International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 4

A Review: Graphene A Key Material in Engineering and Medical Field

Vaibhav Kodag, Ajay Adsule, Kishor Kamble
P.G Student, Department of Environmental Science and Technology,
Department of Technology, Shivaji University, Kolhapur, Maharashtra, India

ABSTRACT

Graphene is found to be a versatile material having its applications near about in every field. The Paper gives an insight about the different properties of graphene and its uses in various aspects of research. The fields of particularly engineering and medical are discussed in the paper. The review has found that graphene has a good electrical, desalination, Bio medical, mechanical, thermal, optical properties. Also the it is found that doping of graphene or its derivatives like Graphene oxide (GO) on semi-conductor materials improved superconductive property, enhanced capacitance values, Power conversion efficiency (PCE) in case of schottky diodes. Results also describes that graphene has good performance for water desalination with 100% salt rejection for defect ratio of < 0.5 (i.e for small pore size) along with many factors governing the salt rejection which is discussed in the paper. Removal of radioactive materials by graphene oxide has been studied and found to absorb up to certain limits. Graphene is also a better biomedical tool against bacterias, cancer cells and it could be used for drug delivery, bio sensing, bio imaging and in many more fields.

Keywords: *Graphene, graphene oxide, desalination, biomedical, electrical*

INTRODUCTION

Graphene is aNano material consisting of carbon as basic element which has two dimensional orientation with a hexagonal pattern of atomic bonds.. It is the basic structural element of other allotropes, including graphite, charcoal, carbon nanotubes and fullerenes. It is found to be an indeterminate large aromatic molecule, which lies under the class of flat polycyclic aromatic hydrocarbons. It is a single atomic layer of graphite which are tightly bonded carbon atoms in hexagonal lattice. Graphene has properties such as electronic, mechanical, thermal, optical, biomedical, Purifying etc. These properties makes graphene a versatile material for its use in various fields. In this paper we discuss about graphene and its composites for engineering and medical sectors.

True lines stating that "By 2030 nearly half the global population could be facing water scarcity, with demand outstripping supply by 40 percent", said United Nations Secretary General Ban Ki-Moon. Over 97% of the water on the Earth is saline water, and two thirds of remaining 3%, is frozen It seems that in the near future, desalination of seawater will be the only way to provide fresh water[3]. Large population still are facing problems of receiving potable drinking water and it's the duty of us a technocrats to fulfil the desire of providing pure water to everyone. Graphene has been found to be an effective material in water purification.

Considering the power sector, the energy requirements are increasing day by day and minimization of losses is must or we face energy crisis. As it is said that "Necessity is the mother of invention" .In order to cater the problems of controlling energy losses and increasing the efficiency we need to alter the power system contents. The recent electric components are becoming obsolete and maintenance increases the cost so there is necessity of trying and using new energy efficient materials like graphene and its derivatives in solar cells, semiconductors diodes etc. Also in infrastructure sector we have a scarcity of innovations along with electrical and environmental programmes. So one material satisfying the requirements of all fields by utilizing its various properties will be discussed.

Entanglement regarding to infectious diseases have vitally reduced because of the availability and utilization of a long range variety of antibiotics and antimicrobial agents. However, excessive use of antibiotics and antimicrobial agents over years has increased the number of drug resistant pathogens. Bacterial versatile drug resistance exhibit an intense risks and consequently research attention has again concentrated on finding options for antimicrobial treatment [9]. Hence here also it becomes necessary to tackle these problems by a suitable cost efficient method available.

LITERATURE REVIEW

Lu Huang et.al. (2018) has stated that Graphene oxide membranes with excellent properties possess potential applications in numerous fields. Due to the confinement of Nano capillaries within graphene oxide membranes and the mobility difference of ions, an electricity generation process has been achieved using graphene oxide membranes. In this study, for the first time, the influence of source concentration, applied pressure and membrane thickness was investigated on electricity generation in aqueous environment. The results revealed that these three factors could successfully control the electricity generation with graphene oxide membranes. Electrical potential difference would become larger with increasing the source concentration and membrane thickness. Applying thicker GO films and highly-concentrated source solutions could efficiently increase voltage generated, which has a significant engineering application.

