International Journal of Composite and Constituent Material
eISSN: 2456-5237
Vol. 3: Issue 1
www.journalspub.com

Graphene Nanocomposites

*S. Gawande**
Rani Durgawati Vishwavidyalaya, Jabalpur, Madhya Pradesh, India

ABSTRACT
This paper provides an ample review of the present trends in graphene research with an emphasis on graphene-based nanocomposites and their applications. Various synthesis routes have recently been devised for mass production of graphene to address the needs of the composite industry. This paper describes the worldwide scenario of applications and uses in the field of graphene nanocomposites. It concludes with a discussion of the impact of graphene in composites and the future challenges to meeting industrial demands.

***Corresponding Author**
E-mail: soniagawande71@gmail.com

INTRODUCTION

Graphene can be described as a one-atom thick layer of graphite. It is the basic structural element of other allotropes, including graphite, charcoal, carbon nanotubes and fullerenes. Graphene is the strongest, thinnest material known to exist. Graphene is an atomic-scale honeycomb lattice made of carbon atoms. Graphene is a 2D crystal of carbon atoms, arranged in a honeycomb lattice. Each carbon atom is sp2 hybridized and it is bound to its three neighbours [1].

The single-layered atom-thick flatbed structure has revolutionized the nanotechnology platform since its discovery. To date, several attempts have been made to synthesize graphene on a large scale to address the needs of various industries, particularly the composite industry, in which the use of graphene has dramatically transformed the global market for the production of state-of-the-art composite materials. The addition of graphene to a host matrix has achieved a number of enhanced properties with promising applications in many industries, such as aerospace, electronics, energy, structural and mechanical, environmental, medicine, and food and beverage. Since 2004, graphene has taken the nanotechnology platform by storm, with exponential growth in its applications. The remarkable properties of graphene make it a “magic bullet” for the composite world. Several papers on graphene and graphene-based nanocomposites have been published [1].

The present review presents the current research trends, its properties and applications about graphene and its nanocomposites.

STRUCTURE

Graphene is a crystalline allotrope of carbon with 2-dimensional properties (Figure 1). Its carbon atoms are densely packed in a regular atomic-scale chicken wire (hexagonal) pattern. Each atom has four bonds, one σ bond with each of its three neighbours and one π-bond that is oriented out of plane. Sheets of graphene held together by van der Waals bonding make graphite. Graphene sheets are composed of carbon atoms linked in hexagonal shapes with each carbon atom covalently bonded to three other carbon atoms. Each sheet of graphene is only one atom thick, and each graphene sheet is considered a single molecule. In simple terms, graphene is a thin layer of pure carbon; it is a single, tightly packed layer of carbon atoms that are bonded together in a hexagonal honeycomb lattice. In more complex terms, it is an allotrope of carbon in the structure of a plane of sp2 bonded atoms with a molecule bond length of 0.142 nm. The layers slide over each other easily because there are only weak forces between them, making graphite slippery. Graphite contains delocalised electrons (free electrons). These electrons can move through the graphite, carrying charge from place to place and allowing graphite to conduct electricity. Like graphite, graphene's atoms are arranged in a hexagonal lattice. What distinguishes it is that rather than being made of stacked layers, graphene is one single layer just one atom thick. There are several ways graphene can be produced [2].

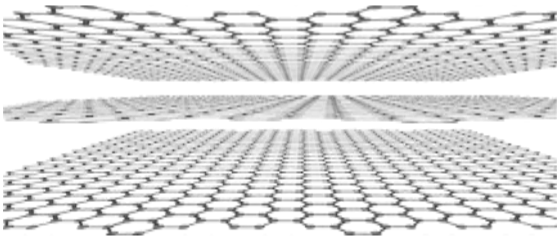

Fig. 1. *Structure of graphene.*

CHEMICAL PROPERTIES

- Graphene is chemically the most reactive form of carbon.
- Only form of carbon (and generally all solid materials) in which each single atom is in exposure for chemical reaction from two sides (due to the 2D structure).
- Carbon atoms at the edge of graphene sheets have special chemical reactivity.
- Graphene burns at very low temperature (e.g., 350°C).
- Graphene has the highest ratio of edgy carbons (in comparison with similar materials such as carbon nanotubes).
- Graphene is commonly modified with oxygen- and nitrogen- containing functional groups [3].

