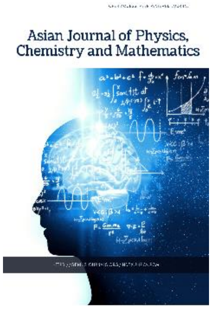

Review: Graphene Oxide

Hawraa Hameed Rady Chemistry Department, College of Science, Misan University-Maysan,Iraq.
(howraaatchem@uomisan.edu.iq)

Safaa Sabri Naij Chemistry Department, College of Science, Misan University-Maysan,Iraq.

ABSTRACT

In domains including physics, chemistry, biology, and materials science, multilayered graphene oxide (GO) has recently gotten a lot of interest. The layered structure of graphite oxide is comparable to graphite's, however the carbon atoms are arranged differently are arranged differently. Oxygen-containing groups are abundantly decorated on graphite planes. Exogenous functional groups in graphene oxide (GO) include epoxy (which bridges oxygen atoms), carboxyl and carbonyl moieties in the basal plane, and hydroxyl in the basal plane that border the nano sheet boundary. It's very hydrophilic and can create stable aqueous colloids, making it easier to put together macroscopic structures with low-cost solution methods; and (ii) In terms of structure, Under aqueous circumstances, it is very hydrophilic and forms stable colloids, making it easy to construct macroscopic structures; and (ii) in terms of structure .Under aqueous circumstances, it is very hydrophilic and forms stable colloids, making it easier to construct macroscopic structures.

Keywords: Graphene oxide, structure modeling , properties , preparation, application

1. Introduction

Graphite oxide is a type of graphite that has a lot of The oxygen-containing groups embellish the plane of carbon atoms, increasing interlayer distance while also making the atomic-thick layers hydrophilic. Under ultra-sonication, n water, these oxidized layers may exfoliate. Graphene oxide is made up of graphene sheets are sheets with only one or a few layers of carbon atoms exfoliated (GO).The oxidation of graphite crystals produces GO, which is a layered substance made up of carbon, hydrogen, and oxygen molecules on a single atomic level[1,2]. It is water dispersible and simple to process. Recovering conjugated structures by eliminating oxygen-containing groups, the GO can be (partially) reduced to graphene-like sheets[3]. GO has two distinguishing features: It has the potential to produce stable aqueous colloids that make the construction of macroscopic structures easier utilizing affordable As a raw material, graphite, and cost-effective chemical processes with a high yield are used, in addition to being very

Hydrophilic.graphite is inexpensive as raw material and chemical methods with highyields are highly effective and cost-effective for the assembly of macroscopic structures because It is extremely hydrophilic and capable of forming stable aqueous colloids. Apart from its minuscule ripples, the graphene sheet is completely flat and made up of exclusively trigonal linked sp^2 carbon atoms[4]. As a result of structural deformation and the covalent bonds between carbon atoms GOsheets are composed of tetrahedral carbon atomsdisplaced slightly in one or more directions. Several researchers looked at the surface of GO and found areas that were severely damaged. Other parts remain almost undamaged, most likely owing to the presence of oxygen. According to a study, Despite having disarray (i.e., carbon atoms attached to functional groups move), GO's graphene-like honeycomb lattice is conserved, while its unit cell size is similar to graphene's GO is a mixture of oxidized parts with oxygen-containing functional groups and non-oxidized areas with sp^2 hybridization maintained by the majority of carbon atoms. In graphene research and development, GO and rGO are hot topics, especially in terms of mass applications[5-7].

2. Structural modeling

A structural model was created by Hofmann and Holst.of GO in early 1939 that featured only Epoxide groups. They proposed that epoxide connections with an ideal formula of C_2O were used to connect oxygen to the hexagon layer planes' carbon atoms. Then, in Ruess proposed a structural solution in 1947model based on the hydrogen content of GO that included hydroxyl groups. This model also shows that, rather than Hofmann and Holst's sp^2 hybridized model, The structure of the GO basal plane is in an sp^3 hybridization state. Scholz and Boehm studied the stoichiometric ratio and found that it could be improved. based on Ruess' model, offering a model with conjugated carbon backbone ribbons and typical quinoidal species without epoxide groups[8,9].