Anand P Tiwari et.al.(2017) studied and found that Theory predicts that doping the surface of the graphene effectively alters the electronic structure, thus promoting propensity towards Cooper pair instability. Here they report the upcoming of superconductivity at 7.4 K in Li-intercalated few-layer-graphene (FLG). The Superconductivity vanishes in lithium combined graphite and the double dimensioned graphene layer which shows new properties of electronic phenomenon have led to superconductivity in Li-FLG. Also reported the superconductivity at 7.4 K for the Li-FLG, which is the highest Tc among the intercalant FLG compounds. The discovery not only confirms the theoretical prediction that the two-dimensional graphene-based superconductivity is very different from the bulk graphite based counterpart, but also is expected to expedite further research on superconductivity in low-dimensional materials, particularly aiding in the ability to achieve higher *Tcs*through the manipulating layer thickness and the adsorption process: 17~18 K of Tc is theoretically predicted in the graphene-based Li2C6 compound.

SinaSafaei et.al.(2017) studied the work and found that as per the researches, Graphene oxide membranes gave best desalination properties because of cost efficient, No sophisticated processes etc.In their experiments they came to know from their simulation results that the oxygen atoms in hydroxyl and epoxide groups play an important role in rejection of the Cl ions and attraction of the Na ions. The hydroxyl groups have the most impact on disordering of the water molecules between GO membranes. It has come to researchers notice that antifouling property of the GO membranes can be seen clearly, even in higher salinities compare to seawater. Therefore, according to our results and previous studies, GO membranes exhibit much better desalination performance in compare to commercial RO membranes such as high water permeability and excellent resistance to fouling.

ShahinHomaeigohar et.al (2017) has explained that graphene and its composite offer extraordinarily high surface area, mechanical durability, atomic thickness, nanosized pores and reactivity toward polar and non-polar water pollutants. These properties give enhanced selectivity and water permeability, and hence shows better water purification.Graphene membrane could be coupled with R.O for sea water desalination.

Bernard Cornali et.al. (2017)stated that when compared to currently used filters. The graphene and its derivate filtersmedia are able to filter out salt efficiently in a way that permits for quick water flow. Other research supports that graphene oxide coatings can increase the water permeability of filters up to 86% [9] further increasing the viability of graphene as a filtration substrate. A single layer of graphene itself, not just the oxide, has also been shown to be effective in filtering sodium chloride (common salt)The increased efficiency of graphene sieves over more traditional filters allows for less energy to be used in the process of desalination and the increased resistance to degradation allows for less frequent filter replacement.

SardarKashif Ur Rehman et.al.(2017) studied and found that the Graphene nano platelets GNP cement based composite showed 30% increase in load carrying capacity and 73% increase in overall failure strain. Piezo-resistive characteristics of GNP were employed to evaluate the self-sensing composite material. The results showed that GNP cement composite are able to find deterioration in concrete when the resistivity was declined by 42% at highest compressive load. Finally, the practical application of this composite material was evaluated by testing full length reinforced concrete beam. The results revealed about graphene cement mix could halsen crack response against crack orientation.

J. Chapman et.al. (2016) stated thatreport superconductivity in calcium-decorated graphene achieved by intercalation of graphene laminates that consist of well separated and electronically decoupled graphene crystals. In alterations to added graphite, researchers came to know that Ca when added to graphenesuccessfully lead superconductivity in graphene plates above 1.8 K among other elements utilized in experiments like potassium, cesium and lithium. Ca-containing graphene becomes superconducting at approx.6 K and the transition temperature is found to be strongly dependent on the confinement of the Ca layer and the induced charge carrier concentration.

Muniyappan Rajiv Gandhi et.al. (2016) explained that graphene nanocomposites have found to show very promising applications in all types of water purification. The present review highlights the recent developments in the applications of graphene and graphene-based composites as adsorbent, catalyst, photo catalyst, electro catalyst, photoelectrocatalyst, and disinfection and desalination agent in comprehensive water purification systems. The graphene composites degraded various types of organic pollutants with sun light, and the electro photolysis-assisted technique showed great potential and can be applied to industrial water treatment. Also effective in sea water desalination.

Yi You et.al. (2016) stated by controlling the pore size of GO membranes may prove to be low cost of manufacturing as it gives 100% salt removal for on site applications. With respect to Nano porous graphene, stacking of graphene oxide membranes have been provedto exhibit greater in the following aspects. The nano channels are the space between two layers of graphene, unlike the synthetically prepared holes in graphene and its derivatives like GO depend on twisted paths in the interlimkednano channels that provide water passage.

Sabine Szunerits et.al. (2016) stated that Graphene, dual dimensioned ultra-thin nanomaterial, exhibiting best biocompatibility, placing it at first for various applications in biosensing, drug delivery, biomedical device development, diagnostics and therapeutics. Graphene-based nanostructures also hold great promise for combating microbial infections. While graphene based materials may be beneficial for wound healing and dental care etc.

