A Brief Review on Graphene-Metal Matrix Nano Composite And Its Applications

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Abstract- *Graphene is a new two-dimensional carbon material showing unique mechanical, transport and thermal properties.The main aim of this paper is to give an overview of research efforts focused on graphene and metal matrixnano composites. Graphene is considered the strongest material in the world. It is an ideal replacement material for metal matrix composites. It has some exceptional properties, excellent mechanical, electric properties, high thermal conductivity, high Young's modulus and high tensile stress. Additionally, graphene is extremely light; the density. In this paper will introduce graphene reinforced metal matrix nano composites. The application of graphene reinforced composites.*

Keywords- Graphene, Metal matrix composites, Mechanical properties.

I. INTRODUCTION

Graphene is a truly remarkable nano-carbon material and has become a subject of an ever growing research interest all over the world due to its unique structure and intriguing mechanical and electronic properties. It consists of a single atomic layer of sp2 hybridized carbon atoms arranged in a honeycomb structure with a carbon-to-carbon inter-atomic length, a C–C, of 0.142. The unit cell comprises of two carbon atoms and is invariant under a rotation of 120 around any carbon atom Aluminum is the most popular matrix for the metal matrix composites and thus aluminum and its alloys are one of the most widely used materials in MMCs as matrix both from research and industrial view-points. Aluminum metal and its alloys are quite attractive due to their low density, high thermal and electrical conductivity, their capability to be strengthened by precipitation, their good corrosion resistance and their high damping capacity[1]. They offer a large variety of mechanical properties depending on the chemical composition of the aluminum matrix. Aerospace and automobile industries require lightweight, high-strength materials. These materials lead to a decrease in fuel consumption and an increase in payload. Most traditional metals and alloys cannot meet these requirements, so the solution is to develop metal matrix composites (MMCs). These materials have been widely used in the aerospace and automobile industries.

Reinforcement materials are critical for MMCs[2-4]. Traditionally, they were ceramic, carbon or other high-stiffness particles, whiskers, short fibres or continuous fibres.
In order to get lightweight, high-strength MMCs, high strength and lightweight reinforcement materials are needed. Among them, carbon materials are outstanding, such as graphite whiskers, carbon fibres, carbon nanotubes (CNTs) and graphene. Recently graphene-based metal composites' research work has been reported, but it still has not received much attention compared to graphene-based polymer composites. This lack of attention could be due to the great difficulties in homogeneous dispersion of graphene in the metal matrix, nano composite fabrication problems and the likely interfacial chemical reactions between graphene and the metal matrix.

It can be found that very few papers were published in the field of graphene-reinforced MMCs. Several review papers on graphene-based materials have been published

Already. But no review work has been done on graphene-reinforced MMCs. Because graphene reinforcedMMCs' research is just at its beginning stage, it is necessary to have a systematic study of the efforts being done on processing, measuring mechanical properties, understanding interfacial reaction and the microstructure of graphene-reinforced MMCs. This review work will give a clear picture of the state of graphene reinforced MMCs by summarizing the work that has been done in this field, thus helping those who will do further research on graphene-reinforced MMCs.

II. PROPERTIESOFGRAPHENE

Industrial graphene are 10-15 layer aggregates of the submicron sheet with a lateral dimensions of 10-15 microns with aspect ratio 1000 more than 98% carbon content along with natural presence of other entities. Greyish black flakes are in the form of powder and seek unlimited application.

Optimally, when industrial grade graphene mixes in minute quantity to host matrix such as polymer, metals, it improves the mechanical, thermal and electrical properties without significant increase in the finished product cost. Produced by chemical exfoliation proprietary method.