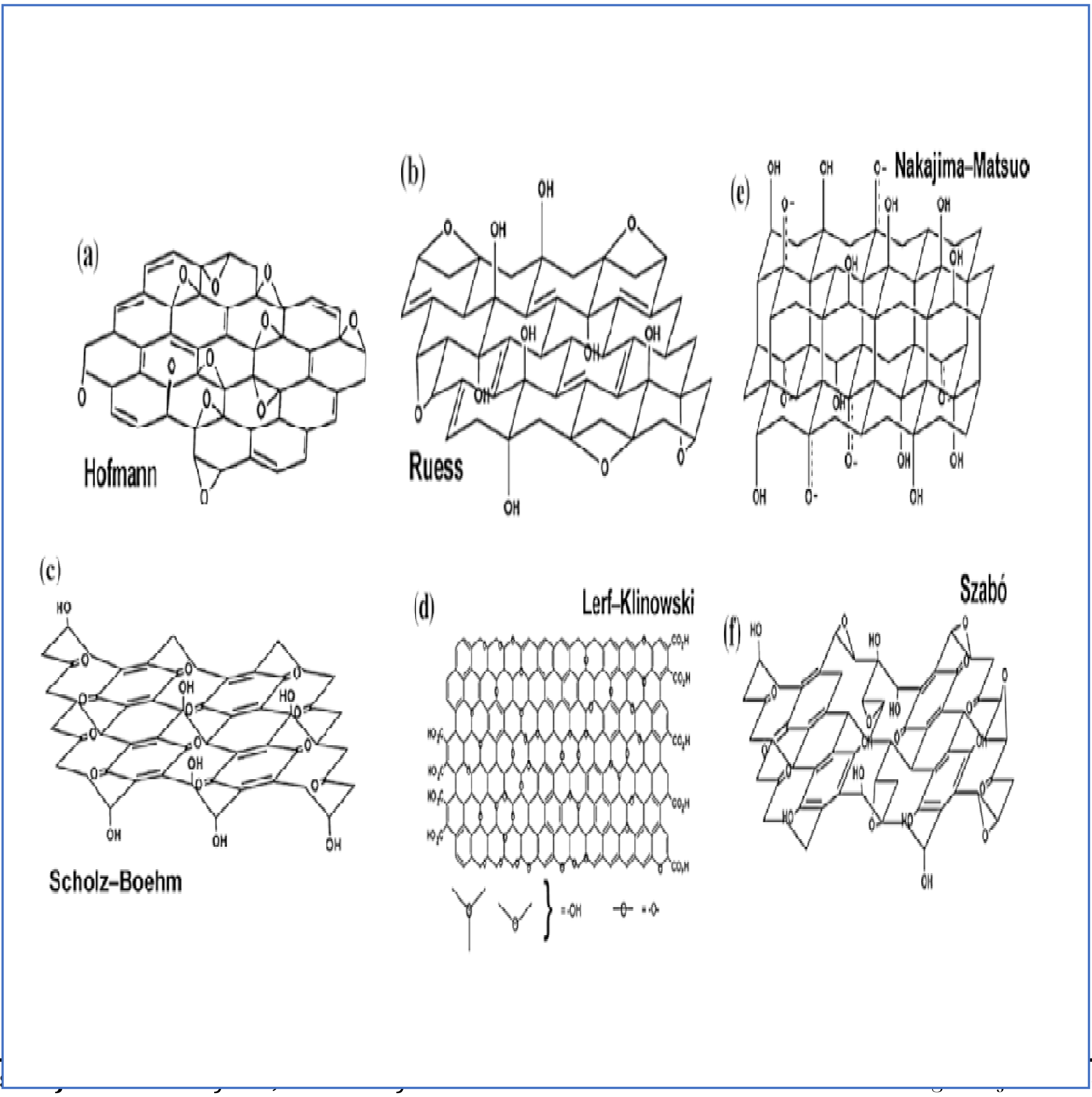

Figure (1): Structurer modeling of graphene oxide

3. Synthesize of graphene oxide

Multilayered Benjamin Brodie first created graphene oxide (graphite oxide) in 1859 , who used powerful oxidizers to reveal the structure of graphite for the first time. Brodie used lamellar graphite that had been heated. (as opposed to amorphous graphite) for a few days (3–4 days) at 60 °C in a solution of potassium chlorate ($KClO_3$) and nitric acid fumes (HNO_3). After four to seven oxidative treatments, washing, and drying, the product is ready to use. the product he generated (GO-BR) Having a carbon, hydrogen, and oxygen makeup, $C_{11}H_4O_5$ (C/O: 2.2) is the averaged general formula Brodie also discovered that the chemical could be dissolved in either pure or basic water, but that it flocculated in more acidic environments. Furthermore, when put on litmus paper, the substance displayed a weak acid response. Brodie developed the name "graphic acid" (GA) to characterize his new finding for this reason[1-6].

