SHORT COMMUNICATION

Recent development in nano-carbon materials

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Dubey P. Recent development in nano-carbon materials. Nanotechnol. lett.2023; 8(1):22-24.

ABSTRACT

Carbon nanomaterials have piqued the interest of medicinal researchers due to their exceptional characteristics and flexible dimensional configurations. Carbon Nanomaterials (CNMs) exhibit electrical characteristics, a large thermal surface area, and a high cellular internalisation, making them ideal for medication and gene delivery, antioxidants, bioimaging, biosensing, and tissue engineering. Carbon nanomaterials such as graphene, carbon nanotubes, fullerenes, nanodiamond, quantum dots, and many more will have exciting uses in the future.

The functionalization of the carbon nanomaterial surface has the potential to change its chemical and physical characteristics, as well as increase drug loading capacity, biocompatibility, reduce immune response, and direct drug delivery to the desired spot. Carbon nanoparticles might possibly be used with proteins and pharmaceuticals to minimise toxicity and improve efficacy in the pharmaceutical industry. Carbon nanomaterials are so ideal for use in pharmacological or biological systems.

Key Words: *Carbon; Multifunctional nanomaterial; Sensor; Drug delivery*

INTRODUCTION

Carbon is the universe's fourth most prevalent element. Carbon is transformed into the foundation of all organic chemistry. Carbon and its derivatives play an important role in many high-performance materials, particularly electrochemistry. Several carbon-based materials have been investigated and reported for a variety of key applications [1]. Carbon has many advantages as a green material, including long stability, promoting stable bonding with many functional groups for material modification, low background current, and a wider potential window, which makes it widely used in a variety of fields, including synthesis, sensor drug delivery and therapy [2].

Nanotechnology development has advanced dramatically in recent years. Carbon Nanotubes (CNTs), fullerene, graphene, and nanodiamond are all being explored for a variety of uses by researchers all over the world. Carbon materials' biocompatibility is particularly helpful in medical and pharmaceutical applications due to its great characteristics. Carbon materials with biocompatible qualities, such as carbon fibre, nanodiamond, Carbon Nanotubes (CNTs)/Chitosan, carbon dots, and diamond-like carbon, have been used in bio-related applications such as biomedical devices and bone implants [3].

Carbon nanostructured materials have a relatively large surface area, making nanocarbon more reactive than in its bulk form. Because of their superior electrical, chemical, and mechanical capabilities, nanoparticle materials have a significant potential for use in sensor applications.

Applications of biosensor

The use of nanomaterials in the construction of biosensors has piqued the interest of many researchers. These nanomaterials' distinct structure enables them to engage noncovalently with organic molecules by forces such as stacking, hydrogen bonding, hydrophobic interactions, Van der Waals, and electrostatic forces [4]. Because of these interactions and their hollow nature, they are ideal candidates for analytical applications. Carbon nanoparticles employed as electrodes demonstrate excellent electrocatalytic capabilities.

Nano-biosensors are advantageous due to their high surface area to surface volume ratio. Furthermore, it is frequently employed for sensor applications due to its superior chemical stability and biocompatibility when compared to other common sensor materials.

CNTs

CNTs are carbon materials that are very sensitive and selective due to their electrical characteristics, allowing molecules to be adsorbed on their surface [5]. CNT may be utilised as an electrochemical and photochemical sensor, which is very useful in pharmaceutical applications.

Many researchers are now interested in this type of application. CNT may be used as an Isoniazid (INZ) detection sensor, which is one of its uses. Meanwhile, Tuberculosis (TB) is one of the top 10 leading causes of mortality. This might be avoided by using INZ as a commonly used

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Received:-14 January 2023, Manuscript No. PULNL-23-6071; Editor assigned: 21 January 2023, Pre-QC No. PULNL-23-6071 (PQ); Reviewed:-23 January 2023, QC No. PULNL-23-6071 (Q); Revised:-25 January 2023; Manuscript No. PULNL-23-6071 (R); Published:-28 January 2023, DOI:10.37532.pulnl.23.8 (1) 22-24.

antibiotic for TB prevention and diagnosis [6]. An overdose of this medication can result in seizures, metabolic acidosis, comas, and even death [7].

Thus, detecting isoniazid in the human body is critical to preventing inadvertent events.

Fullerene

In 2013, Rather and De Wael created an electrochemical sensor for Bisphenol A (BPA) detection by altering GCE and utilising 98% pure C60 [8]. BPA is an estrogenic toxin that is commonly used in the production of plastics and has the potential to disrupt human health through a variety of negative effects including altered brain development, sexual differentiation, and immunological function [9]. Mazloum-Ardakani and Khoshroo developed electrochemical sensors built of C60-functionalized Carbon Nanotubes (CNTs)/Ionic Liquid (IL) composites modified GCE to detect Norepinephrine (NE), Isoprenaline (IP), and dopamine (DA) in 2014. Mazloum-Ardakani et al. redeveloped an electrochemical sensor made of C60-functionalized CNTs/IL nanocomposite for the simultaneous detection of hydrazine and hydroxylamine in 2015 [10]. Thirumalraj et al. developed electrochemical sensors to detect DA in 2016 [11]. DA is a catecholamine from the phenethylamine family that aids in the regulation of movement and the emotional response of the human body [12]. Parkinson's disease, Attention Deficit Hyperactivity Disorder (ADHD), and restless legs syndrome can all be caused by a lack of DA (RLS). Rahimi-Nasrabadi et al. created an electrochemical sensor for detecting diazepam in 2017 [13]. Diazepam is a medication of the benzodiazepine class that is widely used to treat anxiety, depression, sleep problems, and seizures. Short-term diazepam usage is harmless, but long-term diazepam use can produce dependency and other negative effects, and diazepam overdose can be fatal.

