

# Chapter 4

## Fullerene–Based Modifier: Biosensing and Nanobiotechnological Industrial Applications

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### ABSTRACT

*Fullerene molecules are composed entirely of carbon, in the form of a hollow sphere, ellipsoid, or tube. Fullerenes in the cylindrical form are called carbon nanotubes (CNTs) or buckytubes and fullerenes in the spherical form are referred to as buckyballs. Fullerenes have attracted considerable attention in different fields of science since. Their unique carbon cage structure coupled with immense scope for derivatization makes them a potential therapeutic agent. The fullerenes can be utilized in organic photovoltaic (OPV), portable power, medical purpose, antioxidants, and biopharmaceuticals and dentistry. Recently, fullerene-C60 contributed greatly to the field of biosensing and bio-nanotechnology. Fullerene allows its wide use for designing the highly sensitive chemical/biosensors. Fullerene is not dangerous to biological systems. Fullerene, as the first symmetric nanostructure in the carbon nanomaterials family, opened up new perspectives in nanomaterials field leading to discovery and research on other symmetric carbon nanomaterials.*

### 1. INTRODUCTION

Fullerene was discovered as carbon allotrope by Kroto et al. in 1985, who was awarded with Nobel prize of chemistry in 1996 for their amazing discovery (Kroto et al. 1985). Since then, fullerene has been widely explored in cancer theranostics because of its special structures and distinct physio-chemical characteristics. Fullerene is viewed as a form of graphene sheet that rolled into a hollow sphere, ellipsoid, or tube shape. It entirely consists of 60 carbon atoms linked by 30 carbon double bonds with abundant  $\pi$ - $\pi$  conjugation in cage-type structure (Augustine et al. 2017). Interestingly, the unique geometry and molecular topology of fullerene endow it with prominent properties such as large surface area, small particle size, and

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high reactivity. Furthermore, fullerene also exhibits electronic, optical, thermal, mechanical properties, and other versatile physicochemical features (Jariwala et al.2013) . The large specific area and unique 3D scaffold structure of fullerene enable the loading of multiple drugs in the fullerene cage through covalent bonding (Augustine et al.2017). Given the excellent characteristics of penetration into solid tumors and high chemical reactivity, fullerene can also be designed as stimuli-responsive systems based on the special conditions of the tumor sites to achieve targeted delivery of therapeutic molecules (Ding et al.2016) . In addition, due to its inherent optical and thermodynamic properties, fullerene has been proved to act as a good photosensitizing agent, making it a promising nanomaterial in cancer imaging, hyperthermia, PDT, and photoacoustic/thermoacoustic assisted theranostics (Shi et al.2019). Notably, owing to its anticancer activity and sensitization effect on cancer cells, fullerene can serve as a strong antineoplastic agent (Ye et al.2021). Besides, fullerene can be employed as an antioxidant due to its free radical scavenging capacity (Ye et al.2021). Interestingly, metal atoms can also be incorporated into fullerene to generate metallofullerene, which inherits the combined properties from carbon cages and internal metal, showing promising prospects for application as contrasts in magnetic resonance imaging (MRI) and X-ray, radiotracers and anticancer agents (Wang et al.2019).

Recently, fullerene- $C_{60}$  contributed greatly to the field of biosensing and bio-nanotechnology. The unique electrochemical and physicochemical properties, together with biocompatibility characteristics of fullerene, allow its wide use for designing the highly sensitive chemical/biosensors.

Concerning all-carbon fullerene polymers, these are fascinating materials which continue to be the subject of intensive research. One-, two- and three-dimensional structures have been synthesized, and many more potential all-carbon polymers are possible. Therefore, electrochemical biosensors based on fullerene- $C_{60}$  with their cost-effectiveness and suitability for micro-fabrication can be expected to become increasingly popular in the near future.

## 1.1. Nanotechnology for Carbon Nanomaterials

In 1985 Kroto, et al., the serendipitous discovery of fullerene triggered the research of carbon structures into the world of symmetric nanomaterials. Consequently, Robert F. Curl, Harold W. Kroto and Richard E. Smalley were awarded the Noble prize in chemistry for their discovery of the buckminsterfullerene ( $C_{60}$  with a cage-like fused-ring structure). Since its first discovery, fullerene- $C_{60}$  has been the object of extensive research. Their unique and favorable characteristic of easy chemical modification, conductivity, and electrochemical properties has led to its tremendous use in (bio) sensor applications. Nanotechnology is becoming increasingly important in the field of (bio) sensors. Bio-nanotechnology is a new emerging field of nanotechnology and combines knowledge from engineering, physics, and molecular engineering with biology, chemistry, and biotechnology aimed at the development of novel devices, such as biosensors, nanomedicines, and bio-photonics (Baghchi, et.al.2013).

It is the aim of this chapter to present the most recent and relevant contributions in the development of biosensors based on fullerene- $C_{60}$ , graphene and different biological components. A brief introduction and history of fullerene- $C_{60}$  is first presented. Available methods for synthesis and functionalization of fullerene- $C_{60}$  are mentioned also.

The important parameters in the exact diagnosis are sensitivity and accuracy. These two terms can describe the technological power of the diagnostic systems. In the development of sensitivity and accurate measurement, nanomaterials have an important place in today's technologies (Lim et.al.2015).

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