EFFECT OF ALUMINIUM METAL MATRIX COMPOSITE REINFORCED WITH GRAPHENE

S.SANTHOSH KUMAR.[1], N. NATARAJAN.[2], S. DHAYANEETHI.[3]
1Assitant. Professor, Department of Mechanical Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India1
2 Professor & Head, Department of Mechanical Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India1
3Assitant. Professor, Department of Mechanical Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India1
****1Corresponding author: Mobile: 7402600117, Email: s.santhoshkumar@skct.edu.in***

Abstract: Graphene is a form of carbon that is of planar sheets and one atom thick, its atoms is arranged in a honey comb structure. Graphene has recently attracted significant academic and industrial interest because of its excellent performance in mechanical, electrical and thermal applications. Graphene can significantly improve physical properties of metals extremely when incorporated appropriately. Graphene has remarkable mechanical properties, which makes it suppositional a good reinforcement in metal composites. Due to its ability and superior mechanical properties, which make it remarkable filler for producing multifunctional metal matrix composites (MMC), Ceramic matrix composites (CMC) and Polymer matrix composites (PMC). It also has high thermal and optical properties which will also be useful in MMC, CMC and PMC. For the past few years diminutive attention has been given on graphene reinforced metal matrix composite (GRMMC) and also towards GRCMC and GRPMC's. In this present review article it gives a wide-range of overview on the state of dispersal of graphene in composites, including materials already synthesized and characterized.

Keywords: About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

Graphene is a new and an exciting material composed of carbon atoms densely packed in a honeycomb crystal lattice and is one atomic layer thick sheet of carbon or film of carbon atoms. Having received significant attention in recent years, due to its excellent properties like high current density, good electrical conductivity, large theoretical specific surface area, chemical inertness, optical transmittance, high thermal conductivity and super hydrophobicity at nanometre scale. Graphene is characterized as the thinnest material in our universe, explored a wide range of applications in various industries such as photovoltaic cells, capacitors, sensors, transparent conductive electrodes and new nanocomposites. Graphene nanoplatelets (GNPs) consist of small stacks of graphene that can replace carbon nanotubes because it possesses all the properties compared to CNTs. The main advantages of using graphene over CNTs are a higher specific surface area and fewer tendencies to twist, which makes it easier to disperse into a matrix, simultaneously improving mechanical properties in terms of strength and stiffness. It is also relatively relaxed to produce, inexpensive and potentially has not much health hazards compared to other allotropes of Carbon. Certain idiosyncratic properties of graphene that makes it unique are: it is about 200 times stronger than the strongest steel, another graphene's stand-out properties are its inherent strength. Due to the strength of its 0.142 Nm-long carbon bonds, graphene is the strongest material ever discovered, with an ultimate tensile strength of

130,000,000,000 Pascal (or 130 giga Pascal). It is often said that a single sheet of graphene (being only 1 atom thick), sufficient in size enough to cover a whole football field, would weigh under 1 single gram. What makes this particularly special is that graphene also contains elastic properties, being able to retain its initial size after strain. Conducts electricity better than silver, and heat better than diamond. A good bonding interfaces between graphene and matrix is observed. The research of graphene including the control of the graphene films on substrates, functionalizing graphene, as reinforcement and exploring the applications of graphene has grown exponentially as shown in Fig. 1. According to Web of Science database, there were 164 papers published in 2004 with the word “graphene” in their titles, abstracts or list of keywords. By 2010, there were 3,671 such articles recorded to the Source Thomson Reuters Web of Knowledge. However with this substantial advantages need to be reinforcing to the material which are especially in application with aeronautical, aerospace and automobile industries. However it’s hard to achieve improved mechanical performances using alloy components modification, deformation and heat treatment processes. Matrix with (C,Al203, SiC, B4C and CNTs) reinforcement’s composites is roughly investigated. Now the biggest challenges is to develop the equivalently graphene dispersion strengthened composite without damaging the intrinsic structures. GNFs/Metal Matrix nanocomposites may be favourable candidate for the next age group nanocomposites. Some of the important mechanical and physical properties of graphene are summarized in table no:1.