Brodie's method was improved by L. Staudenmaier, who changed the way of adding potassium chlorate steadily adding sulfuric acid to the reaction mixture throughout the process. Which he did almost forty years later. To limit the possibility of heat and flammable by-products creation, $KClO_3$ was included in trace amounts. to make the mixture's acidity higher, H_2SO_4 was added, which increased graphite oxidation while simultaneously decreasing the reaction time[9]. More importantly, lower pH needed less fuming nitric acid for oxidation, resulting in decreased toxic gas emissions (NO_2, $N_2O_4$and the control of a huge number of individuals of caustic and dangerous components, making the process safer overall. He was able to manufacture materials (GO-ST) that were equivalent to GO-BR using this procedure. Hofmann also developed a safe technique for making GO-HO with less oxidation (C/O > 2.5) using simply $KClO_3$ and non-fuming nitric acid in 1937. Nitric acid has been demonstrated $KClO_3$ is a powerful oxidant that can In situ, it can be utilized as a molecular oxygen source, although it reacts violently with aromatic carbon surfaces like carbon nanotubes. The $KClO_3$ and HNO_3 the characteristics were among the most potent oxidative ways available. available at the time, and they are still used for preparative scale GO synthesis today[7,5].

Over a century after Brodie's discovery, Hummers and Offeman discovered the In the field of science, the most significant method is graphite oxidative chemical exfoliation. The quickest and safest traditional method for generating GO-HU was devised by Hummers and Hoffman. Which is extremely similar to GO-BR and has a C/O ratio of 2.25. (2.2)[3]. An excess of potassium permanganate and sulfuric acid were used in their procedure, and a little amount of sodium nitrate on graphite. Because explosive ClO_2 was not produced, their technology was far safer than chlorate-based methods. Excess $KMnO_4$ was also easily neutralized using a diluted solution of H_2O_2, resulting in Manganese sulfate salts that are non-toxic and gaseous oxygen that may be removed easily during the purification process[5]. Despite this, During the acidification of sodium nitrate, nitric acid was generated in situ, along with a slew of other hazardous gases (NO_2, N_2O_4). So far, materials made using the More faults have been found in Brodie, Staudenmaier, and Hummers' approaches (perforations, creases, irregular shape, pollutants, and so forth.) Hummers' process is of particular importance since it is a simple reaction that is well suited to produce huge quantities of graphite oxide (MlGO) that can be delaminated into GO using liquid exfoliation processes, in comparison to those resulting from micromechanical graphite cleavage[1]. Due to covalently bound sulfates and nitrates or absorbed sulfuric and nitric acids, it produces GO with traces of sulfur (up to 6%), as well as nitrogen. In 2010, a modified Hummers' technique was employed to develop a better procedure for producing GOES with high oxidation levels. Instead of sodium nitrate, Phosphoric acid (H_3PO_4) was used as a dispersive and etching agent to help graphite oxidative chemical exfoliation to create larger quantities of GO. The GO manufactured utilizing the In comparison to GO-BR, GO-ST, and GO-HU, the Tour technique (GO-TO) had greater oxidation and a more uniform structure with fewer flaws in the basal plane. The formation of five-membered cyclic phosphate groups between phosphoric acid and two vicinal diols explains the more regular structure. generated on the graphite basal plane[8,9]. After Brodie, Staudenmaier, and Hummers (A comprehensive investigation The intercalation process illustrates the intercalation of sulfuric acid and potassium permanganate into graphite integralities),this one-pot approach is quite common and widely acknowledged as the "fourth" primary way to manufacture GOES[2].

4. Properties of graphene oxide

Due to the existence of oxygen functions, one of the advantages of GO is its ease of dispensability in water and other organic solvents, as well as in a variety of matrixes. This property is still relevant when the material is blended with To improve electrical and mechanical properties, ceramic or polymer matrixes can be used. Electrical conductivity is a phrase used to describe how well something conducts electricity, GO is commonly recognized Due to the disruption of its sp^2 bonding networks, it acts as an electrical insulator. Reduced GO must be used to reestablish hexagonal honeycomb lattice and electrical conductivity that comes with it the properties of GO can be considerably changed by functionalizing it once the majority of the oxygen groups have been removed. As a result, chemically modified graphene's might be significantly more adaptable for a wide range of applications[10].

