Graphene Based Nanocomposite: A review

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Abstract:

Since 2004, graphene has revolutionised industries, scientific research, and medical world. Due to the simple methods of synthesis, graphene has become door-to-door process. Due to graphene's unique and astounding properties, graphene and its nano-composites have modernised whole world in technical and industrial aspects. This review will summarize about history, structure, thermal, mechanical, electronic properties of graphene. In this review synthesis and application of graphene-based nano- composite will also be presented.

Index Terms: Graphene, nano-composites,

1. Introduction

Carbon, the primary elements known to us is the bone of contention of all chemical reaction and elements. The carbon has allotropes in zero, one, two and three dimension and first 2D structure is in the form of graphene. The graphite is sp^2 hybridised, whereas the diamonds is sp^3 hybridised. Graphene is sp^2 hybridised with carbon atoms bonded in honey comb structure. Graphene is building block of graphite, CNTs. The carbon element has 3 covalent bonds the graphene has a one delocalised electron which is in the layers of graphite its structure is enough strong it has hexagonal structure. Graphene has been the centre of attention for the researchers recently and has revolutionised whole world in its research field from 2004, when Geim and Noveselov have given the simple method for fabrication. Since the exposure of this carbon building discourage, graphene has maneuverer in customary examination concerning its incredible physical, invention, and mechanical properties, and another examination region for materials science and merged issue material science has opened up, planning for wide-broadening and contrasted creative employments of graphitic materials. Graphene is with zero band gap, massless Dirac fermion's having resistance less than silver and ultra-high mobility. It is the thinnest element known till now, due to its unique properties, it is used in biosensors, electrodes, hydrogen storage, batteries, supercapacitors etc. Now a days, nano-composite of graphene has revolutionised the research in energy and environmental sections, such as biological , fuel cell , water purification super capacitors etc In this review a detail study on graphene and its nanocomposite has been presented. .

2. Synthesis of graphene

After knowing the best and the world class properties of graphene, the hot and the sparking challenge was how to synthesize such two-dimensional material. Until 2004 no one was interested to found the methods of synthesizing graphene, then after 2004 Noveslove has found a simple method. Then after researcher have found chemical and mechanical methods for fabrication of graphene.

2.1 Mechanical exploitation

Mechanical exploitation method is the key method in the synthesis of graphene till now. This synthesising process is used to obtain a rich and good quality of graphene through this the size from 5 to 10 μm has obtained, this method is not used for mass production. The layers of graphene the peeling is done by various methods such as scotch tape, ultra-sonication, electric field and transfer technique. This method has disadvantages as it is time consuming and needs lots of steps. Serious and a lot research to be done in this manufacturing method to overcome the challenge of production of graphene. Geim and Novoselov used this method of micro mechanical elevation they used scotch tape method or peel off method. They have again and again used graphite crystals to split into thinner and thinner pieces. The tape was put into acetone, after further some steps the two monolayer and multilayer where separated and studied under microscope. Jayasena et al. have used the same method, but he introduced crystal diamond wedge to cleave a highly ordered pyrolytic graphite. Graphene was obtained in few micrometres area crystalline size. the sheets of graphene who has different thickness can be obtained by exploitation or by peeling.

2.2 Chemical exploitation

This method is one of the industrial scale methods for graphene synthesis. Brodie et al. have used this method first time. It is a two-step process, in which, first a reducing agent is used to increase inter layer Vander walls forces to inter layer spacing so it can form the graphene intercalated compounds, using oxidising agent as $KMNO_4$ and $NaNO_3$. in H_2SO_4 the mixture in the ratio of 9:1.

2.3 Reduction of graphene oxide

In this method the graphene oxide is oxidised by oxidizing agents which include H_2SO_4 etc. another method we use for graphene reducing is sonification and reduction of graphene oxide other methods are by thermally. This method was the old one to get high quantity.