2.1 Technical Parameters of Graphene:

Thermal density – conductivity 3,000 watts/m-k, 6 watts/m-k, Tensile modulus >1,000 Gpa, Tensile strength >5 Gpa, Electrical conductivity 107siemens/m, bulk density 0.30g/cc, diameter average x & y dimensions 10-15 micron, thickness average z dimension 10-15 nm, purity >98% , number of layer – average number of layer 10-15, surface area- 112m2/g

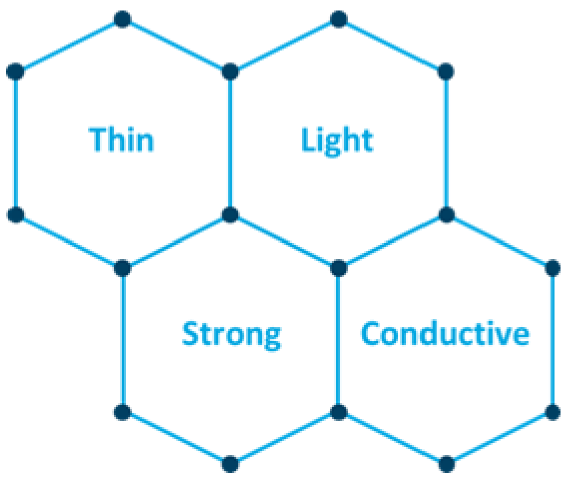


Fig: 1. Graphene properties

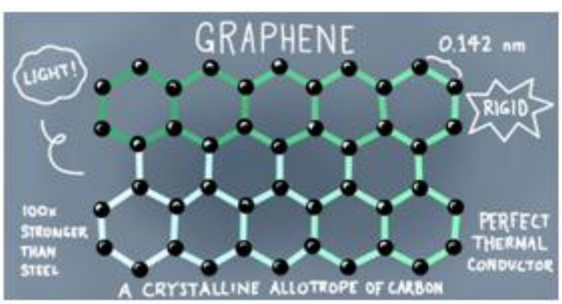


Fig: 2. Graphene structure

Single layer graphene (SLG) is unique in electronic structure ,as it shows band-overlap in two conical points (K and K') in the Brillouin zone. The charge carriers in this structure, known as mass-less dirac fermions, are electrons losing their rest mass ,mo and can best be described by (2+1)-dimensional Dirac equations. Thus SLG is expected to show some unusual properties, as compared with metals and semiconductors and typical of a semi metal.

Bi-layer graphene shows the gap less state with parabolic bands touching K and K', in contrast to conical bands of a single layer graphene. Thus Bi-layer graphene have finite mass and called massive Dirac fermions. The structure also shows an anomalous QHE, but different from that of single layer graphene and as a result, it remains metallic at the neutraility points. However application of a gate voltage can change the carrier concentration and introduces asymmetry between the two layers. This results in formation of semiconducting gaps and restoration of normal QHE.

FLG has also been used effectively has part of composite electrodes in new generations Li-ion batteries due to its ability to take part in electro chemical reactions. Graphene showed similar or better kinectics in many electro chemical system than that of graphite or activated carbon. Such composites electrodes were found to enhance the performance of the batteries. Application of graphene in energy storage devices, such as batteries and super capacitors, are very recent; but the success of the reported studies are expected to attract more research efforts in this field.

All varieties of graphene, single-,bi-and few layer, have found potential applications in fields of electronics , memory, biotechnology, sensor, energy storage devices etc. As synthesis methods control the structure and properties of graphene, a variety of process in techniques are used by researches, especially for large scale production. The subsequent sections will discuss different synsthesis of graphene and its main applications reported so far.

III. DIFFERENT GRAPHENE-REINFORCED MMCS

MMC is a composite material containing at least two constituent parts, one being a metal or alloy matrix and the others being reinforcement. Here, graphene reinforced MMCs are classified according to their metal matrix provides an overview of graphene reinforced MMCs. As mentioned above, graphene has outstanding thermal, electrical, mechanical properties, but these properties were measured in ideal conditions for single-layer graphene. In most cases, the used graphene was not single-layer graphene. And it was also pointed out that atomic defects, interfacial interactions with matrix metal and increased number of carbon layers may make these properties become worse. So the graphene used in those research works. But have not been compared with each other in detail.

