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Bio-Sensing Applications of Graphene Based Composite Films

Abstract

Graphene based composite materials have been extensively studied for the sensing applications attributing to their 2D structures, high conductivity, controlled modification and large specific surface areas, unique mechanical, optical, chemical, electrical, and catalytic properties. Therefore, a number of high quality sensors have been fabricated in recent years. Graphene based composite films (GCFs) that is base of such sensors can be prepared by combining Graphene with different functional nano-materials (carbon materials, noble metals, polymer materials, metal compounds etc.). In this review, we focus on the recent advances in bio-sensing applications of Graphene based composite films.

Keywords: Graphene; GCFs; 2D; RGO; QD; Bio-sensor

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Introduction

Graphene is a two-dimensional (2D) material having honey-comb crystal lattice and thickness of one-atom. It has unique mechanical, electronic, chemical, optical, and thermal properties [1-5]. Particularly its one atom thickness, high charge mobility and high surface-to-volume ratio make it eligible for very sensitive sensing applications [6-7]. Applicability of GCFs for various applications is also limited by their fabrication process. Graphene based biological sensors fabricated through screen-printing electrochemical process has some pros and cons [8]. In this review, we focus on the recent advances in bio-sensing application of Graphene based composite films. Bio sensors are discussed based on usage and sensing mechanism. The key difficulties and future points of view in this quickly emerging field going for GCFs for future sensing applications are given.

Discussion

Various biologically- relevant substances/biomaterials such as DNA, blood sugar, other parameters and H_2O_2 can be detected using Graphene and/ or its composite films [9-15]. We will discuss GCF based bio-sensors according to their sensing mechanism.

Photo-electrochemical (PEC) bio-sensor

Photo catalytic oxidation /reduction of molecules produces improved electron transfer between semiconductor and analyte when light falls on it. This is the basic principle of Photoelectro-chemical bio-sensors. Generally, quantum dots are used as visible-light active materials. Authors in [16] used CdS QDs-DNA-Graphene composite film as modified electrode. Very high conductivity of Graphene has improved the photo- current significantly. This highly sensitive and high stability PEC sensor can be used to track genotoxic pollutants.

Field-effect transistor (FET) based bio-sensor

Conduction of channel region of FET changes upon adsorption of target molecules, and this is the basis of FET based bio-sensors. Authors in [17] discussed FET based biosensor to detect cholesterol. Authors in [18] developed a cholesterol sensor using NiO-Graphene nano composite film. Authors in [19] developed DNA FET sensor using AuNPs-Graphene composite films.

Enzymatic & non-enzymatic electro chemical biosensor

Authors in [20] fabricated a new electrochemical sensor for sensing application of H_2O_2. Non-enzymatic sensors have some advantages over their enzymatic counterpart such as cheap fabrication, reusability, wide detection range, excellent selectivity and high sensitivity. Authors in [21] fabricated MnO_2-RGO (Reduced Graphene Oxide) film modified electrode based biosensor. Authors in [22] also reported RGO-PLL-Mn_3O_4 based biosensor with improved catalytic activity toward glucose. Authors in [23,24] have reported, non enzymatic H_2O_2 sensor based on RGO-AuNP hybrid membranes.

Fluorescent biosensor

Fluorescent bio-sensors are based on energy transfer due to fluorescence resonance, and simultaneous multiplex target detection. Authors in [25] developed Graphene quantum dots (GQDs) based biosensor to detect hydrogen peroxide (H_2O_2) and glucose in diabetes patients. This same sensor can be used as electro-chemical and fluorescent bio-sensor. Authors in [14] also reported GO-AuNPs fluorescence system for DNA sensing.

Other Graphene biosensors

Proteins have charges/dipoles those changes under physiological conditions and this made them suitable for electronic detection of proteins using scattering of field effect [9]. Authors in [26] reported sensor for bacteria detection with very high sensitivity (up to single-cell level). Highly sensitive Graphene hybrid nano-sensors can be directly integrated with biomaterials. These are battery- free that can be used for remote monitoring of pathogenic bacteria and food safety analysis. WS_2/Au NPs based bio interfaces were fabricated for 17b-estradiol [27]. Authors in [28] reported, complex MWCNT/MoS_2/Au/GOx based bio interfaces for DNA sensing. Table 1 summarizes different biosensors based on GCFs.

Table 1: Biosensors based on GCFs.

Materials	Analyte	References
RGO-ZnO	DNA & TNT	[13]
G-CdS-DNA	Catechol	[16]
G-NiO	Cholesterol	[18]
G-AuNPs	DNA	[19]
RGO- AuNP	H_2O_2	[20]
RGO-PLL-MnO_2	Glucose oxidase, H_2O_2	[21]
RGO-PLL-Mn_3O_4	Glucose	[22]
RGO-AuNPs non-enzymatic	H_2O_2	[23]
RGO-AuNPs- non-enzymatic	H_2O_2	[24]
WS_2/Au NPs	17b-estradiol	[27]
MWCNT/MoS_2/Au/GOx	DNA	[28]
Aminophenylboronic acid (APBA)-functionalized RGO	Glucose, glycated hemoglobin	[29]
Thrombin binding aptamer (TBA)/GOx	thrombin	[30]

Conclusion

Two dimensional Graphene, GFCs and Graphene-like nano-materials is a class of emerging nano-materials with specific planar morphology and properties have attracted considerable attentions. Taking the advantage of chemical compositions and assorted biological effects, these possess attractive and matchless properties and provide colossal opportunity for their ample applications. This review article highlights the recent progress in the development of GFC based bio-interfaces for their bio-sensing applications. Some researchers have done in-depth analysis and reported that there are plenty of possibilities to prepare different GFC based biosensors as more reactions and more molecular structure changes can be taken as bridged media of biosensors. Availability of large surface-to-volume ratio and recognition ability of the biological molecules reactions of Graphene materials increases the selectivity and sensitivity of the biosensors. But everything is not ok with GFC based sensors high salt concentration is one of them. High salt concentration changes surface charge arrangement of GFCs by its aggregation and precipitation [29,30]. It is clear that the immense possibilities in terms of synthesizing Graphene and GFCs and fabricating functional bio-interfaces will lead to the fast development in this hot research area.

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