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Graphene Oxide and its applications

Priyanka Mishra[1], Kirti Chache[1], Nidhi Ghag[1], Dipti Lokhande[1]

[1]*S. H. Mutha College of Arts, Commerce and Science,*
Kalyan (Maharashtra, India)

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Abstract:

Graphene is one of the allotrope of carbon which is sp^2 hybridised and arrange in the form of sheet.Graphene is good electrical conductors, inherent strength and ability to absorb a 2.3 % of white light and also it is super thin, super strong, transparent. When an oxygen functionalized group is introduced on the graphene layers then it is called graphene oxide. GO shows a wide range of applications due to their active surface area. Recently found that the graphene oxide is used for Cancer treatment with tumor growth retardation.

1. Introduction:

There are several allotropes of Carbon, such as diamond, graphite and fullerenes. Nowadays, allotropes of carbon have been introduced including ball shapes such as buckminsterfullerene and sheets such as graphene. Graphene is a two dimensional allotrope of carbon. The unit structure of graphene is hexagonal carbon ring with an area of $0.052 nm^2$.Graphene consists of thick single atomic layer of sp^2 carbon atoms arranged in a honeycomb-like structure.

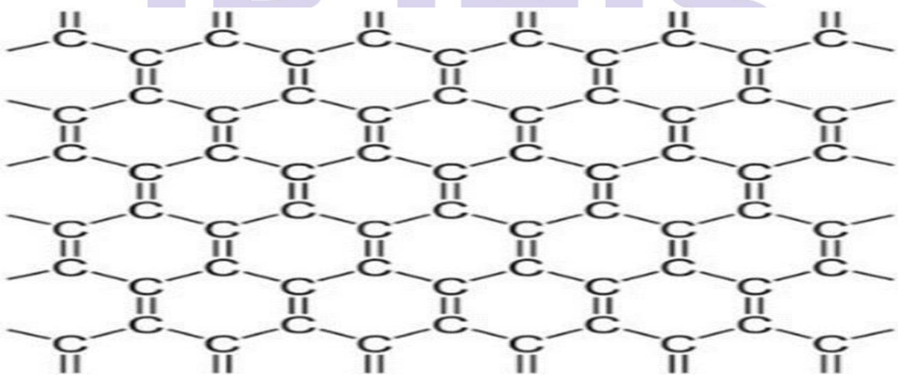

Figure 1. Structure of graphene

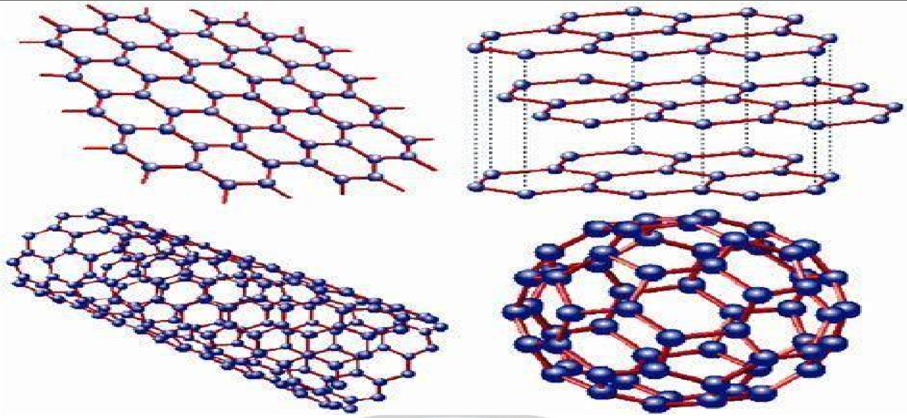

Figure 2. Graphene (top left) is a two dimensional honeycomb lattice of carbon atoms

2.1. Applications:

2.2. Use of GO in desalination devices-

In this process, the water can be desalinated using solar energy and GO as the absorber. This is a quite efficient process without the loss of can be used for the desalination of large quantities of water which can be beneficial for the countries which are facing scarcity of water. [3]