2.4 Chemical vapour deposition method

Comparing several processes of production, chemical vapour deposition is the process by which large size and electronic grade production of graphene is achieved. The CVD process is done in four steps, first one is heating, then annealing of the metal substrate, then deposition of graphene, and at last fast cooling. This method led to high quality graphene. This process is observed under vapours to create thin films which can be used in semiconductor industries. Zhen-Yu Juang et. al. have synthesized graphene centimetre scale using Ni foils. A. Houriet has synthesized graphene using copper sulphate through CVD. Metals like Cu, Ni, Pt etc., act as catalyst for graphene growth at high temperature. The precursor of carbon is dissociated on surface of these metal and by post cooling at high rate the dissociate carbon atom on metal surface arrange themselves as graphene. The metal is then etched by etchant and free-standing graphene film is acquired.

3. Graphene based Nanocomposites

A composite is a blend of at least two different materials that are shifted in a vitality to mix the best properties of both. A composite material involves of a gathering of two materials of unique natures execution and letting us to accomplish a material of which the arrangement of execution physiognomies is better than that of the constituents taken unconnectedly. Generally composite material comprises of at least one sporadic period of coursed in one constant stage. Cross breed segments are what are with a few disconnected periods of various natures. Incoherent stage is generally firmer and with higher mechanical possessions than unending stage. The unremitting stage is classified "framework". The broken stage is classified "supporting, or strengthening material. here we have to discuss about graphene nanocomposite. Zhang et. al. have fabricated tin oxide and graphene composite by mixing $SnCl_4$ and GO in water and filtered the precipitate. Nanocomposite of tungsten oxide and graphene have been fabricated by Srivastava et. al. with help of adding graphene in tungsten chloride dissolve in ethanol. Xu et. al. have synthesized cuprous oxide and graphene oxide composite by mixing and stirring Cu_2O and graphene (obtained from reduction of rGO). Jafari et. al. have fabricated polyaniline-graphene nanocomposite by magnetic stirring sodium salicylate, graphene and aniline monomer. Wen et. al. have synthesized SiO_2 xerogel nanopowder and graphene nanocomposite by stirring these material in tetrahydrofuran. Singh et. al. have synthesized iron oxide and graphene nanocomposite by adding the in 1M NH_4OH and collecting the precipitate. In this way graphene nano composite with other material can be synthesized as per applications.

3.1 Synthesis of graphene Nanocomposite

There are in situ method and Ex situ method to synthesized graphene based Nanocomposite. In-situ method composed of reduction method, hydrothermal method, microwave assisted, electromechanical deposition and pulse laser ablation in liquid method. Ex situ method composed of further two types Non-covalent interaction method and covalent method here non-covalent interaction method is further divided into 2 types π-π stacking method and electrostatic interaction method. In situ method: the formation of nanocrystals are formed in the occurrence of functional nanomaterials which are followed by rise of nanostructures on the surface of graphene. Reduction method: it is used in noble metal graphene composites, highly efficient method. Hydrothermal method: it is used as metal and metal oxide composites, its pure method of preparation. Microwave-assisted method: it has less reaction time and dried Electrochemical deposition method :its electro chemically reduced to graphene So on and so far other methods are also very useful in manufacturing the graphene nanocomposites. Tang et. al. have demonstrated dispersion of graphene oxide for the simple moulding of polymer solution. WANG et al, have developed two one monolithic graphene and other composite graphene. Singh et al, have used in situ Ziegler–Natta polymerization for the fabrication of PP/GO nanocomposites. Tang et al. have conveyed an remarkable method for the preparation of butadiene-styrene vinyl pyridine rubber (VPR) composites containing graphene oxide(GO), by combining the general co-coagulation process and in situ interface tailoring. Hansma et. al. (2007) have delivered a new method of preparation graphene nanocomposites. Wen et. al. have used hummers method to prepare LDHs /GO nanocomposites

4. Application of graphene nano composite

The unique properties of graphene Nano composition have their own vital applications in bio sensing, diagnosis, drug delivery, gene delivery, as catalysis, water purification, methanol cells, bio imagining, photo thermal therapy, antibacterial properties, gas sensing, photocatalytic activity etc.