3.1 Graphene – reinforced matrix composite

Graphene-reinforced Al matrix composites were reported firstly among graphene-reinforced MMCs. In 2011, Bartolucciet al. reported that composites of graphene platelets and powdered Al were prepared by ball milling, hot isostatic pressing and extrusion. But the test results were not encouraging. The graphene–Al compositeshowed lower strength and hardness values than pure Al and multi-walled CNT-reinforced Al composites. The inferior mechanical properties were explained by the formation of Al carbide during the consolidation, and subsequent heating and extrusion process. The optical micrographs of the graphene composites. In 2012, Wang et al. reported that Al composites reinforced with graphene nanosheets (GNSs) were fabricated through flake powder metallurgy, compacting and extrusion. The tensile strength of Al composite reinforced with only 0.3 wt-% GNSs is 249 MPa. It was 62% enhancement over the unreinforced Al matrix. The results were not as good as theoretical expectations, but it demonstrated for the first time that GNSs can actually act as effective reinforcements in MMCs. The tensile properties of the composite and the corresponding

3.2 Graphene-reinforced Cu matrix composites

Graphene-reinforced Cu matrix composites were fabricated almost as early as graphene-reinforced Al matrix composites. In 2011, Jagannadham reported that Cu graphene composites were fabricated. They were fabricated by dripped the GO solution on the Cu substrate and after it was dry, a thin film of Cu was deposited on top of the GO particulates by laser physical vapour deposition(LPVD), and then reduced GO to graphene. They repeated this process to make six layers of Cu film, containing the dispersion of graphene on the Cu substrates. SEM image in backscattering mode of the Cu-graphene layers. The dark regions are graphene, and the connected grey regions are Cu film. It was reported that the cross-plane thermal conductivity is reduced because of the low thermal conductivity of graphene perpendicular to the ab planes, and the planar thermal conductivity in the Cu-graphene layers was not reduced. Graphene ab plane orientation will affect the thermal conductivity of composites; random orientation of graphene in composites will achieve isotropic thermal conductivity. Later in 2011, Jagannadham reported that graphene-reinforced Cu matrix composites were fabricated by electrochemical co-deposition from $CuSO_4$ and graphene oxide solution. The composite film's (thickness > 200μm) thermal conductivity is 460 W m K^{-1} at 300 K; 510 W m K^{-1} at 250 K and 440 W m K^{-1} at 350 K. Both of Jagannadham's papers did not mentionthe mechanical properties[1].

3.3 Graphene-reinforced Ni matrix composites

It is amazing that the number of reports on graphene reinforced Ni matrix composites is very few, for not only is Ni a very important industrial material, but also it is very stable with carbon materials. In 2012, Huetal. reported Ni/graphene composite sheets. It was synthesised from graphene oxide sheets using electroless Ni-plating in a $NiSO_4$ solution. The microstructure of the Ni/graphene composites. It was pointed out that the synthesised composites have the potential to be used as catalysts, due to the high-specific surface area, the porous structure and the uniform dispersion of Ni particles on the graphene sheets surface[1].

3.4 Graphene-reinforced Mg matrix composites

The first report on graphene-reinforced Mg matrix composites was published in 2012 by Chen etal. Liquidstate ultrasonic processing and solid state friction stirring were employed to fabricate the composites. It was said electrodeposited Ni. Later, a similar work was carried out by Ren..etal.,the mechanical test results of which were a little different.

3.5 Graphene-reinforced iron matrix composites

Up to now, only one effort was made on graphene reinforced iron matrix composites. In 2014, Lin etal.,reported oxide graphene (GO)-reinforced iron composites. They were prepared by laser sintering. The reported surface micro hardness of laser sintered 2 wt-% GO composite was 600 HV, which has an increement of 93.5% compared with that of base material. The strengthening mechanism was discussed. The GO–iron interfacial structure was investigated; the study reported cementite formation and provided theoretical analysis as well as solid proof of the formation of cementite.

3.6 Graphene-reinforced Ni_3Al matrix composites

In 2015, Zhai et al. reported the mechanical and tribological properties of MLG-reinforced Ni_3Al matrix composites, which were fabricated by ball milling and SPS. This was the first graphene-reinforced inter metallic compound matrix composites. It was found that graphene can strengthen the matrix effectively and dramatically improve the wear resistance and decrease the friction coefficient [1]

3.7 Other graphene–metal composites

There were a lot of studies that have reported many other graphene–metal composites. These composites weremainly used as catalysts, photo-catalysts, energy storage and transformation materials, biosensors and others. There are graphene–Fe–Nicomposites, graphene Agcomposites, graphene Aucomposites, graphene–Ptcomposites, graphene–Pb composites, graphene Cd composites and so on. In most of these graphene– metal composites, metal particles were distributed on the graphene surface, and compared with the graphene reinforced

MMCs discussed previously in this article, the ratio of metal in the composites is very low.