GO may be functionalized in a number of different ways depending on the context. Amines can be used to replace organic covalent functionalization of graphene in organic solvents in optoelectronics, biotechnology, or as a process of transporting drugs. GO platelets have also been shown to attach Porphyrin-functionalized primary amines and Fullerene-functionalized secondary amines are examples of porphyrin-functionalized amines. Improving nonlinear optical performance. It's critical to develop an oxidation and reduction procedure that can isolate individual carbon layers without affecting their structure, allowing GO to be used as a bridge between monolayer and few layer graphene sheets. Although chemical reduction of GO is presently thought to be the best way for mass synthesis of graphene, scientists have struggled to accomplish the challenge of creating On a much larger scale, Mechanically exfoliated graphene sheets of comparable quality[11].

5. Application of Graphene Oxide

In the production of numerous electrical devices, For at least one component, GO has been used as a beginning material. One such device is a graphene-based field effect transistor(FET). Chemical and biosensors have been developed using rGO-based FETs. Biosensors based on FETs with The semiconductor functionalized rGO have been utilized to find catecholamines, avidin, and DNA in the human body[12]. The electrochemical glucose sensor was investigated using GO functionalized with glucose oxidase and placed on an electrode. The creation of transparent conductive films after they have been put on any substrate is one of the most prevalent uses for GO. Coatings have the potential to benefit Solar cells, liquid crystal devices, chemical sensors, and touch screen technology are all examples of flexible electronics. Water permeability across the membrane was blamed for causing GO structures to expand, allowing a water penetration channel to form between individual GO layers. In dry Hummers graphite oxide, the interlayer distance was reported to be 6.35, but in liquid water, it increased to 11.6. The membranes have a water penetration rate of 0.1 mg/min/cm2 and a water diffusion rate of 1 cm/h. With these oxides, KCl, HCl, $CaCl_2$, $MgCl_2$, and $BaCl_2$ solutions might be used as cation exchange membranes. Large alkaloid ions have also been observed to pass through the membranes because they can pass between the GO layers. In the 1960s, GO membranes were also being investigated for use in water desalination, although they were never deployed in practice. In this investigation, GO membranes that have been stabilized in a reverse osmosis system were shown to have retention rates of more than 90% for NaCl solutions. Seawater filtering might be done with GO membranes[13,14].

Water " Because the GO layer is so thin, it "pops through the very, very small holes in the graphene and leaves the salt behind" (just one atom thick).The strongest filter on the market is 500 times thinner than GO film, which is B1000 times stronger than steel. yet it has B100 times the permeability of the best competing membrane. Ions from ordinary salts flow through the filter, while some bigger ions are retained in the sample. Monolayer or bilayer water can move swiftly via narrow capillaries. Helium cannot travel through the membranes while they are dry, but it can if they are subjected to humid gas, but water vapor can easily pass through. When dry laminates are They act as molecular sieves when submerged in water, preventing specific solutes from interacting with hydrated radii higher than 4.5[15,16].

Under dry conditions, multilayer GO films are optically transparent and water resistant. They let molecules of a certain size pass through when exposed to the elements (or water vapor). Millions of randomly arranged flakes with microscopic capillaries between them make up the films.

Chemical reduction using hydro-iodic acid closes these nano capillaries, resulting rGO films are completely impervious to gases, liquids, and strong chemicals. The thickness is 100 nm. Corrosive acids can be stored in glassware or copper plates that have been coated with graphene "paint." To extend the shelf life of medical packaging, graphene-coated plastic sheets might be employed.

GO has been successfully used to detect DNA and proteins in fluorescent-based biosensors, suggesting improved HIV detection. The fluorescence resonance energy transfer (FRET) phenomenon was used in a fluorescein-labeled ATP aptamer to detect ATP at concentrations as low as 10 M. In biosensors that exploit the FRET effect, GO has been used as a fluorescence quenching substance[17]. The researchers discovered that single-stranded DNA (ssDNA) carrying a fluorescent tag bound to GO non-covalently, causing the tag's fluorescence to be quenched. The addition of a corresponding ssDNA to the GO surface erased the tagged DNA and the fluorescence was restored Ovarian cancer and breast cancer cells from humans were detected using GO that had been functionalized with folic acid[18,19].