4.1 Biological application

4.1.1 Bio sensing

Bio sensing is the high rated activity which is used to detect diseases applicable in security of health care and environmental safety. Pumera et. al. have describes the enzymatic bio sensing immune sensing DNA sensing and future development of this field. Due to graphene’s electro active properties Zero gap semiconductor, it has application in enzymatic biosensors, geo sensors etc. Loan et al Graphene layer cannot only active inhibit the reaction between MoS_2 and the surroundings but also smooth the DNA modification on this biocompatible edge. Now we can say that Graphene Oxide based fresh biosensors through electrochemical norm have been made by enchanting use of its vast surface area, decent electrical conductivity, and outstanding skill of filling numerous biomolecules through chemical or physical connections

4.1.2 Gene delivery

Gene delivery is the method in which foreign genetic material is introduced such as DNA and RNA into host cells. It is advanced method of treatment of various diseases. Even it found new way for cancer treatment recently. Liu et. al. poly ethylenimine (PEI)-modified GO (PEI-GO) for gene therapy. It is used for treatment of cystic fibrosis, Parkinson's disease etc. Recently a research group of Singapore have studied the amalgamation of chitosan-functionalized GO (GO-CS) sheets and their solicitation for drug/gene delivery. Shen et. al. have studied the gene delivery therapy for cancer, in which they have used DOX and Bcl2 i RNA to HeLa cells consuming a PEI-GO Nano carrier

4.1.3 Drug delivery

Drug delivery refers to the transporting system of pharmaceutical compound in the body to reach the target point. Initially Dai *et al.* have explored the nanoscale Graphene Oxide (NGO) as a unique and effective nano carrier for transport of water indecipherable musky anticancer drugs into cells . Chen et. al. have also studied the pH-sensitive drug release behaviour from many different GO-based drug delivery systems later. Most recently, Rana et. al. have used the distribution of an anti-inflammatory drug, Ibuprofen, by means of a chitosan-grafted GO

4.2 Water purification

It is a necessary and an efficient property of graphene nano composition, by which water can be purified. There comes a vast research on graphene based nano composition for water purification. The water purifiers used in our daily life are made of graphene based nano composites. Graphene oxide is mainly used in purification of water. Joshi et. al. have demonstrated a new treatment system made by converting naturally occurring graphite into graphene oxide membranes, that allow high water flow at atmospheric pressure, while removing virtually all of the organic matter. The filtration method based on graphene nanocomposite has come close to removal of 99% of natural organic matter from water at low pressure. Varma et. al. have demonstrated the featured of the removal of Ni from water using graphene nano composition and used MnO_2 for removal of nickel. The adsorbent capability of Ni (II) for GNS/S –MnO_2 is 1.5 times higher than other composite of MnO_2. en et all used Mg-Al layered double hydroxides and graphene LDH/GO nanocomposites are expected to have potential as adsorbent for AS(V) in polluted water. Jung et. al. have removed Escheria using graphene oxide nano composite membrane. Zeng et. al. have fabricated an bacterial filter using silver /reduced graphene oxide for water dysfunction. E.coli in water was found 36.4 when treated with Ag/Rgo and the inactivation rate was found as 94.5%. Kumar et al. have reported that graphene oxide $MnFeO_4$ magnetic hybrids removed lead and arsenic from water induced GoNH of np and removed 100% pbII AND 99.5% AS(V) and ASIII 96.48% from water .Jiahua et. al. have removed arsenic from water through magnetic graphene nano platelet composite, and found higher adsorption capacity (11.34 mg /g) than other adsorption values.

4.3 Supercapacitor

Supercapacitors based on polymer/graphene nanocomposite may fetch new design prospects of the device configuration for energy storage in the future wearable electronic area. Supercapacitor is an electrochemical capacitor, that stores energy through ion surface absorption, with possible fast reversible Faradic reactions. Such devices provide much energy density than other conventional solid-state devices and batteries. Wang et.al have constructed an asymmetric electrochemical super capacitor with graphene–nickel cobaltite nanocomposite as a positive electrode and commercial activated carbon as a negative electrode, each having a mass of 10 $mg{\cdot}cm^{-2}$. The GNCC positive electrode shows significantly higher capacitance (618 $F{\cdot}g^{-1}$) than graphene–Co_3O_4 (340 $F{\cdot}g^{-1}$) and graphene–NiO (375 $F{\cdot}g^{-1}$) nanocomposites. This was due to the no. of faradic reactions on the nickel cobaltite. Mostly, graphene increases the conductivity of nickel cobaltite and allows the positive electrode to charge/discharge at the rate of commercial AC negative electrodes. Chen et.al have used graphene oxide-MnO_2 nano composite for super capacitors. They have found that integration of graphene oxide and needle like MnO_2 crystals enables composites to possess good electrochemical behaviour that are good electrode material for super capacitors. The electric stability of CMG and nanotube is in the range of 0-1 V AT 200Ma g^{-1} in 1 $Na_2\,So_4$ solution . Guangyu et. al. have prepared hydrothermal Co_3O_4-graphene nano composite for supercapacitor with enhanced capacitive performance and found high performance capacitance of 415 F/g with large current density of 3 A/g in 6M KOH electrolyte, which is most valuable for super capacitance. Guang et.al have also designed a Co_3O_4-graphene based super capacitor with ultra-high energy.