Property	Graphene	Ref
Tensile Strength	130 Gpa	20
Elastic modulus	0.5 – 1 Tpa	21
Thermal conductivity	5.3 ×103 Wm-1K-1	19
Co efficient of thermal expansion	-6×10-4/K	21
Specific surface area	2630m^2 g^{-1}	20
Electron mobility	1500 cm^2 V^{-1} s^{-1}	19
Transmittance	>95% for 2nm thick film >70% for 10nm thick film	21

Table 1 Mechanical and Physical Properties of Graphene

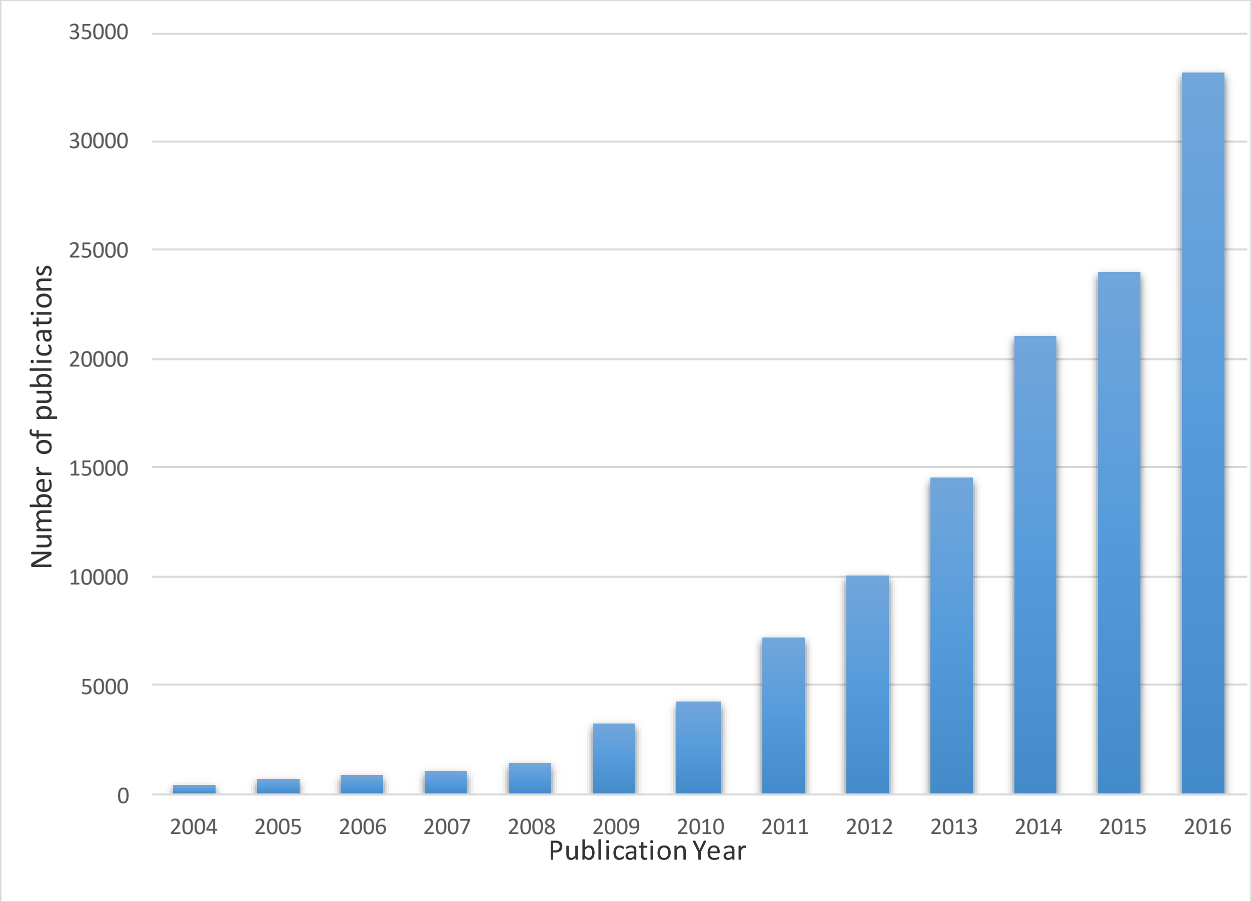

Fig.1 Graphene publication time line in past years

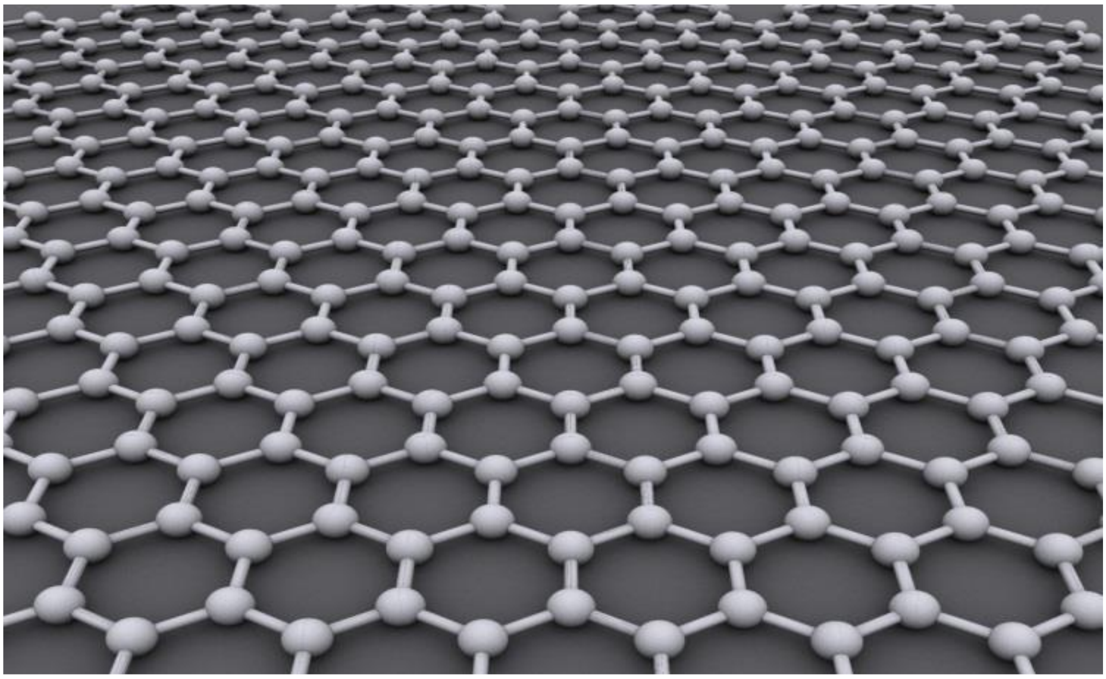

Fig 2. Single Atomic Layer Of Graphene

1. GRAPHENE

Graphene, a singlelayerofsp2-hybridized carbon atoms arranged in a two dimensional (2D) lattice, has attracted tremendous attention in recent years owing to its exceptional thermal, electrical and mechanical properties. Mechanical measurements show that a perfect single-layer graphene exhibits a Young's modulus of 1.0TPa and fracture strength of 130GPa. The explanation of graphene covers all forms of graphitic material from 100 nm <thick platelets down to single layer graphene. However, the obtainability of single-or few-layer graphene that has caused the interest. In fact, it is possible to distinguish between flakes of graphene with different numbers of atomic layers in a transmission optical microscope due to its nature of significant optically energetic. The work to determine the number of layers to be used for the reinforcement was formed and found that monolayer has the higher stress transfer than the bilayer graphene and the flakes are sufficiently large(>30 micro meter) and aspect ratio should be high for the effective reinforcement of both bilayer and monolayer graphene in the composite. There has already been considerable effort put into the development of way of preparing high-quality graphene in large quantities for the research purposes and also with the view to possible applications where it is suitable. The very first attempt given to graphene preparation is break the graphite down into graphene by techniques known as a mechanical cleavage or liquid phase exfoliation. The other method chemical vapour deposition (CVD) is also used to synthesize graphene and in recent day thinner forms of graphite nanoplatelets (GNPs) by different techniques known to be acid irradiation of graphite to microwave radiations, ball milling and ultrasonication. Fig.2 shows a molecular model of single atomic layer graphene sheet.

2. METAL MATRIX COMPOSITES – GRAPHENE

Metals and alloys are generally produced and shaped in bulk form but can also be intimately com-bined with another material that serves to improve their performance: The resulting material is a metal matrix composite (MMC). This class of composites encompasses many different materials that can be distinguished according to their base metal (e.g., aluminum, copper, titanium); according to the other, reinforcement, phase (e.g., fibers, particles, whiskers); or according to their manufacturing process (e.g., powder metallurgy, diffusion bonding, infiltration, stir casting).