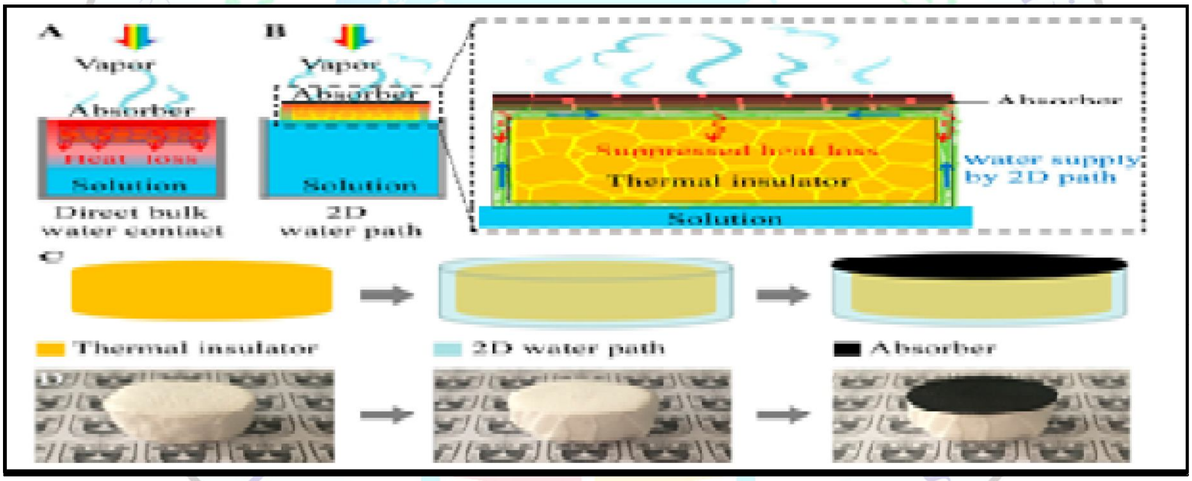

Figure 10: A) Conventionally used solar steam generator with direct water contact. B) Solar desalination device with 2D water supply. C) Flowchart showing the making of solar desalination device

The desalination device must consist of an absorber which is very thin for the efficient absorption of solar energy and more vapour generation and also to minimise the amount of heat lost because of heating of the water or because of the dissipation of heat to the environment.[3]

The previously used method consisted of the absorber in direct contact with the water because of which the absorbed energy was dissipated to the water which led to the loss of absorbed energy in the form of heat which is undesirable. Hence, a new method was put forth by Xiuqiang Li *et al.* where a thermal insulator (polystyrene foam) was coated with a hydrophilic cellulose layer and a thin GO film was placed on top of it. The entire assembly floated on water since only the cellulose layer was in direct contact with the water, the absorber was efficiently supplied water by the capillary action of the cellulose. GO was used as an absorber because of its low thermal conductivity, porous structure and its low cost production by modified Hummer's method.

Thus the water can be desalinated effectively using the desalination device without the need of thermal insulators or optical concentrators [3].

2.3. GO based biosensor for food toxin detection:

Aspergillus Flavus and *Aspergillus parasiticus* under certain conditions produce Aflatoxin, a group of secondary fungal metabolites which are food toxins that cause contamination of food products. Aflatoxin B_1 is the most toxic and it causes the human hepatocellular carcinoma.

Singh *et al*. recently reported that GO biosensor for sensitive detection of Aflatoxin B_1 as this biosensor shows high sensitivity, high detection limit, and good storage stability.Go/Au electrode is prepared by uniformly spreading ten microliters aqueous graphene oxide on gold electrode, dry this in a vacuum oven overnight at 50° C

This electrode is used for immobilization of antibody molecules. Biofunctionalization occurs through covalent amide bond formation between carboxylic groups of graphene oxide and amino terminal of anti AflatoxinB_1 [7].

2.4. Application of prepared reduced GO-Nickel oxide in sensors:

The simultaneous determination of presence of neurotransmitters like dopamine and epinephrine is difficult as they are structurally similar and so their oxidation potential gets overlapped with each other and thus it is important to derive a method through which they can be successfully analysed separately. The synthesized rGO-NiO/ITO electrode was used for simultaneous detection of these neurotransmitters by Square wave voltammetry (SWV). The modified electrode works well even in the presence of interferents like ascorbic acid, uric acid or fetal bovine serum samples [9].

2.5. Application of graphene oxide for wireless humidity sensing:

GO is highly hydrophilic in nature due to the presence of numerous hydroxyl, epoxy groups present which shows large absorption of water molecules. The extent of absorption of water depends on the humidity of the environment, thus making GO sensitive to environmental humid content [13]. This exclusive property of GO makes it a device for keeping a check to humidity. The uptake of water in the interlayer film of GO affects various properties like electrical conductance, molecular permeation, mechanical and dielectric properties.

