Chapter 14

Surface Plasmon Resonance–Based Sensor Modeling

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ABSTRACT

Exceptional optical and electrical characteristics of graphene based materials attract significant interest of the researchers to develop sensing center of surface Plasmon resonance (SPR) based sensors by graphene application. On the other hand refractive index calculation of graphene based structures is necessary for SPR sensor analysis. In this chapter first of all a new method for refractive index investigation of some graphene based structures are introduced and then the effect of carrier density variant in the form of conductance gradient on graphene based SPR sensor response is modeled. The molecular properties such as electro-negativity, molecular mass, effective group number and effective outer shell factor of the molecule are engaged. In addition each factor effect in the cumulative carrier variation is explored analytically. The refractive index shift equation based on these factors is defined and related coefficients are proposed. Finally a semi-empirical model for interpretation of changes in SPR curve is suggested and tested for some organic molecules.

INTRODUCTION

Graphene with a single atomic layer of carbon is an ideal nominee on sensor application because of high surface-to-volume ratio. Two dimensional (2D) honeycomb lattice of graphene has exclusive optoelectronic properties with enormous application potential on future nanoscale devices (Costamagna & Dobry, 2011; Luican et al., 2011). Its interesting optical properties lead to low-cost and accurate optical devices as well. Moreover, band energy as a major factor which plays a significant role on carrier transport has

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been explored widely (Abergel, Apalkov, Berashevich, Ziegler, & Chakraborty, 2010; Adonkin, Gorelov, Dyakin, Karpov, & Prikhodko, 1994; Akdim & Pachtert, 2011; Elias et al., 2009), moreover different stacking of graphene sheets leads to different electronic properties (Craciun et al., 2009) which cause to different optical features. On the other hand, increasing industrial and clinical demand on graphene based optical devices such as Surface Plasmon Resonance (SPR) sensors requires its optical properties to be explored (Acik & Chabal, 2011; Afzali, Bol, Kasry, & Tulevski; Huang, Dong, Liu, Li, & Chen, 2011; Phan & Viet, 2012). As the first step, Bilayer Graphene Nanoribbon (BGN) which consists of two Bernal AB stacked layers and Trilayer Graphene Nanoribbon (TGN) with three layers of graphene and a tunable band gap as two examples of graphene based structures are considered.

In this chapter, firstly optical properties of BGN and TGN in the presence of applied voltage for different incident wavelength are explored. BGN and TGN dielectric constants and refractive indices based on their conductance are theoretically modeled and obtained results are numerically simulated. Additionally, the applied bias effect on BGN and TGN optical parameters are discussed based on the presented model. It is notable that, obtained results can be used in SPR modeling. Furthermore, SPR based sensors as an attractive configuration which operates by sensing the interactions between sensing element and the sensor metallic surface. From sensor point of view, its sensitivity is one of the main features, so to overcome the sensitivity confinement, new technological developments in device and material characteristic are needed (Zuppella, Tosatto, Corso, Zuecon, & Pelizzo, 2013). Moreover, it should be mentioned that the graphene and Graphene Oxide Sheets (GOS) based SPR structures sensitivity have been approved by (Maharana, Jha, & Palei, 2014; Pradeep Kumar, Triranjita, & Rajan, 2014; Wu, Chu, Koh, & Li, 2010), in addition, the GOS sensor chip is 3.7 times more sensitive than the graphene based chip as reported by Stebunov, et al (Stebunov, Aftenieva, Arsenin, & Volkov, 2015). These advantages motivate researchers to work on analytical prediction model of GOS film-based SPR sensor. So as the second step in this chapter, the analytically modeled response of GOS film-based SPR sensor which is covered by organic molecules is investigated.

OPTICAL PROPERTIES OF GRAPHENE BASED STRUCTURES

Optical Properties of Bilayer Graphene Nanoribbon

BGN with unique optical and electrical properties has been studied in different nanoscale fields (Rahmani, Ahmadi, Ismail, & Ghadiry, 2013; H. Sadeghi et al., 2011). In contrast with graphene nanoribbon, BGN consists of two Bernal AB stacked layers which is shown in Figure 1. Optical properties of BGN, which is necessary for SPR sensor applications (Acik & Chabal, 2011; Afzali et al.; Huang et al., 2011; Huang et al., 2010; Phan & Viet, 2012), in the presence of applied voltage for different incident wavelength based on conductance can be modeled. Conductance is one of the main parameters which need to be discovered then the optical properties of BGN can be derived from conductance in specific condition.

First step to analyze of BGN conductance is started with parabolic band energy approximation. For the proposed BGN, the tight-binding technique is adopted in order to calculate the energy band structure of BGN with AB stacking (Hatef, SeyedMahdi, Meisam, MohammadTaghi, & Razali, 2012):