There are number of motives to develop graphene-metal composites. The strengthening mechanism of graphene reinforcement is thought to be related to the excellent mechanical and the unique structured characteristics of graphene, and good bonding interfaces between graphene and matrix. There are many challenges involved to get graphene dispersed metal matrix composite with the existing conventional metallurgical process or methods due to huge density difference between GNFs and metal matrix, more interfacial contact area than carbon nanotubes and also reaction at matrix reinforcement interface because metals are much reactive. The work relating to this field is still remaining in their infancy. But the increase of publications in this category signifies that growing an interest towards graphene based metal composites. Both graphene oxide (GO) and graphene nanoplatelets (GNPs) are considered in some of research work. The dispersion of GNFs into matrix were presently took place by Chemical mixing, Mechanical mixing and electrode deposition method. In contrast to monolayer graphene, graphene nanosheets (GNSs) or graphene nanoplatelets formed by several layers of graphene have been also found to possess outstanding mechanical properties [1–2], which make them excellent potential reinforcements in metal matrix composites. To date, a number of studies on GNS composites have been focused on polymer matrix composites [3, 4]. It has been reported that the improvement in the mechanical properties of GNS–polymer composites is much better in comparison to that of other carbon filler-based polymer composites.

With the excellent tensile strength (130Gpa) and toughness (0.5-1TPa) of graphene (Table.1) make it as an efficient reinforcement to strengthen and stiffen the metal.

3. SYNTHESIS OF GRAPHENE OXIDE:

Graphene oxide is synthesised by Modified Hummers method through oxidation of graphite. Graphite flakes (2g) and NaNO3 (2g) are to be mixed in 50 ml of H2SO4 (98%) in a 1000 ml volumetric flask kept in ice bath (0-5°C) with continuous stirring. The mixture has to be stirred for 2 hrs at this temperature. Potassium permanganate (6g) has to be added to the suspension very slowly. The rate of addition should be carefully controlled to keep the reaction temperature lower than 15°C. The ice bath can then be removed, and the mixture to be stirred at 35°C until it became brownish. Further this solution has to be diluted by adding additional 200ml of water with continuous stirring. The solution should be finally treated with 10ml H2O2 to terminate the reaction by appearance of yellow color. For purification, the mixture has to be washed by rinsing and centrifugation with 10% HCl and then with deionized (DI) water several times. After filtration and drying under vacuum at room temperature, GO would be obtained as a powder.

4. SYNTHESIS OF F-Al2O3:

For the f-Al2O3 (functionalized Al2O3), 0.4 g of nano-Al2O3 and 8 g of APTS (3-aminopropyltrimethoxysilane) were added into 200 g of anhydrous ethanol, and the mixture was treated while stirring using a mechanical stirrer at 78℃ for 4h. Then, 16 g of DI (De-ionized) water was added slowly into the solution, followed by filtration, flushed with anhydrous ethanol and DI water several times and dried in a vacuum oven at 60℃ for 24 h to obtain f-Al2O3.

5. SYNTHESIS OF GO-Al2O3 HYBRIDS:

F-Al2O3 (0.1 g) was dispersed in 250 ml DMF to form a homogeneous suspension. GO (0.4 g) was added into the suspension via ultrasonication for 1 h. The reaction mixture was stirred for 5 h at 105℃, and the product obtained was filtered, washed, and dried 24 h at 60℃ in a vacuum oven.