Conclusion

Research into GO applications, like many other topics, has progressed dramatically and is quickly growing. The progress made thus far in this field is exciting and promising; nonetheless, the hurdles are significant and must be surmounted. Understanding Interactions between graphene cells (or tissues or organs), particularly the cellular absorption mechanism, is one such stumbling barrier. Such information will undoubtedly aid in the creation More efficient GO-based nanoplatforms for drug delivery, biosensing, and other applications are being developed. The in vitro biotoxicity of graphene is connected to oxidative stress and cell membrane breakdown. Clearly, before graphene may be employed in biomedicine, a thorough examination is required to resolve the safety concerns. These goals can only be met by a combined effort including chemistry, biology, materials science, and nanotechnology. It is critical to develop appropriate For careful control of GO size, size distribution, and shape, chemical synthesis and functionalization methods are used The performance of GO-based nanoparticles for biological applications and safety concerns are all tied to structural flaws and oxygen-containing groups.

References

1. FY. Ban, SR. Majid, NM .Huang, HN. Lim ,Graphene Oxide and Its Electrochemical Performance. Int J Electrochem Sci, **7,** 4345-4351 , (2012).
2. M .Cecilia, E .Goki, A .Stefano, M .Steve, K.Andre ,Evolution of Electrical,Chemical, and Structural Properties of Transparent and Conducting Chemically Derived

Graphene Thin Films. Adv Funct Mater, **19,** 2577-2583, (2009).

3. V .Gunasekaran, K. Karthikeyan, M .Rajneesh, K .Sang ,An investigation the electrical transport properties of graphene-oxide thin films. Materials Chemistry and Physics **,132:** 29-33 (2012).
4. Hofmann, U., Holst, R.: Ber. Dtsch. Chem. Ges. **B 72**, 754–771 (1939)
5. Ruess, G.: Monatsh**.** Chem. **76**, 381–417 (1947) .
6. Scholz, W., Boehm, H.P.Z.: Anorg. Allg. Chem**.** 369, 327–340 (1969) .
7. Lerf, A., He, H., Forster, M., Klinowski, J.: J. Phys. Chem**.** B 102, 4477–4482 (1998) **.**
8. Nakajima, T., Mabuchi, A., Hagiwara, R.: Carbon, **26**, 357–361 (1988).
9. S. Berkesi, O., Forg, P., Josepovits, K., Sanakis, Y., Petridis, D., Dékny, I.:Chem. Mater**. 18**, 2740–2749 (2006) .
10. J.Zhao ,L .Liu ,F.Li , Graphene oxide Physical and Application , Chap .3 , 31- 54 (2015).
11. Loh, K.P.; Bao, Q.; Eda, G.; Chhowalla, M., Graphene oxide as a chemically tunable platform for optical applications. **Nature Chem.,** 2 (12), 1015–1024 (2010).
12. Chua, C.K.; Pumera, M., Chemical reduction of graphene oxide: a syntheticchemistry viewpoint. Chem. Soc. Rev**., 43 (1),** 291–312 (2014) .
13. Dreyer, D.R.; Todd, A.D.; Bielawski, C.W., Harnessing the chemistry ofgraphene oxide. Chem. Soc. Rev**., 43 (**15), 5288–5301 **,(**2014)
14. Eigler, S.; Hirsch, A., Chemistry with graphene and graphene oxide – challenges for synthetic chemists. Angew. Chem. Int. Ed**., 53** (30), 7720–7738 **,(**2014).
15. S.Ray , Applications of Graphene and Graphene-Oxide Based Nanomaterials , Chap .2,44, **(**2015).
16. Paulchamy B1, Arthi G2 and Lignesh BD3A Simple Approach to Stepwise Synthesis of Graphene Oxide Nanomaterial , Nanomed Nanotechnol, 6:1 , (2015).
17. Abd el at , Addition of Some Primary and Secondary Amines to Graphene Oxide, and Studying Their Effect on Increasing its Electrical Properties , Baghdad Science Journal , **13**(1)2016.
18. A.Hameed , 'Phosphate Based Cathodes and Reduced Graphene OxideComposite Anodes for Energy Storage Applications **',** Chap.1 , 25 **,** (2016).
19. J.Zhao ,L .Liu ,F.Li , **"**Graphene oxide Physical and Application ", Chap .4 ,57-77 (2015).