Sumedh P. Surwade et.al.(2015) explained that atomic-sized pores are introduced into mono layer graphene using a suitable oxygen plasma etching process that allows adjusting of the pore size. The So formed graphene membrane has increased salt removing capacity and quick water passage, thus performing in best salt removal membrane. Salt rejection selectivity of nearly 100% and exceptionally high water fluxes exceeding 105 g m-2 s-1 at 40 °C were measured using saturated water vapor as a driving force.

Xiaoqiang Li et.al. (2015) revealed in their work that silicon is at lower level to GaAs for solar cell because the energy level difference of 1.42 eV prevails and electron motion are recorded to be about six times more with respect to silicon.. graphene/GaAs solar cells with conversion efficiency (Eta) of 10.4%and 15.5% without and with anti-reflection layer on graphene, respectively. The Eta of 15.5%is higher than the state of art efficiency for graphene/Si system (14.5%). Later, our calculation points out Eta of 25.8% can be reached by reasonably optimizing the open circuit voltage, junction ideality factor, resistance of graphene and metal/graphene contact. It is also found in study that higher conversion efficiency can be expected when the doping concentration of GaAs substrate is optimized. It is noteworthy that the bonds between graphene and

GaAs are vander Waals forcesand thus the formed Schottky diode is different from the bulk ones and work demonstrates that graphene/GaAs Schottky diode is a very promising structure for high efficient and practical useful graphene solar cells.

Tae-Hyung Kim et.al. (2015) discussed that Graphene based composites namely like GO, graphene-based scaffolds, pure graphene hydrogels, and graphene hybrid nanoparticles, were known to be best in accelerating and guiding stem cell differentiation, controlling their growth and direction within 2D/3D environments, and were shown to be useful in monitoring stem cell differentiation in an easy, precise, and non-destructive manner. various studies investigating the in vivo biocompatibility of graphene and GO, which turned out to be safer than most other types of nanomaterials.

Jianliang He et.al. (2015) revealed in their study that GO nanosheets were highly effective in inhibiting the growth of dental pathogens. Transmission electron microscopy (TEM) images showed that the cell wall and membrane of bacteria lost their unity and the contents in the cell fell out after they were treated by GO. Therefore, Graphene and its derivatives are seen to be best against the bacteria's, dental pathogens hence looking at this property they have found a place of implementation in treatments.

T. Naveen Kumar (2014) stated that Comparing to silicon solar cells , graphene solar cells are more efficient and provides double the power output in less time. Checking out the difference for the selection of elements between silicon and graphene, graphene leads with respect to properties like electrical conductivity, thermal conductivity, material strength and flexibility. The main difference is its inexpensiveness.

Joshua Paul Conklin (2014) stated that graphene and its derivative components are good adsorbents and are capable of removing the radioactive material from any liquids and test showed that their performance is better than that of bentonite clay and activated carbon in eliminating actinide from radioactive wastes water. The GO-containing radionuclide could be easily coagulated and precipitated. The simplicity of industrial scale-up of GO, its high sorption capacity and its ability to coagulate with cations makes it a promising new material for responsible radionuclide containment and removal.

AhmadrezaSedaghat(2014) described that numerous times it has been seen to check the alterations in thermal and micro structural Graphene added Portland cement..At different stages of graphene and cement ratios the diffusivity of heat and electric current conduction were recorded.The graphene added cements density was checked by mass volume method. Particle size distribution of Portland cement was measured by using a laser scattering particle size analyser. TAMAIR isothermal conduction calorimeter was used for checking of heat hydrated by Portland cement..Minute atomic structural particles were studied using Scanning electron microscopy of water containing graphene mixed cement. The mineral content of graphene mixed cement was investigated by X ray diffraction. The result findings depicted that addition of graphene improves the thermal properties of the hydrated cement showing a potential for decreasing of early age thermal cracking and durability improvement of the concrete structures.

SOFIA SIDERI (2014) stated that feasibility of implementing graphene into the cement matrix for improving its compressive and tensile or flexural strength. In addition, graphene coating was also investigated for protecting reinforcement steel bars in concrete from corrosion.The utilization of graphene along with steel and cement could improve their properties of durability, strength and increase their life span.

Sudesh et.al. (2013) stated that about the effect of graphene oxide (GO) doping on the structural and superconducting properties of MgB2. In the present work, we have studied the effect of GO doping on the superconducting properties of the MgB2 compound.The superconducting critical current density is significantly improved with GO doping into the sample over the entire magnetic field range (0–8 T) without affecting the transition temperature up to a doping level of 3 wt%.

