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DISSEMINATION OF CONTEMPORARY GRAPHENE OXIDE-BASED NANOCOMPOSITES, SYNTHESIS AND APPLICATIONS

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Abstract: Graphene has received increased attention in recent years, particularly due to its easy synthesis, innovative hybrid materials, and uses. Graphene oxide (GO) and reduced graphene oxide (rGO) nanocomposites have also recently drawn the attention of researchers, which has resulted in the creation of numerous applications. They are excellent candidates for hybridization with polymers, metal oxides, and biomaterials due to their remarkable and remarkable properties. We will go over the successes of efficient methods for creating graphene oxide-based material nanocomposites in this succinct review, along with some of their more recent uses.

Keywords: Graphene oxide, Reduce graphene oxide, Synthesis, Application

I. Introduction

Due to its cluster of reactive oxygen functional groups, graphene oxide (GO) is a promising for chemical functionalization in a variety of applications. GO, which is made of graphite oxide, has proven to be a successful route for the large-scale manufacture of graphene. However, graphene's limited dispersibility in water, which reduces its surface area, is a significant disadvantage that restricts its use. This results from aggregation brought on by the graphene sheets' π–π stacking and strong van der Waals contacts. As a result, attention has focused on hybridizing GO with materials that have strong water dispersibility in order to integrate it with other materials [5]. Aggregation can be reduced or eliminated by adding functional groups to the graphene sheets through chemical oxidation, which creates graphene oxide. Only in polar solvents does GO's dispersibility rise because of its hydrophilic functional groups [7]. Furthermore, by completely removing the C-O bonds, controlled oxidation offers tunability of the mechanical and electrical properties, including the potential to attain zero-band gap graphene [8]. Because of its many surface capabilities, GO is a perfect platform for chemical modification, which could produce materials with incredible qualities.

In addition to its sophisticated qualities, GO's intricate molecular structure has been the subject of an intriguing discussion throughout the years, but no verified model has yet been put forth. The structural features of GO, such as the abundance of oxygen functional groups like epoxy, hydroxyl, and carboxylic acid groups on its surface, are the only things that are shared [9]. The lack of accurate analytical methods for describing GO's amorphous feature and nonstoichiometric berthollide character makes it difficult to find a true model of GO.

II. Related Work

Numerous scholars, have already put out a structural model [1]. All of these models suggest that GO is typically built by regular lattice, made up of distinct repeating units. Furthermore, to measure the structure of the C and O K-edges to clarify the atomic and electronic structure of GO. The GO sheet is said to have a surface roughness of roughly 0.6 nm and a mostly amorphous structure as a result of sp3

C-O bond distortion. The findings also showed that 40% of the carbon bonds might be converted into sp3 bonds with an oxygen to carbon atom ratio of 1:5.

They discovered that the GO sheet has a hole of roughly 5 nm and that the graphitic region extends up to 8 nm2. In addition, there is no order in the unstrained sp2 bonds that connect the carbon atoms in the oxidized zone to the GO sheet, which form a continuous network. In 1859, the process for creating graphene oxide was already established [6]. The material produced by Brodie's reaction at that time between graphite and KClO3 in fuming HNO3 had a higher mass of flake graphite. Staudenmaier improved on the earlier technique in 1898 by adding the chlorate in multiple aliquots throughout the reaction and increasing the mixture's acidity with concentrated H2SO4 [3]. Graphite was oxidized in the procedure using concentrated H2SO, KMnO4, and NaNO3 [4]. Nowadays, this approach is commonly employed with a few tweaks and enhancements.

In [11] created a synthesis technique that increases the oxidation process's effectiveness by utilizing a 9:1 mixture of H2SO4/H3PO4 and removing the presence of NaNO3. In comparison to the traditional Hummer process, this approach has been shown to produce more hydrophilic GO material; it also readily regulates temperature and doesn't emit any harmful gases [12]. Using expanded graphite oxide as a starting material, In [2] also modified Hummer's approach to create a simple synthesis method of GO. This process has a great efficiency, uses very little energy, reduces acid significantly, and doesn't release any harmful gas [13]. Up till now, quick and ongoing research has been conducted to provide easier and more environmentally friendly ways to prepare GO.