Multilayered GO electrical and dielectric properties have been studied at low frequency under different humidity conditions[13]. There are different GO capacitors being constructor which work well at low frequency but are not that efficient at high frequency due to parasitic effect. GO is also used in battery-free wireless sensor in which instead of using GO capacitor, graphene oxide layer was coated on to RFID antenna (Radio Frequency Identification) RFID antennas are very much sensitive to environment when graphene oxide is coated on the RFID antenna it eventually become sensitive to humidity due to graphene oxide layer [13].

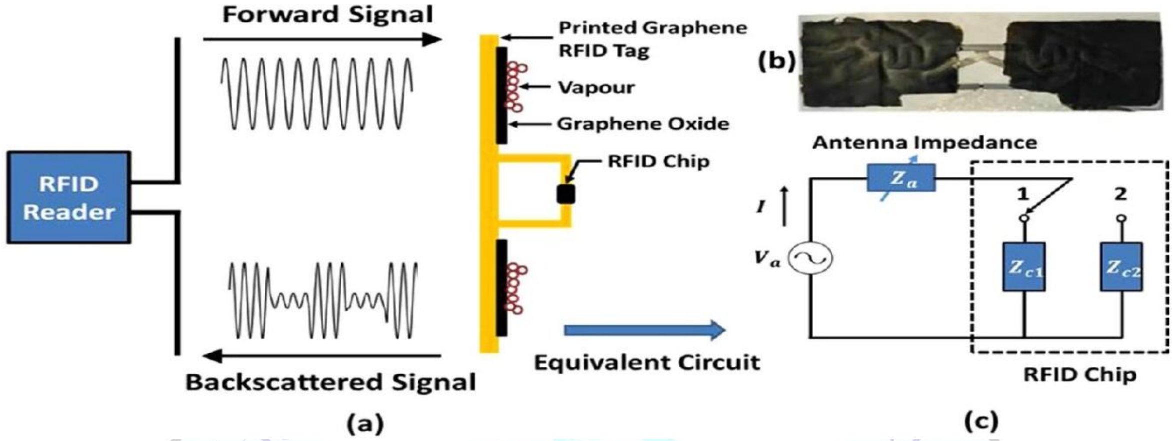

Figure 14: (a) Operating principle of the GO based printed graphene RFID sensor system (b) Printed graphene antenna with a layer of GO on top(the thickness of the GO layer (c) The equivalent circuit of the RFID tag.

2.6. Biomedical applications in therapeutics of GO:

Therapeutics is a branch of research that distributes drug delivery and treatment of the affected biological sections.

2.6.1 Drug delivery:

GO has conservative properties such as surface area, layer number, lateral dimension, surface chemistry and purity which are useful for their drug delivery and other biomedical applications.

Ibuprofen is a universal non-steroidal anti-inflammatory drug that is as usual used for the analgesic. .when Ibuprofen was combine with chitosan-functionalized GO connected by amide linkages, the functionalized GO showed excessive (20 %) biocompatibility compared to GO sheets for human acute lymphoblastic leukemia cell lines (CEM) and Michigan Cancer Foundation 7 cell lines (MCF-7).

JOO.*et.al* introduced that GO connected with poly ethylene glycol loaded with doxorubicin (DOX) via pi–pi interactions prove the promising real-time release of DOX from combined with poly ethylene glycol at specific loci after an external triggering by glutathione (GSH). [14]

Another research team introduced that GO combined with doxorubicin showed excessive drug delivery at pH 5.3 because of the dented coordination between DOX and the drug carrier. GO conjugated with DOX display improved cellular toxicity and assurance tumour growth retardation, with almost 66–91% cell death.

When paclitaxel and methotrexate combined with GO via p–p stacking and amide bonds showed impressive cancerous effects on lung cancer and breast cancer which drive in retardation about 66–90% of tumour growth. [14]

When GO combine with a second-generation photosensitizer chlorine 6 (Ce6) derived in its excessive in tumour cells, principal to an elevated photodynamic effectiveness upon irradiation. [14]

2.6.2 Gene delivery:

JOO.*et.al* introduced that when GO combined with vascular endothelial growth factor-165 (VEGF) Proangiogenic gene is an impressive distribution for myocardial therapy.