Li et. al. have synthesized graphene /SnO_2 nanocomposites for application in electro chemical super capacitors. The electrical impedance spectroscopy of graphene /SnO_2 have presented a phase angle close to $\pi/2$ at low frequency which indicates a good capacitive behaviour. Wang et. al. have doped graphene oxide with polyaniline for super capacitors and obtained specific capacitance of 531 F/g in potential range from 0-0.54 V. Wang et. al. have used CeO_2 nanoparticles for graphene nanocomposite for high performance super capacitors. This nano-composite have high specific capacitance and power density, with value of specific capacitance as 208 F/g and maximum power density of 18 kg kwatt. Wang et.al have synthesized Fe_2O_3 and graphene nano-composite for supercapacitors with specific capacitance of 226 F/g at current density of 1 A/cm^2. Wang et.al have fabricated CoS_2-graphene nano-composite by solvothermal synthesis for high performance capacitors. The CoS_2 graphene have exhibited specific capacitance of 314 F/g in aqueous electrolyte and 141 F/g in the organic electrolyte at the current rate of 0.5 A/cm^2.

4.4 Fuel cell

Fuel cell is a cell, which transforms chemical energy into electrical energy with help of proton exchange. Graphene based nanocomposite with earlier used material have improved efficiency of fuel cell remarkably, high surface area, conductivity and thermal stability may be a reason for this improvement. Seger et. al have studied electrocatalytically vigorous Graphene-Platinum nanocomposite. The electrochemical agent enactment as assessed from the hydrogen fuel cell exhibits the part of graphene as an effective provision substantial in the growth of an electro catalyst the incompletely abridged graphene. GO-pt based fuel cell have advanced a thorough going power of 161mw/cm^2 compared to 96mw/cm^2 for an unsubstantiated pt centred fuel cell. Yakun et.al. have depicted that in anhydrous condition the proton is exchanged through the polydopmine modified graphene oxide. They have found that the conductivity of proton results in the membranes of nanocomposites consuming high cell enactments under 120 ºC and hydrous conditions, acquiescent a 47% upsurge in all-out current density and a 38% upsurge in all-out power density. With these constant conduction feature, a promising extraordinary performance of fuel cell in the anhydrous GO have depicted similar function in enriching the extreme current density (608.9 mA./cm^2) and power density (156.0 mW/cm^2). Qiu et. al. have reported that the deposition of Platinum nanoparticles on Graphene act as an electrocatalyst for direct methanol fuel cells electrochemical readings disclose that the Pt/graphene nanocomposites with electrochemically active surface area of 141.6 m^2/g show outstanding electro catalytic activity toward methanol oxidation and for the oxygen reduction.