The process used to manufacture GO-based material nanocomposites is highly scrutinized. Numerous techniques and procedures, such as the hydrothermal method [14], electrochemical code position [16], in situ polymerization [15], and microwave-assisted method can be used to create GO-based material nanocomposites. GO appears in the GO-based nanocomposite either as a substrate to immobilize the other components or as a functional component [10]. As a result, the primary focus of this section will be on an efficient synthesis technique that some researchers have used.

III. Synthesis

A. Electrochemical Deposition

The process of depositing a substance from an ion solution onto the surface of an electrode or electrical conductor is known as electrochemical deposition. This technique is mostly used to deposit nanocomposite material onto an electrode in order to manufacture the electrochemical sensor. A new glucose sensor based on the rGO-based nanocomposite using the one-step electrodeposition approach. This study uses the chronoamperometry approach to electrodeposit a dendritic gold nanostructure that has been hybridized with rGO functionalized with the globular protein βlactoglobulin on a glassy carbon electrode (GCE). Two electrodes were submerged in a colloidal rGO/Cn nanocomposite suspension to prepare the electrodeposited electrodes, with ITO glass substrate serving as the anode and platinum foil as the cathode [33]. In addition to the electrochemical electrode and sensor, this technique can help with coated film preparation.

B. Electrospinning

A popular and adaptable method for creating nanocomposite nanofibers with diameters ranging from a few micrometers to tens of nanometers is electrospinning. Because of its ease of use and adaptability in creating uniform fibers with a microstructure that includes different nanofillers and an adjustable diameter, it is a successful method for creating nanofibers. GO/polyaniline/polyvinylidene fluoride nanofibers , GO/poly(vinyl alcohol) , GO/poly(vinyl alcohol)/TiO2 , polyacrylonitrile/GO, and GO/vanadium pentoxide are only a few examples of the nanocomposites that have been created recently using the electrospinning technique. Generally speaking, a blunt-end stainless steel needle was inserted into the open end of a 5 mL syringe containing GO composite solutions. The needle was then given a high DC voltage between 0 and 50 kV. The collection screen was made of aluminum foil, which was attached to the power supply's ground electrode. At room temperature, the electrospinning procedure was performed. To lessen the amount of GO in the nanofibers, the produced nanofibers were post-annealed at 500 °C using N2 and H2.

Transmission electron microscopy (TEM) shows that the GO nanoplatelet clusters are orientated in the fiber axial direction and are obviously well integrated into the polymer matrix. This is because of the higher draw ratio, which increased the stress on the fiber during electrospinning and provided the two-dimensional GO pallets with the appropriate alignment along the fiber axis nanostructures and surface nanomechanical properties of the polyacrylonitrile/graphene oxide composite . GO/vanadium pentoxide composite nanofibers with uniformly flat surfaces have the same shape.

C. Photocatalysis

Another method for creating GO-based material nanocomposites is photocatalysis. Since the functional groups on the graphene sheet cannot be entirely eliminated, photocatalysis is used as a production technique. High-feature graphene-based nanocomposites can be created utilizing this one-step method without the need of any hazardous stabilizing reagents during the reduction phase. Additionally, by adjusting reaction time, the photocatalytic reduction's prolongation can be adjusted as needed.

As is often known, GO is made up of functional groups that contain oxygen, including as carboxyl, carbonyl, hydroxyl, and epoxy groups. As a result, photocatalysts such as ZnO and TiO2 can form strong bonds with these functional groups and spread easily throughout the GO surface, facilitating the GO's photocatalytic reduction. The photocatalyst will excite electrons from the valence band to the conduction band when exposed to UV light, forming electron-hole pairs that can move and start redox reactions with oxygen and water. Through electrostatic and/or van der Waals forces, the majority of GO's oxygen-containing functional groups are reduced, and the photocatalyst particles stay on the rGO surface.

D. Microwave

For the synthesis of inorganic nanomaterials by soft chemistry, microwave synthesis has recently been demonstrated to have a significant influence, be more environmentally friendly, and need less energy than conventional heating. This method can increase the reaction rate by orders of magnitude and provides a more uniform heating process. By selectively transferring energy to polar solvents that absorb microwave radiation and simultaneously raising the self-generated pressure inside the sealed reaction vessel, it can swiftly raise the reactant's temperature to a high level. As is well known, oxidation/reduction processes, polymerizations, and organic and inorganic syntheses have all used microwave radiation.