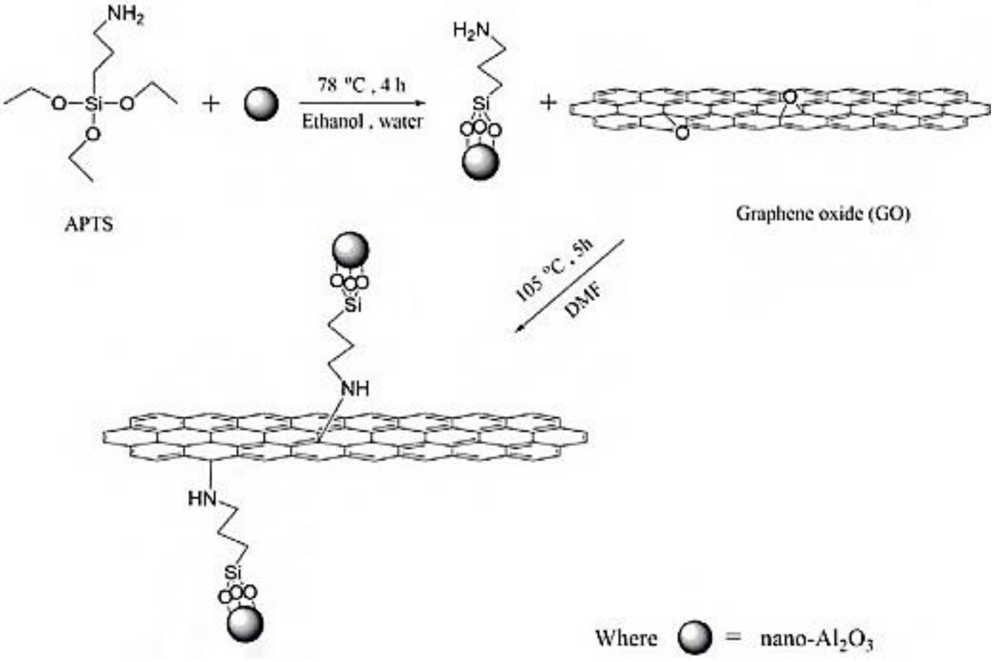

Fig 3 Illustration of the synthesis procedure for GO-Al2O3 hybrids.

6. PREPARATION OF THE GO, NANO-Al2O3 AND GO-Al2O3 COMPOSITE COATINGS:

To prepare the composite coating precursor, the epoxy emulsion was mixed with GO, nano-Al2O3 and GO-Al2O3 hybrids of 2wt% by ultrasonication for 1 h to form a homogeneous dispersion system. Meanwhile, the base metal (P110) was processed into a steel sheet of 1mm×10mm×20 mm, where the effective area of steel was about 4 cm^2. Then, the mixture was sprayed on the surface of the steel after ultrasonic oscillation and mechanical stirring, degassed in a vacuum oven at room temperature for 0.5 h, and cured with the following cycle: 120℃ for 1 h and 220℃ for 2 h. The pure epoxy sample was also prepared under the same curing condition. The dry film thickness of the coatings was required to be measured utilizing screw micrometer and calibrator. And the cured epoxy coatings were named GO/epoxy, nano-Al2O3/epoxy, GO-Al2O3/epoxy, and pure epoxy, respectively.

Fig 4 Schematic of the preparation process for GO-Al2O3/epoxy.

7. APPLICATIONS OF GRAPHENE:

Composition	Properties and applications	Ref
Pt-Graphene	Super capacitor- fuel cell applications Electrochemically active surface area-Catalyst carrier in electrocatalysis and fuel cells applications	[5] [6]
Al/Pd/Pt	Acts as catalytic methanol oxidation-Methanol fuel cell applications	[7]
Au-graphene	DNA gets adsorbed faster than only Au surface Biosensors, Biodevices and DNA Sequencing applications Voltammograms of electrolytic reduction of oxygen and glucose oxidation shows more Au- Graphene than alone Au- Fuel cell and bioelectro analytical chemistry applications Apparent electrode area Environmental monitoring – detection of mercury Electroactive surface area-electrochemical detection of DNA specific sequence applications	[8] [9]
Co-Graphene	Anode material for Li-ion battery applications	[10]
Si-Graphene	Anode material for Li-ion battery applications	[11]
Al powder graphene	Graphene as reinforce -Strengthening of Composite applications Decreased strength and hardness Lower failure strain and higher Vickers hardness	[13] [14] [13]

Mg-Graphene based composite	Production of Ultra high performance metal matrix composite	[15]
Cu-graphene composite foil	Higher the electrical conductivity and hardness compare to copper alone	[16]
Mg-1%A-1%Sn reinforced graphene	Superior Nano-filler adhesion and increased and tensile strength	[17]
Au-Graphene- HRP - CS	H2O2 Biosensor applications	[18]

High-speed electronics:

One of the first proposed real-world applications of graphene is related to the conductivity of graphene being extremely high. One would think that a high conductivity would be ideal for high speed electronics. While this is true, electronic devices consist of semiconductors which exhibit small yet significant band gaps which are required for ‘on and off’ states in an electronic device.

