Chapter 13
Carbon Materials Based Ion Sensitive Field Effect Transistor (ISFET): The Emerging Potentials of Nanostructured Carbon–Based ISFET with High Sensitivity

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ABSTRACT

Graphene and SWCNT-based Ion Sensitive FET (ISFET) as a novel material with organic nature and ionic liquid gate is intrinsically sensitive to pH changes. pH is an important factor in enzymes stabilities which can affect the enzymatic reaction and broaden the number of enzyme applications. More accurate and consistent results of enzymes must be optimized to realize their full potential as catalysts accordingly. In this chapter, an appropriate structure to ISFET device is designed for the purpose of electrical measurement of different pH buffer solutions. Electrical detection model of each pH value is suggested using conductance modelling of monolayer graphene. In addition, ISFET based on nanostructured SWCNT is studied for the purpose of electrical detection of hydrogen ion concentrations. Electrical detection of hydrogen ion concentrations by modelling the conductance of SWCNT sheets is proposed. pH buffer as a function of gate voltage is assumed and sensing factor is defined. Finally, the proposed new approach improving the analytical model is compared with experimental data and shows good overall agreement.

**INTRODUCTION**

**Carbon Materials as a Based-Biosensor**

Graphene is a 2 of sp² bonded carbon atom, which makes its structure apparently looks like honeycomb crystal as seen in Figure 1 (Enoki, Kobayashi, & Fukui, 2007; Fang, Leiber, Xie, & Xiong). It is called the mother of graphite (many layers of graphene) form because it can act as all these allotropes basic building block.

Graphene is theoretically discovered back in the 1940s, but at that time graphene (a 2D layer crystal) are believed thermodynamically too unstable to be produced in real world (Martoccia, Björck, & Schlepütz, 2010). However, Andre Geim and Konstanstin Novoselov successful to produce graphene by just using scotch tape in 2004 (Geim & Novoselov, 2007). This method is called Mechanical Exfoliation because it mechanically exfoliates layers of graphene from graphite.

Nowadays, there are few ways how to produce graphene other than mechanical exfoliation, the common ways are Epitaxial grown, Reduced Graphene Oxide and Chemical Vaporization Deposition (CVD). CVD is considered as the most promising method to commercialize graphene, because its low cost and readily accessible techniques for growing in a large area and high quality Graphene.

Intrinsic graphene actually has no band gap, which are bad, we can produce a tune-able band gap of graphene by, at first make it bilayer graphene, and then induced E-field to the bilayer of the graphene or by doping the Graphene chemically. Besides graphene, carbon can make many other forms, this variance of form is called allotropes which each allotropes have its own properties. Another kind of carbon allotropes such as carbon nanotube and graphene nanoscrolls is cylindrical and spherical. Graphene is attracting interest majored in electrical, physical, chemical and even biology since of its unique properties (M. J. Kiani, Ahmadi, Abadi, & Rahmani, 2013). Because of physical and electrical properties of graphene it really suit to make this material as Field Effect Transistor.

Also, Carbon nanotubes (CNTs) can be imagined as a sheet of carbon atoms turned up into a pipe with a diameter of approximately ten of nanometres. Two major kinds of CNTs, exist, namely, Single-walled (SWCNTs) and multi-walled carbon nanotubes (MWCNTs), the latter being shaped by numerous concentric layers of turned graphene (Figure 2). Particularly, a high feature proportion describes SW-CNTs. Furthermore, their multipurpose physicochemical aspects facilitate the noncovalent and covalent beginning of several biosensing and biomedicine function appropriate entities.

Therefore development of their distinctive thermal, optical, electrical, and spectroscopic possessions in a biological framework is expected to defer great progress in the treatment of disease and discovery biomolecules such as antigen–antibody, cells, DNA, and other biomolecules.

*Figure 1. Monolayer graphene atoms arrangement with only one atom thickness*