretically analyzed the effect of different wurtzite nitrides including Si & Ge on performance of a G-SPR sensor.

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COMPUTIONAL METHODOLOGY

In this proposed model, N-layer structure has been taken for computation of minimum reflectance using TMM [8]. Here number of layer is 6. The Figure.1 shows the diagram for the proposed optical sensor. The reflectance co-efficient of 6-layer system for TM- light is [7]

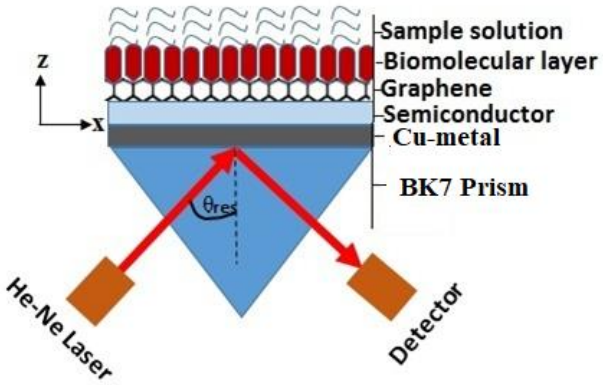


Fig.1 Schematic G-SPR sensor.

$$R = \left| \frac{(M_{11} + M_{12}q_N)q_1 - (M_{21} + M_{22}q_N)}{(M_{11} + M_{12}q_N)q_1 + (M_{21} + M_{22}q_N)} \right|^2 \quad (1)$$

The electric field intensity has been calculated by [7]:

$$H_{\perp} = \frac{2 \times q_1}{(M_{11} + M_{12}q_N)q_1 + (M_{21} + M_{22}q_N)} \text{ and } E_{||} = \frac{\mu_N n_1}{\mu_1 n_N} H_{\perp} \quad (2)$$

RESULT AND DISCUSSIONS

The metal film such as Cu-layer thickness has been optimized for attaining reflectance minimum without using semiconductor & graphene layer. It is found that optimized thickness of Cu is 32 nm. Then the thickness of semiconductor & graphene layers has been optimized for achieving $\Delta\theta_{max}$ which is directly proportional to sensitivity of a biosensor. The effect of various semiconductors like Si, Ge, and wurtzite nitrides on sensitivity of the sensor has been examined. It has been observed that InN enhances the sensitivity comparatively higher than other semiconductors for Cu based G-SPR configuration/ sensor (Figure 2). It is found that the improvement factor is 2.38. In addition, the highest enhancement factor of electric field intensity (EFIEF) has been observed for InN in comparison to other semiconductors (Figure 3). The analysis shows that better overall performance is achieved for TM polarized light (632.8 nm) when optimized thickness of Cu and InN are 32 nm, 13 nm respectively with single graphene layer.

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Thus, Indium Nitride would be a better choice for SPR sensor in comparison to other semiconductors.

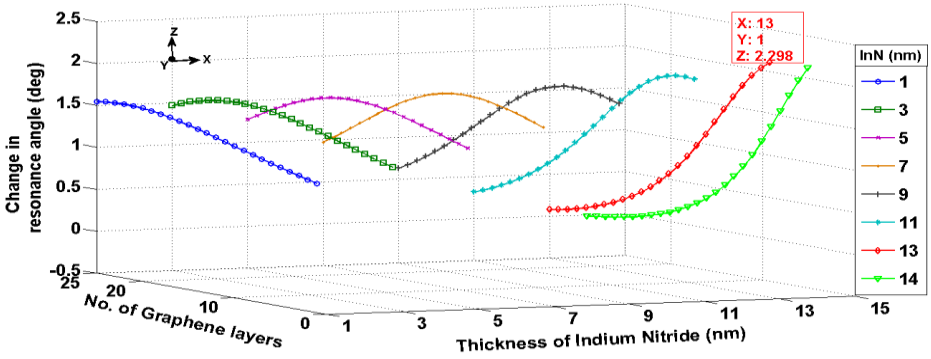


Fig. 2 Shift in resonance angle with Indium Nitride.

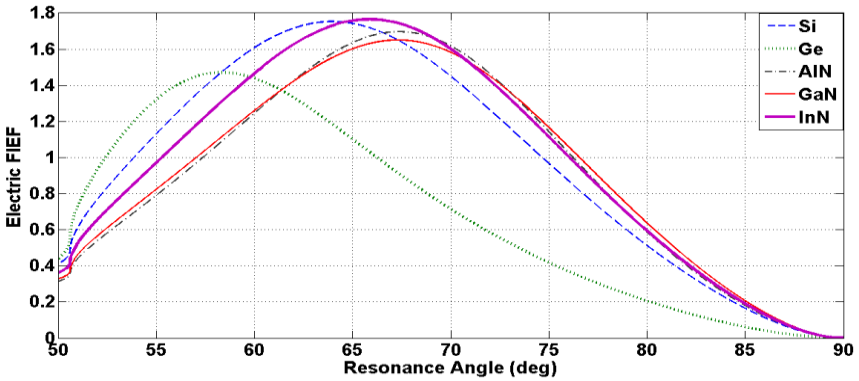


Fig.3 EFIEF for different semiconductors.

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