Data storage:

Reducing the size of data storage devices, or increasing the capacity of data storage devices whilst maintaining the size of a (flash-drive scale) piece of hardware is an area which is lesser studied in the graphene world, yet has seen some impressive discoveries. Researchers investigating the storage properties of graphene oxides have shown that indium tin oxide electrodes modified with polymers and graphene oxide exhibit the write-read-erase read-rewrite cycle for a non-volatile memory device.

Supercapacitors:

Energy storage devices are utilized in almost every electronic device as they are responsible for delivering high electric currents over a short space of time. Supercapacitors are energy storage devices which deliver far higher currents than a normal capacitor. Most supercapacitor technologies utilize high internal surface area materials to store charge, and given that graphene exhibits an internal surface area of 2630 m2 g1 it seems an obvious choice. The capacitative storage record was broken by a graphene supercapacitor in 2010 in a report by Liu et al. One example of the need for a supercapacitor is to power electric cars which require high currents for acceleration. Several attempts of producing graphene-based supercapacitors are presented within the scientific ether; readers are referred to Refs. [23–27] for recent examples of attempts to create such technologies.

8. SUMMARY AND CONCLUSIONS:

The following are the conclusions drawn from the applications of graphene:

1. Currently, aerospace engineers are incorporating carbon fibre into the production of aircraft as it is also very strong and light. However, graphene is much stronger whilst being also much lighter. Ultimately it is expected that graphene is utilized (probably integrated into plastics such as epoxy) to create a material that can replace steel in the structure of aircraft, improving fuel efficiency, range and reducing weight. Due to its electrical conductivity, it could even be used to coat aircraft surface material to prevent electrical damage resulting from lightning strikes.
2. The same graphene coating could also be used to measure strain rate, notifying the pilot of any changes in the stress levels that the aircraft wings are under.
3. These characteristics can also help in the development of high strength requirement applications such as body armour for military personnel and vehicles.
4. Graphene can contribute to creating stronger but lighter materials allowing to make larger jets that fit more passengers and run on much less fuel. Rising fuel costs and the risk of emissions

trading schemes have both been targeted as key threats to the aviation market, and graphene proposes to address them both.

5. The rapid development of modern electronics packed with highly integrated circuits generates severe electromagnetic radiation, which leads to harmful effects on highly sensitive precision electronic equipment as well as the living environment for human beings. Great effort has been made for the development of high-performance electromagnetic interference (EMI) shielding materials. In addition to high EMI shielding performance, being lightweight and flexible are two other important technical requirements for effective and practical EMI shielding applications especially in areas of aircraft, aerospace, automobiles.
6. Graphene infused conductive coatings can also de-ice an aircraft quickly and cheaply. Currently, the task of de-icing an aircraft is expensive, difficult and takes a long time, where a team of airport staff have to spray the wings of the plane with a hot liquid, either propylene glycol or ethylene glycol to melt the ice.
7. Although some positive results have been achieved, there still have a lot of unknown influencing issues need to be explore in graphene reinforced metal matrix nanocomposites and the future research will be focused on the optimization of processing parameters to improve the content and dispersion of GNFs in the metal matrix, also sintering and extrusion parameters. However, to date, these technologies are not yet widely available. Such graphene based super capacitors are an exciting prospect as they could contribute to green energy solutions by use in electronic cars, trains and perhaps even one day, aeroplanes. Indeed, supercapacitors are already used in aeroplanes (such as the Airbus A380) but for minor electronic job such as opening fuselage doors.

ACKNOWLEDGEMENT

I would like to thank Dr. A. Ramesh, Principal Sri Krishna College of Technology, and Dr. N. Natarajan, Professor and HOD of mechanical engineering department, Sri Krishna College of technology, Coimbatore Tamil Nadu for their valuable support to publish this paper.

REFERENCES:

[1] H. Chen, M.B. Müller, K.J. Gilmore, G.G. Wallace, D. Li, Adv. Mater. 20 (2008) 3557–3561.

[2] M. Fang, K. Wang, H. Lu, Y. Yang, S. Nutt, J. Mater. Chem. 19 (2009) 7098–7105

[3] S. Stankovich, D.A. Dikin, G.H. Dommett, K.M. Kohlhaas, E.J. Zimney, E.A. Stach, R.D. Piner, S.T. Nguyen, R.S. Ruoff, Nature 442 (2006) 282–286.