According to Baek, the greater absorption of GO in comparison to solvent and metal oxide precursors is the basis for the benefit of microwave radiation. Because GO is the primary microwave absorber, it may be heated selectively, which causes the metal oxide to nucleate onto its surface. The precursor solution was typically magnetically stirred and ultrasonically agitated over time. The slurry was then exposed to cyclic microwave radiation for a number of cycles in a microwave oven. To prevent bumping, cyclic microwave radiation was used. Centrifugation and product drying are the next steps in the process.

IV. Applications

A. Sensor

The rapid response, high sensitivity, renowned long-term stability, exceptional conductivity, reproducibility, and ease of manufacture of graphene oxide-based nanocomposite sensors have garnered a lot of interest. Nanocarbon material has recently emerged as a novel viewpoint on the subject of gas and humidity sensors. The many oxygen functional groups, including carboxylic acid, hydroxyl, and epoxy groups, that are adorned on the graphene oxide's edge and basal plane and can increase its hydrophilicity, are what give it its sensitivity to water molecules. For sensor applications, nanostructured materials typically exhibit some obvious advantages, such as exceptional carrier mobility, large specific surface area, mechanical rigidity, remarkable adsorption capacity, and improved stability. Numerous biosensors utilizing GO-based nanomaterials have attracted the interest of researchers thus far. Among these is the glucose biosensor, which can be effectively created using one-step electrodeposition. rGO/β-lactoglobulin serves as a stabilizer and a great template for the development of dendritic gold nanostructures (Au Nps) in this investigation. Au Nps is given special attention in the electrochemical field because of its large surface area, high mechanical stiffness, remarkable high carrier mobility, large specific surface area, exceptional biocompatibility, enhanced electrode conductivity, and ability to facilitate electron transfer between electrodes and biomolecules

B. Biomedical

A nanocomposite based on graphene oxide has revealed intriguing uses in the biomedical industry. Since its two-dimensional plane and one-atom thickness provide it with better specific surface area for immobilizing a variety of substances, including a broad spectrum of metals, biomolecules, fluorescent compounds, and drug stability, graphene oxide (GO) finds considerable use in biomedical applications. Because of its high surface area, superior mechanical qualities, bioactivity, and resistance to corrosion, titanium and its alloy are widely used in electrochemical devices. As a result, used GO cross-linked gelatin as reinforcement fillers in an electrochemical deposition technique on TiO2 nanotube arrays to create a hydroxyapatite covering. The increased surface area of TiO2's nanotubular surface promotes cell proliferation, adhesion, and differentiation while providing enormous active reaction sites for chemical reactions. Furthermore, the sensing capabilities of GO/aptamer-carboxy fluorescein have been investigated using in situ molecular probing in living cells as well as in vitro.

C. Electronic

GO has been used as a starting material for numerous electrical devices, including lithium ion batteries and supercapacitors. Lithium ion batteries and supercapacitors are thought to be great options for energy storage. These devices have been developed using a variety of metal oxides. These metal oxides do, however, have specific disadvantages that impede the technical and chemical process. To improve the device's performance, GO and rGO are thus hybridized with these metal oxides. The nanocomposite's surface area can be increased by the presence of GO and rGO. It is well accepted that, particularly at the nanoscale, smaller particles have a stronger tendency to agglomerate and decrease surface area. Surface morphology experiments that demonstrate how the GO morphology and the supercapacitor material's cascade structure help to raise the composites' specific surface area and improve electrical conductivity provided support for that notion.

V. Conclusion

In conclusion, the number of recent studies on nanocomposites based on graphene oxide is growing quickly. Due to the remarkable and distinctive qualities of nanocomposites, scientists have been vying to create a new nanocomposite using a variety of synthetic techniques. The synthesis process is essential for controlling the quality of the nanocomposite and producing larger-scale production. The techniques should also be economical, effective, and environmentally friendly. Additionally, the presence of GO significantly improves the performance of other materials. Therefore, a lot of work needs to be done to manipulate the two-dimensional GO sheets for advanced technology in the future. It appears that when production expenses are taken into consideration, research efforts come to a standstill. Nonetheless, as long as the graphene industry's manufacturing sector continues, research into incorporating graphene into applications will be fruitful, and graphene's future remains extremely promising.