Feng.et.al found that when polyethylenimine- GO carrier to transfect the plasmid DNA into theHena cells and resulted that PEI-GO generated upgrade of the transfection efficacy by proton-sponge effect. [14]

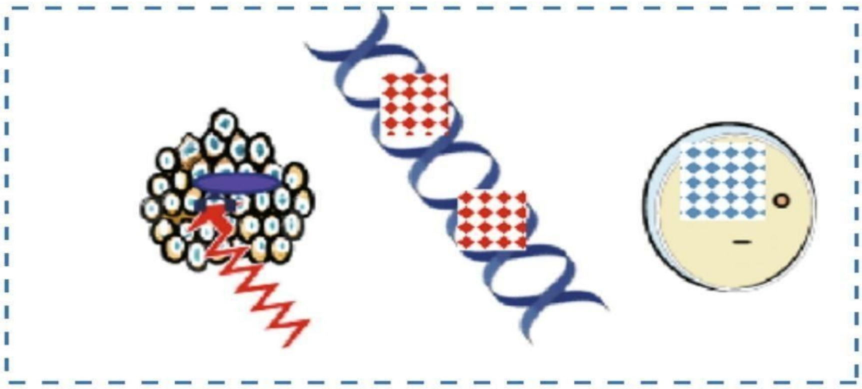

Figure 15: GO as therapeutic

2.7. Application of GO in purification of water containing dye:

Organic waste contains many organic and inorganic dyes. Many dyes are toxic and environmentally harmful. So purification of these dyes from water is a very crucialstep.

Graphene based Go-TiO2 sheet shows important application in filtration of methyl orange and Rhodamine B dyes from water.

Preparation of Go-TiO_2 sheet done by adding 25mg of GO and 60 mg of TiSO4, mixture can be dispersed in 40 ml of distilled water, this mixture heated at 60°C Overnight , to remove impurities the product obtained were centrifuged and washed with distilled water. To obtain stable dispersion, the product was re-dispersed in water with addition of ammonia to increase pH up to 10.

GO-TiO_2 raps dyes molecules very efficiently by overcoming the adsorption property of dyes[21].

2.8. Using GO beads for cleaning up of hazardous chemicals:

Enormous quantities of chemicals are used daily and the waste chemicals generated are released into the environment causing environmental pollution. In addition, there are chemical spills or accidents which risk the lives of people living in the surrounding areas. Fast cleaning up of the chemicals either by neutralising them or by absorbing them or diluting them to concentrations below the harmful level is necessary. These chemical accidents also have the risk of catching fire hence it is necessary to make use of adsorbents which are fire retardants [23].

Hence GO based materials were used as absorbers. The GO was made into beads in which the core is made up of GO foam whereas the shell is made up of GO membrane.

Layered silicates were incorporated in these GO beads making them good fire retardants [23].

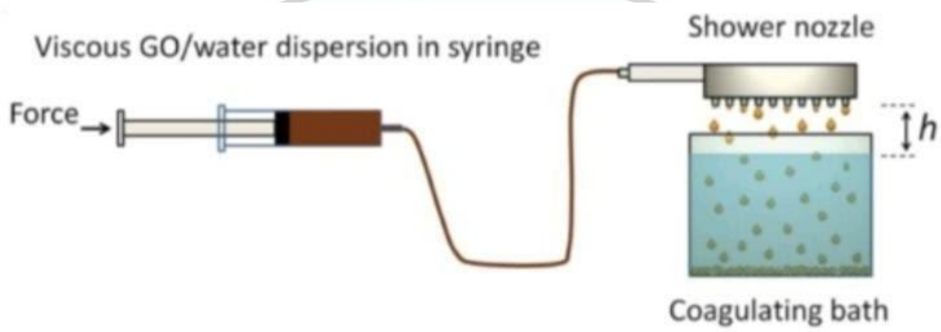

Figure 16: GO / water dispersion flowing down the nozzle in to the coagulating bath forming GO beads

These GO beads were able to absorb the acid of almost the same volume as the bead. The core prevented the leakage of the acid. Thus these GO beads can be effectively used to absorb and prevent the chemical spill from spreading further. These GO beads can also be used as carriers for sustained release [23].

2.9. Ionic liquid-graphene oxide hybrid used as anti-corrosives:

Ionic liquid-GO hybrid has anti-corrosion properties which works wonderfully on epoxy based water bond coating. This property was tested by a salt spraying test. The results were surprising that pure and reduced graphene oxide epoxy coating does not show satisfactory anti-corrosive ability as compared to Ionic liquid-GO severe rust was seen on pure and reduced graphene oxide after 100-hour test while Ionic liquid-graphene oxide showed great anti-corrosion even after 300 hour.