[4] H. Kim, A.A. Abdala, C.W. Macosko, Macromolecules 43 (2010) 6515–6530

[5] Samulki, E T 2008. Exfoliated graphene separated by platinum nanoparticle. Chem. Mater.20; 6792-6797

[6] Yueming Li, Longhua Tang, Jinghong Li Preparation and electrochemical performance for methanol oxidation of pt/graphene nanocomposites volume 11. Issue 4, April 2009, pages 846-849.

[7] C Xu, X Wang, J Zhu - The Journal of Physical Chemistry C, 2008 - ACS Publications Graphene−Metal Particle Nanocomposites J. Phys. Chem. C, 2008, 112 (50), pp. 19841–19845.

[8] Song B, Li D, Qi W, Elstner M, Fan C, Fang H. Graphene on Au (111): a highly conductive material with excellent adsorption properties for high-resolution bio/nano detection and identification. Chemphyschem. 2010 Feb 22; 11(3):585-9.

[9] Jingming Gong, Ting Zhou, Dandan Song, Lizhi Zhang Mono dispersed Au nanoparticles decorated graphene as an enhanced sensing platform for ultrasensitive stripping voltammetric detection of mercury(II), Volume 150 ,Issue2, 28 October 2010, Pages 491-49.

[10] Meng Du, Tao Yang and Kui Jiao Immobilization-free direct electrochemical detection for DNA specific sequences based on electrochemically converted gold nanoparticles/graphene composite film J. Mater. Chem, 2010, 20, 9253-9260.

[11] Shubin Yang Dr, Guanglei Cui Dr, Shuping Pang, Qian Cao, Ute Kolb Dr, Xinliang Feng Dr, Joachim Maier and Klaus Mullen Pro, Volume 3, Issue 2, pages 236–239, February 22, 201.

[12] Chou, S, Wang, J, Choucair, M, Liu, HK, Stride, JA & Dou, SX (2010), Enhanced reversible lithium storage in a nanosize silicon/graphene composite, Electrochemistry Communications, 12(2), pp. 303-306.

[13] Ebinezar, Bheemraokamble, Analysis of hardness test for aluminium carbon nanotube metal matrix and graphene, Indian journal of Engineering, volume10, Number 21, April 2, 2014.

[14] Stephen F. Bartoluccia, Joseph Parasa, Mohammad A. Rafieeb, Javad Rafieec, Sabrina Leea, Deepak Kapoora, Nikhil Koratkarc Graphene–aluminum nanocomposites Materials Science and Engineering A 528 (2011) 7933– 7937.

[15] Caterina Soldano, Ather Mahmood, Erik Dujardin CEMES Volume 48, Issue 8, July 2010, Pages 2127–2150.

[16] Chokkakula L. P. Pavithra, Bulusu V. Sarada1, Koteswararao V. Rajulapati, Tata N. Rao1 & G. Sundararajan A New Electrochemical Approach for the Synthesis of Copper-Graphene Nanocomposite Foils with High Hardness scientific reports 4: 4049 DOI: 10.1038/srep04049.

[17] Muhammad Rashada, Fusheng Pan, Muhammad Asif, Aitao Tang, Journal of Industrial and Engineering Chemistry JIEC-1870; No. of Pages 6.

[18] Kangfu Zhou, Yihua Zhu Xiaoling Yang, Jie Luo, Chunzhong Li, Shaorong Luan A novel hydrogen peroxide biosensor based on Au–graphene–HRP–chitosan biocomposites Volume 55, Issue 9 30 March 2010, pages 3055-3060.

[19] Wonbong ChoiIndranil Lahiri Raghunandan Seelaboyina Critical Reviews in Solid State and Material Sciences. 01/2010; 35(1):52-7.

[21] Caterina Soldano, Ather Mahmood, Erik Dujardin CEMES Volume 48, Issue 8, July 2010, Pages 2127–2150.

[22]C. Wei, et al. Nanoscale 5 (2013) 4134.

[23] F. Zhang, et al. Chem. Phys. Lett. 584 (2013) 124.

[24] J. Cao, et al. J. Electroanal. Chem. 689 (2013) 201.

[25] D.A.C. Brownson, et al. J. Power Sources 196 (2011) 4837.

[26] D.A.C. Brownson, C.E. Banks, Chem. Commun. 48 (2012) 1425.

[27] W. Song, et al. Phys. Chem. Chem. Phys. 15 (2013) 4799.