References

1. Norhayati, Hashim, et al. "A Brief Review On Recent Graphene Oxide-Based Material Nanoco Mposites: Synthesis And Applications." (2016).
2. Lingamdinne, Lakshmi Prasanna, Janardhan Reddy Koduru, and Rama Rao Karri. "A comprehensive review of applications of magnetic graphene oxide based nanocomposites for sustainable water purification." *Journal of environmental management* 231 (2019): 622-634.
3. Rana, Azeem, Ibrahim Khan, and Tawfik A. Saleh. "Advances in carbon nanostructures and nanocellulose as additives for efficient drilling fluids: trends and future perspective—a review." *Energy & Fuels* 35.9 (2021): 7319-7339.
4. Meti, Sunil, et al. "Chemical free synthesis of graphene oxide in the preparation of reduced graphene oxide-zinc oxide nanocomposite with improved photocatalytic properties." *Applied Surface Science* 451 (2018): 67-75.
5. Koduru, Janardhan Reddy, Rama Rao Karri, and N. M. Mubarak. "Smart materials, magnetic graphene oxide-based nanocomposites for sustainable water purification." *Sustainable polymer composites and nanocomposites* (2019): 759-781.
6. Nawaz, Shahid, et al. "Mitigation of environmentally hazardous pollutants by magnetically responsive composite materials." *Chemosphere* 276 (2021): 130241.
7. Vinyas, M., et al. "A comprehensive review on analysis of nanocomposites: from manufacturing to properties characterization." *Materials Research Express* 6.9 (2019): 092002.
8. Banakar, Sepideh Hasanzadeh, Mohammad G. Dekamin, and Amene Yaghoubi. "Selective and highly efficient synthesis of xanthenedione or tetraketone derivatives catalyzed by ZnO nanorod-decorated graphene oxide." *New Journal of Chemistry* 42.17 (2018): 14246-14262.

9. Azam, Muhammad Usman, et al. "In-situ synthesis of TiO2/La2O2CO3/rGO composite under acidic/basic treatment with La3+/Ti3+ as mediators for boosting photocatalytic H2 evolution." *International Journal of Hydrogen Energy* 44.42 (2019): 23669-23688.
10. Nujić, Marija, and Mirna Habuda-Stanić. "Toxic metal ions in drinking water and effective removal using graphene oxide nanocomposite." *A new generation material graphene: applications in water technology* (2019): 373-395.
11. Abbaspoor, Saleheh, et al. "Supramolecular donor-acceptor structures via orienting predeveloped fibrillar poly (3-hexylthiophene) crystals on bared/functionalized/grafted reduced graphene oxide with novel thiophenic constituents." *Organic Electronics* 52 (2018): 243-256.
12. Choi, Jong-Soo, et al. "Fabrication of chitosan/graphene oxide-gadolinium nanorods as a novel nanocomposite for arsenic removal from aqueous solutions." *Journal of Molecular Liquids* 320 (2020): 114410.
13. Lajevardi, Aseman, et al. "Green synthesis of MOF@ Ag nanocomposites for catalytic reduction of methylene blue." Journal of Molecular Liquids 276 (2019): 371-378.
14. Abdi, Gisya, et al. "Polyamine-modified magnetic graphene oxide surface: feasible adsorbent for removal of dyes." *Journal of Molecular Liquids* 289 (2019): 111118.
15. Lingamdinne, Lakshmi Prasanna, et al. "Process modeling and optimization of an iron oxide immobilized graphene oxide gadolinium nanocomposite for arsenic adsorption." *Journal of Molecular Liquids* 299 (2020): 112261.
16. Alsuhybani, Mohammed, et al. "Highly efficient removal of Pb (II) from aqueous systems using a new nanocomposite: Adsorption, isotherm, kinetic and mechanism studies." *Journal of Molecular Liquids* 301 (2020): 112393.