Anusha et al. developed a C60 electrochemical sensor with a bimetallic nanoparticle composite sheet to detect vitamin D3 in blood samples in 2020 [14]. Vitamin D3 is essential for bone health and the prevention of certain disorders such as Rickets.

Graphene

Xi and Ming developed a sensor for the sensitive measurement of midecamycin in 2012 (MD) [14]. MD is a macrolide antibiotic with potent antibacterial activity against Gram-positive and Gram-negative bacteria. It is commonly used to treat upper and lower respiratory tract infections, acute laryngopharyngitis, tonsillitis, pneumonia, otitis media, urinary tract infections, and tissue infections.

The goal of developing this sensor is to establish the correct concentration of MD in therapy and avoid harmful MD overdose. The GO/GCE sensor was created by altering a GCE that had been polished with alumina slurry until the surface was mirror-like and sonicated for 3 minutes.

Nanodiamond

Diamond material has sparked a lot of interest due to its great chemical and physical stability. To provide catalytic activity, diamond has been doped and modified.

Wang et al. devised a highly selective, repeatable, and stable monitoring of acetaminophen in 2021 (APAP). Acetaminophen, often known as paracetamol, is a commonly used pain reliever and fever reducer.
Because of its unique qualities, such as large specific surface area, low background current, and quick electron transfer, boron doped diamond (BDD) was utilised as the electrode in this sensor. Furthermore, this sensor has a broad variety of applications in the electrochemical examination of various medicines [15].

Wong et al. suggested a nanodiamond/AuNP/PEDOT:PSS on Screeprinted Electrode (SPE) as an electrochemical sensor for tryptophan detection in 2022 [16]. Tryptophan is a drug used to treat patients suffering from serious depression, schizophrenia, and bipolar disorder.

The human body has a limit dosage for tryptophan; to avoid accidental symptoms caused by overdoes, we must assess the tryptophan concentration in the body. One is an electrochemical sensor. Because of its remarkable selectivity against tryptophan, the Nanodiamond/AuNP/PEDOT:PSS sensor might be a potential choice.

This sensor's combination element provides rapid, easy, and low-cost detection in non-invasive testing of food products.

Nanodiamonds are also often utilised in sensors that detect hormone levels and neurochemicals in the body. Dopamine is one of them. Dopamine (DA) is a neurotransmitter and hormone that is involved in movement, memory, emotional regulation, sleep, and concentration. A high DA level is linked to neurological disorders such as Parkinson's disease and Alzheimer's [17]. Various ways have been taken to address this issue.

Baccarin et al. (2019) recommend another study on the determination of DA [18]. They suggested a high sensitivity electrochemical sensor based on Screen Printed Graphite Microelectrodes (SPE) enhanced with nanodiamond in this study. SPE is used as a substrate because it is less expensive, more repeatable, and disposable than typical carbon electrodes. This SPE/nanodiamond sensor was built utilising the drop casting process.

Drug delivery application of carbon nanoparticles

In terms of drug delivery, nano-carbon materials may be split into two categories: carbon core and skin surface. There is a targeting system on the skin's surface that detects cancer cells amid healthy cells and binds cancer medications that may be released with particular conditions, such as pH or temperature. Related evaluations of nano-carbon material as a drug delivery in pharmaceutical applications aim to give a thorough guideline for nanomedical researchers about the use of nanocarbon in the treatment of certain disorders.

Toxicology risk is one of the considerations examined in establishing the function of semiconductor nanoparticles as nanocarriers for disease treatment. A overview of the toxicological effects of nanoparticles was previously presented [19]. Matsumura and Maeda introduced the notion of cancer medication targeting in 1986 by presenting the Permeability-Enhancing and Retention (EPR) effect, an abnormality effect caused by physical differences between diseased and healthy tissue, such as structural abnormalities.

Furthermore, different nano sizes have been studied, and it has been discovered that the smaller the size, the better the capacity to penetrate into the cell nucleus, but the larger the DNA damage. Nano-carbon outperforms another semiconductor nanomaterial in terms of surface area, toxicity, and biocompatibility, making it a viable drug delivery nanocarrier. Recently, in 2019, the systematic function of nanocarbons in pharmaceuticals for the regulated release and administration of medications or genes, as well as their combination with targeted in vitro imaging, was examined alongside the toxicological implications of utilising nanocarbons as theragnostic.

Assays of nanocarbon composites on several types of cell models, such as fibroblast, epithelial, and endothelial cells *in vitro* and mouse models, dog models, and chick chorioallantois membrane models *in vivo*, yielded results of little or low cytotoxicity [20]. This chapter will focus on the finding after comparing the results of a carbon-based nanomaterial summary for drug delivery *in vitro* by Panwar et al.

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