The main reason for corrosion initiation seen was the pores of unfilled gaps during the coating which leads the corrosive substances creeping inside leading to metal corrosion, the corrosive substances creeps faster to the interface of metal coating in case of pure epoxy coating while in Ionic liquid-GO the graphene sheets are dispersed all over which inhibits the direct penetration of corrosive to the metal surface. Thus it shows better long term anti-corrosion performance.

2.10. GO-Ag nanocomposite for physicochemical application:

Silver belongs to transition group elements and it is most conducting and reacting metals among the other elements of the series when silver is combined with GO it improves its characteristic properties like low resistance, better dispersion and improved mechanical properties. The silver Nano particle with GO gets intercalated between the layer of graphene oxide. The composite was used as a photocatalyst for degrading organic pollutants. For checking the actual utilization methylene blue (MB) was used as sample dye [27]. The dye does not show any considerable absorption over time in the presence of UV-visible radiation which was estimated by plot. The degradation process is given in the figure.

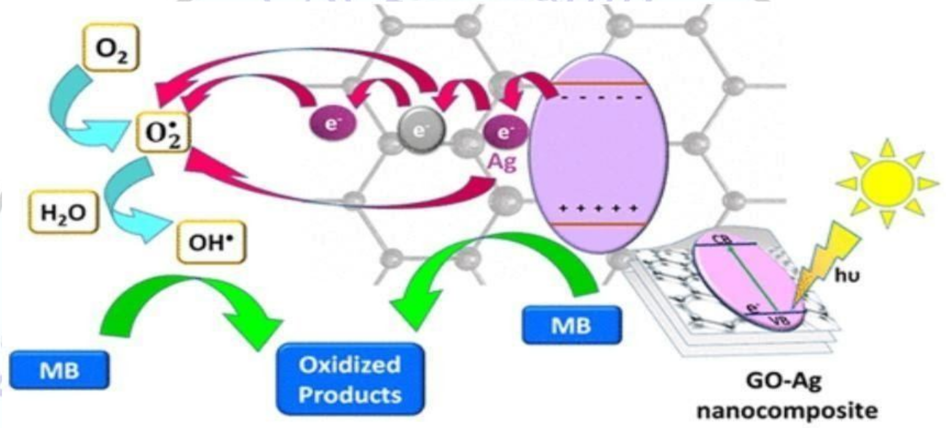

Figure 18: Schematic representation of photo degradation of MB dye through the GO-Ag nanocomposite under UV light irradiation.

Graphene oxide plays a major role as it is an excellent charge acceptor and transporter thus holding the process of recombination of electron and positive charge (hole). Thus due to graphene oxide-silver nanoparticles composite the photolytic degradation of the dye has increased many times. So it can be successfully concluded that graphene oxide-silver nanoparticles can be used in the wastewater treatment process.

2.11. Removal of arsenic using akaganeite decorated graphene oxide composite:

Arsenic is the most toxic as well as carcinogenic element of the periodic table. Hence the pollution of water sources even with the trace quantity of arsenic can prove to be harmful. Hence it becomes important to find an inexpensive as well as an efficient method for the removal of arsenic from the water bodies. So a new method was put forth by *Ming Li Chen et al* [28].

The obtained β-FeOOH@GOCOOH composite has excellent capacity for adsorption of inorganic arsenite and arsenate species. Hence can be effectively used for the removal of inorganic toxic arsenic species from water bodies [28].

Conclusion:

In this review, we highlighted the different ways of synthesis of graphene oxide, its properties and application in different fields. As graphene oxide possesses excellent different properties like biocompatibility, large surface area, high electrical and thermal conductivity and excellent charge mobility due to this it provides a great tool and broad scope to the research field. In this review we summarized different traditional, modified and advanced methods for synthesis of graphene oxide which are low cost, more efficient, high yield, environmentally acceptable. Graphene oxide prepared by the oxidation process of naturally occurring, cheap graphite, which shows miraculous properties as a result is predominantly applied in detection of toxins in food, in desalination process, for cleaning hazardous chemicals, in physicochemical application, lithium sulphur batteries. It also shows application as a catalyst in different C-C coupling reactions. On the basis of combination therapy, graphene oxide is used for cancer treatments with tumor growth retardation. They also have practical applications as humidity sensor, anticorrosive, photocatalytic degradation of dye, biosensor and much more.

With the wide range of applications mentioned in this review GO proves to be an extremely important material which can not only be synthesized on large scale but can also be synthesized cost effectively using greener methods with less wastage and less harm to the environment and has a great scope in future, due to this it opens the many ways for more research in future.

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