David Cohen-Tanugi et.al. (2013) revealed in their research that graphene, a single-layer sheet of carbon with remarkable mechanical and electronic properties, can be patterned with nanometer-sized pores, to act as an ultra-thin filtration membrane. The results clearly show that revising the design for salt removal membrane could obtain important noteworthy developments to the recently prevailing techniques.

DimitriosBitounis et.al. (2013) discussed that the existing improvements with graphene-derived materials in the medical sector and the problems coming with these innovative equipments relative to toxicology and biological profiling in vivo and in vitro terms of biological activity and toxicological profi ling in vitro and in vivo. Graphene materials today have mainly been explored as components of biosensors and for construction of matrices in tissue engineering.

Shannon M. Notley et.al. (2013) stated in their paper that graphene has a potential of tackling bacteria's by destroying the cell wall as the graphene and its derived composites have atomic thickness of 0.3 nm.

Xiaochang Miao et.al. (2012) stated that single layer graphene/n-Si Schottky junction solar
cells that under AM1.5 illumination exhibit a power conversion efficiency (PCE) of 8.6%. The evidences provided after doping graphene with bis (trifluoromethane sulfonyl amide) enhances the values as compared to non-doped device by 4.5 which said to be the topmost PCE for graphene combined solar cell.

Zihan Xu et.al (2012) described that The energy of ionic thermal motion presents universally, which is as high as 4 kJ·kg-1·K-1 in aqueous solution, where thermal velocity of ions is in the order of hundreds of meters per second at room temperature1,2. Moreover, the thermal velocity of ions can be maintained by the external environment, which means it is limitless. However, little study has been reported on converting the ionic thermal energy into Electric current. As the equipment was immersed in $CuCl_2$ solution the resulting voltage was found to be of 0.35 V which prevailed up to 20 days.

David Cohen-Tanugi (2012) studied that by monitoring the salt filtration successfully from water using mono layer graphene. Taking the help of conventional molecular dynamics, researchers reported that pore size, subjected pressure and functional groups are governing factors for salt water filtration of membranes. Our results indicate that the membrane's ability to prevent the salt passage depends critically on pore diameter, with pores in the 0.7-0.9 nm range allowing for water flow while blocking ions. Experimentations reveal that functional groups like OH, epoxy etc. on surfaces of graphene increase the water flux.

Soujit Sen Gupta et.al.(2012) et.al. stated that a green method for the synthesis of graphene material from cane sugar, a common disaccharide. A methodology was adopted to halt the material on sand without any additional support which formed graphene sand composite. The mechanical adsorption shows strong part when tested by spectroscopic ,microscopic along with normal adsorption process. Isotherm data in batch experiments show an adsorption capacity of 55 mg/g for R6G and 48 mg/g for CP, which are superior to that of activated carbon. The utilization of this material for water purification is evident from the data presented

He Shen et.al. (2012) explained about an overview of current advances in applications of graphene in biomedicine with focus on drug delivery, cancer therapy and biological imaging. The research shows that in biomedical field Graphene and its derivative components are capable to enhance development, show distinction and reproduction of stem cells and hence has found applications in clinical fields.

Manu S. Mannoor et.al. (2012) described that due to its minute structure it is capable to easily find analyte structure. In this study researchers show that graphene is easily impregnated on ink which vanishes in water. This in turn permits intimate bio transfer of graphene Nano sensors onto biomaterials, including tooth enamel. The output is totallybio interfaced sensing platform, which could be adjusted to search target analytes. The work shows that whole tooth was selected for remote monitoring of respiration and finding and distinguishing saliva bacteria'sOverall, this strategy of interfacing graphene Nano sensors with biomaterials represents a versatile approach for ubiquitous detection of biochemical targets.

Wenbing Hu et.al. (2010) stated that graphene-based nanomaterials can effectively inhibit the growth of *E. coli* bacteria while showing minimal cytotoxicity. We have also demonstrated that macroscopic freestanding GO and rGO paper can be conveniently fabricated from their suspension via simple vacuum filtration. GO has found to be a better against bacteria's and can be produced in bulk and processed for preparing a paper with flexible property and researches wish that the material performs well in future biomedical applications.