ELECTRONIC PROPERTIES

- It is a zero-overlap semimetal (with both holes and electrons as charge carriers) with very high electrical conductivity.
- Electrons are able to flow through graphene more easily than through even copper.
- The electrons travel through the graphene sheet as if they carry no mass, as fast as just one hundredth that of the speed of light.
- High charge carrier mobility, for which values of 10,000 cm^2/Vs, in some cases even 200,000 cm^2/Vs were reported (Figure 2) [4].

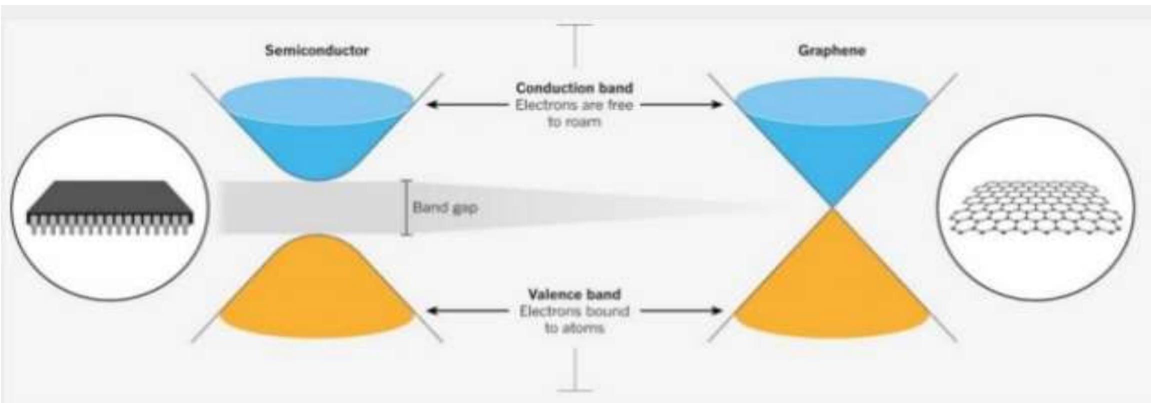

Fig. 2. *In an insulator or semiconductor, an electron bound to an atom can break free only if it gets enough energy from heat or passing photon to jump the 'band gap'. But in graphene the gap is infinitesimal. This is the main reason why graphene's electron can move easily and very fast.*

MECHANICAL PROPERTIES

- To calculate the strength of graphene, scientists used a technique called atomic force microscopy.
- It was found that graphene is harder than diamond and about 300 times harder than steel. The tensile strength of graphene exceeds 1 TPa.
- It is stretchable up to 20% of its initial length.
- It is expected that graphene's mechanical properties will find applications into making a new generation of super strong composite materials and along combined with its optical properties, making flexible displays [5].

THERMAL PROPERTIES

- Graphene is a perfect thermal conductor.
- Its thermal conductivity is much higher than all the other carbon structures as carbon nanotubes, graphite and diamond (>5000 W/m/K) at room temperature.
- Graphite, the 3 D version of graphene, shows a thermal conductivity about 5 times smaller (1000 W/m/K).
- The ballistic thermal conductance of graphene is isotropic, i.e. same in all directions.
- The material's high electron mobility and high thermal conductivity could lead to chips that are not only faster but also better at dissipating heat (Figure 3) [6].