4.5 Anti-corrosion

Anticorrosion refer to protection of material from highly reactive chemical environment. The corrosion degrades the basic properties of material. Generally inorganic material have been used for anticorrosion coating for metal, which are hazardous to environment. Due to its unique properties such as high surface area, inert to many chemicals, high thermal stability etc, graphene has proved itself as anticorrosive material. Yu et. al. have found the excellent anti corrosive properties of polystyrene/graphene-based nanocomposites, with top notch hostile to erosion character. The prepared nanocomposite show predominant character. Hostile to erosion properties contrasted and unadulterated PS, in which the consumption security efficiency has expanded from 37.90% to 99.53% with the mixing of 2 wt% altered GO in the PS polymer framework. Chang et.al contemplated that synergistic impacts of hydrophobicity and gas hindrance properties on the anticorrosion property of PMMA nanocomposite coatings inserted with graphene Nano sheets. They found that there are two conceivable outcomes for insurance of consumption. the hydrophobicity repulsed the dampness and further decreased the water/destructive media adsorption on the epoxy surface, keeping the hidden metals from consumption assault, as prove by conta of HPGN, as confirm utilizing a gas penetrability analyzer (GPA). Yjafari et.al discovered Polyaniline/Graphene nanocomposite coatings on copper for hostile to consumption process when copper is secured with polyaniline it progresses toward becoming deformity free with 97 %. Jabar et.al have electrochemical testimony of nickel graphene composite coatings for anticorrosion obstruction and found that there are refined grain sizes, high miniaturized scale hardness and better erosion opposition execution. Aneja et.al have found that graphene based anticorrosive coatings for Cr (VI) substitution. Graphene, created by high shear fluid peeling course, upon functionalization, gives a conductive and close impermeable obstruction covering edge (wettability) estimations and another by the well-scattered GNSs inserted in the HPGN network could block erosion because of their generally higher angle proportion than mud platelets, which further viably improve the oxygen obstruction property.

4.6 Sensing

Graphene nanocomposites have promising applications as gas sensors. temperature sensors, vapor sensors etc. Zhang et.al have fabricated low temperature sensor by SnO_2 nanoparticles-reduced graphene oxide nanocomposites for NO_2 sensing with rapid response, good selectivity and reproducibility. They have found that introduce of SnO_2 into rGO matrix have significant improved sensing performance for graphene-based sensing materials At low temperature, the response time was found 4.3 s and the recovery time as 177 s, the remarkable sensing properties were found due to heterojunction formation in tin oxide and reduced graphene oxide interface.. Liu et.al. have worked on the organic vapour sensing behaviours of polyurethane-graphene nanocomposites and found high response for cyclohexane, tetra chloromethane, ethyl acetate and acetone. The sensor has fast response, good discrimination ability and reproducibility. Reduced graphene oxide PMMA has used for glucose sensing by Luo et.al. Xu et.al have utilized cuprous oxide–reduced graphene oxide nanocomposites as electrochemical sensor for hydrogen peroxide sensing and found a more extensive straight range (0.03– 12.8 mM), higher affectability (19.5 A/mM).

4.7 Electromagnetic (EMI) shielding

EMI shielding is reduction of electromagnetic field in any vicinity. The shielding may be dominated by reflection or absorption of electromagnetic waves. Graphene can enhance the conductivity of nanocomposite, that can be used for EMI shielding. Gupta el. Al. have used CNT-graphene and polyaniline nano composite as EMI shielding material. The maximum value of EMI shielding has found to be 98 dB. The high value of this shielding was due to high space charge. A highly efficient and light weight shielding material has developed by Wen et. al. using rGO and SiO_2 nano-powder. This material has demonstrated a maximum shielding of 38 %, when GO was 20 % by weight. The shielding has been found due to reflection domination as conductivity of material has been increased. High conductivity due to mobile charge and magnetic dipole combinedly can improve EMI shielding properties remarkably. Singh et. al. have developed a highly efficient EMI shielding material with the help of graphene and iron oxide incorporated polyaniline. The efficient shielding has been found due to dipole interaction due to solid state charge transfer between graphene and polyaniline. A composite with graphene incorporated in epoxy matrix has been used for EMI shielding in microwave X band and shielding efficiency of 21 % has been founded by Ling et. al. Graphene based nanocomposite are appearing as emerging material for EMI shielding application.

Conclusion

In conclusion, synthesis of graphene, its nanocomposites and applications of these nanocomposites in different field e.g. sensing, EMI shielding etc has been presented. Graphene based Nano composites have revolutionised whole world with emerging applications. Due to easy production, device fabrication, graphene-based composites are to replace old technology in many fields. Graphene-based nanocomposites have proved promising materials to encounter the up-and-coming burdens rising from scientific and technologic advances. It is evident that devouring graphene-based nanocomposites in any of these advancements, is an inventive endeavour, determining that future research endeavours will be rich. Presently, this review depicts that graphene based nano-composites have a wide future in the examination.

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