3.8 Potential applications of graphene reinforced

MMCs Graphene-reinforced MMCs are just in the early research stage. Commercial products for real application in industry fields may be a long way off. However, the potential applications for the composites exist in many aspects. For the high specific strength, good thermal conductivity, good wear resistance and corrosion resistance, and low coefficient of thermal expansion, graphene-reinforced MMCs are suitable for application in the automobile industry, aerospace industry, sports industry, chemical industry and electronics industry. Compared with carbon fibres and CNTs, the production cost for MLG in large quantities will be much lower. Graphene has better strength and stiffness than carbon fibres and CNTs and also is easier to disperse in a metal matrix. Therefore graphene- reinforced MMCs are expected to be alternatives in the industry fields where carbon fibre and CNT-reinforced

MMCs are used. Of course, as alluded to in this paperfield. Using it, reasonable results can be achieved with less time and money being consumed. The Fig shows the applications of graphene.

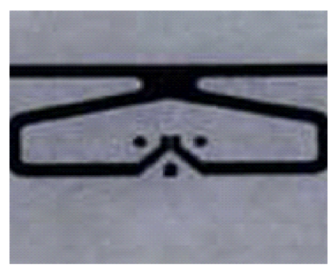
IV. GAPHENE APPLICATIONS

Graphene membrane

Graphene coatings

Graphene energy

Graphene medical



Graphene sensors

Imagine clean drinking water for millions of people living in developing countries. The development of graphene-based membranes at The University of Manchester brings that possibility closer. Graphene is a material with a huge number of outstanding qualities; strength, flexibility, lightweight and conductivity. Imagine fully charging a smartphone in seconds, or an electric car in minutes. That's the power of graphene. Graphene's unique properties allow for ground-breaking biomedical applications: targeted drug delivery; improved brain penetration; DIY health-testing kits and 'smart' implants. Ultra-sensitive sensors made from graphene could detect minute dangerous particles and help to protect in potentially dangerous environments.

V. CONCLUSION

The present trends required to develop newest very effective with high strength, hardness, young's modulus can be achieved by incorporating graphene platelets and few layers sheets in metallic matrices. In various studies found that, metal-graphene nano-composites with low volume/weight fractions improves the strength and hardness of the nano composite. Graphene plays a prominent role in the field of biomedical and composite coatings as well.

REFERENCES

[1] Z.Hu,et al., inferred on graphene reinforced metal matrix nanocomposites. Materials science and technology ISSN:0267-0836 pp 1743-2847.
[2] S.R. Bakshi et al., inferred on carbon nanotube reinforced metal matrix materials. Int.Mater.Rev 2010,pp,44-64.
[3] S .Sankaranarayanan et al., inferred on Nano-AIN particle reinforced Mg composites: microstructural and mechanical properties, Mater. Sci. Technol., 2000,pp.58-67.
[4] S.Rawl inferred on Metal matrix composites for space applications, JOM ,2001,pp.14-17.
[5] J.W.Kaczmar et al., inferred on the production and application of metal matrix composite materials, j.Mater.process.Technol,2000 pp.58-67.
[6] Chi-Hoon Jeon1 et al entitle on Material Properties of Graphene/Aluminum Metal Matrix Composites Fabricated by Friction Stir Processing. International journal of precision engineering and manufacturing Vol. 15, No. 6, pp1235-1239.
[7] I.A. Ovid'ko et.,al entitle studies on metal-graphene nanocomposites with enhanced mechanical properties. Rev. Adv. Mater. Sci. 2014, pp190-200.
[8] Jong-min juet al entitle studies on Facile synthesis of graphene reinforced Al matrix composites with improved dispersion of graphene and enhanced mechanical properties. ELSEVIER journals of alloys and compounds 704, pp585-592.
[9] Muhammad Rashad et,al entitle studies on High temperature formability of graphene nanoplatelets-AZ31 composites fabricated by stir-casting method, ELSEVIER , journals of magnesium and alloys,2016 pp270-277.
[10] Prashantha Kumar H.Get al., entitle on assessment of mechanical and tribological properties of al 2024- sic - graphene hybrid composites.