DISCUSSION

Engineering Field

Electronic Sector

From the thorough study of all above papers it was found that engineering part graphene and its other derivatives like graphene oxide (GO), graphene laminates, graphene Nano sheets etc. perform very effectively. Findings state that GO doping in semi conducting materials provides suitable increase in capacitance values as compared to using individual pure element. (For example a research said that hydrous ruthenium oxide/graphene composite exhibit high capacitance than pure ruthenium oxide and graphene). In Li based batteries as graphene has high surface area, its electrode has high specific capacities, graphene is used as anode in li batteries because of enhanced coulombic efficiency. For applications in solar cell the doping in schottky diode is found to give better results. Schottky diode of graphene and GaAs gave 25.8% conversion efficiency compared to Graphene and n-si with 1.5 to 8.6% conversion efficiency. Doping also efficient in superconductivity from the potassium, calcium, caesium, lithium it was seen that ca decorated graphene became superconducting at transition temperature range of 1.8 K to 6K which was highest among other elements. Also MgB_2, Mn_3O_4 gave good performance in combination with graphene.

Graphene can be used in thermos electric instruments like thermoelectric generators, thermos piles, thermoelectric coolers etc. Also it was found that the Chemical vapour deposition (CVD) of developing graphene film is most efficient method for experimental and practical applications.Graphene could be used in Energy storage devices, Integrated Circuits, Solar cells, Optical electronics.

Environmental Sector

The findings revealed that graphene and its derivatives (GO, Nano sheets of graphene) has a best salt rejection property. The salt rejection depends on the following parameters:

a. Pore size
b. Size of Electrical Double Layer
c. Concentration of solution to be filtered
d. Defect density (I_D/I_G) (I_D/I_G if <0.5 then good salt rejection is achieved) where I_D= Intensity of D band and I_G= Intensity of G band in Raman spectra
e. Presence of Hydrophilic functional group (OH, Carboxyl, epoxy) on graphene surface.

GO when immersed in water it swells & pore size gets affected hence using confining wall pore size could be controlled. Graphene are found to be good performers than RO membranes as RO is linked with problems such as fouling of membrane, low flux rate, poor chemical resistance whereas Graphene has anti fouling properties, chemical resistance. They could be used in combination with RO to achieve good results.

Graphene has also found to filter out radioactive materials as it coagulates with cations and removes radionuclide. As it has high surface area which is better for adsorption of radioactive particles in water. Adsorption capacity of graphene is more than Activated carbon. Graphene Oxide membranes are impermeable to gases hence also be used in gas separations. Also graphene could assist in purification of biofuels. Graphene shows applications in all type of water and gas purification

Civil Sector

It was revealed in the study that graphene when mixed with cement for plaster gave a good bonding and an increase in tensile strength, load carrying capacity, Yield stress, plastic viscosity. Also increase in thermal properties of hydrated cement indicating a potential for reduction in early age thermal cracking and gives good response against crack propogation. Graphene also has anti corrosion properties. It has oxidation suppression properties also as it is impermeable to gases.

Piezo resistive characteristics were employed which found that max. compressive load, electrical resistivity value reduced 42% & GNP (graphene Nano platelets) and cement mixture could detect damage in concrete.

Medical Field

It is found that Graphene based nano materials could easily inhibit the growth E.coli bacteria. It is good against microbial infections and dental pathogens. The Graphene oxide destroys the cell wall of gram positive and gram negative bacteria's.

New research also reveals that the vertical orientation of flakes formed by Chemical vapour deposition technique of graphene acts as knives and rupture the bacterial cell wall.

In Medical applications graphene and its derivatives could be used in stem cell growth, stem cell delivery, bio sensing, drug delivery, cancer Therapy, bio imaging, GO scaffold for cell culture etc. Graphene has only being studied for E.coli , P. aeruginosa and needs to be studied for other bacteria's.

Graphene nano sensors with bio material such as tooth enamel has enabled battery free sensors for remote monitoring of pathogenic bacteria.

But graphene has found to be somewhat harmful to human body ,when inhaled it shows inflamations on tissue surface, pulmonary oedema, granulomatous lesions, cancer.

CONCLUSION

The study has concluded that graphene and its derivatives have proved to be a best material for its wide range of applications. Graphene is cost efficient material and producing the components like Graphene Oxide, Nano sheets of graphene is simple and scalable. Graphene is an emerging material and needs more research for upgrading it in technologies. It is found from the study that graphene has an immense potential in engineering and medical sectors. As there are two sides of coins graphene has some disadvantages ,graphene has found to be harmful in certain aspects for human health and hence measures need to be developed to avoid those effects. In short overlooking certain facts The review paper suggests that Graphene is good superconductor, capacitance when doped. It is good desalination component, radioactive material purifier, good composite with cement concrete for civil engineering applications, Medical applications and needs to be further studied for its applications in Military ,Biotechnology, Instrumentation sector, Automobile sector etc. and we are optimistic that graphene will perform well in these sectors too.

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