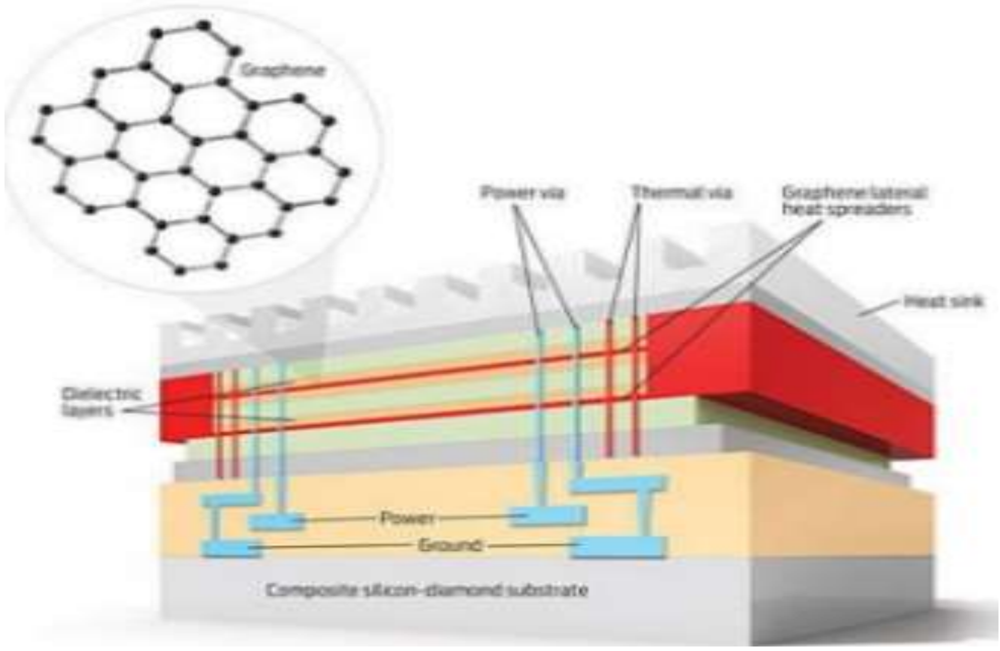

Fig. 3. *Schematic shows a three-dimensional stacked chip with layers of graphene acting as heat spreaders.*

OPTICAL PROPERTIES

- Graphene, despite it is only 1 atom thick, is still visible to the naked eye.
- Due to its unique electronic properties, it absorbs a high 2.3% of light that passes through it.
- Photograph of graphene in transmitted light.
- This one-atom-thick crystal can be seen with the naked eye [7].

APPLICATIONS

Potential graphene applications include thin, flexible, yet durable display screens, electric/photonics circuits, solar cells, electronics, biological engineering, filtration, lightweight/strong composite materials, photovoltaics and energy storage and various medical, chemical and industrial processes enhanced or enabled by the use of new graphene materials.

Biomedical Graphene

It could soon be used to analyse DNA at a record-breaking pace. That's the claim of a physicist in the US who has proposed a new way of reading the sequence of chemical bases in a DNA strand by sending the molecule through a tiny slit in a graphene sheet.

Integrated Circuits

Graphene has a high carrier mobility, as well as low noise, allowing it to be used as the channel in a field-effect transistor. Processors using 100 GHz transistors on 2-inch (51 mm) graphene sheets. Graphene-based integrated circuit handled frequencies up to 10 GHz. Transistors printed on flexible plastic that operate at 25 gigahertz. Terahertz-speed transistor [8].

Optical Electronics

Graphene's high electrical conductivity and high optical transparency make it a candidate for transparent conducting electrodes. Graphene's mechanical strength and flexibility are advantageous compared to indium tin oxide, which is brittle. So, it would work very well in optoelectronic applications: touchscreens, liquid crystal displays, organic photovoltaic cells, and organic light-emitting diodes [8].

Filters Desalination

By very precise control over the size of the holes in the graphene sheet, graphene oxide filters could outperform other techniques of desalination by a significant margin. Ethanol distillation: Graphene oxide membranes allow water vapor to pass through, but are impermeable to other liquids and gases. Such membranes could revolutionize the economics of biofuel production and the alcoholic beverage industry [9].

Solar Cells

Graphene turned to be a promising material for photoelectrochemical energy conversion in dye sensitized solar cells. The transparent, conductive, and ultrathin graphene films are fabricated from exfoliated graphite oxide, followed by thermal reduction. The obtained films exhibit a high conductivity of 550 S/cm and a transparency of more than 70% over 1000–3000 nm [9].

Energy Storage Devices

Due to the extremely high surface area to mass ratio of graphene, one potential application is in the conductive plates of Supercapacitors. It is believed that graphene could be used to produce Supercapacitors with a greater energy storage density than is currently available [10].

Antibacterial

In 2010, the Chinese Academy of Sciences has found that sheets of graphene oxide are highly effective at killing bacteria such as Escherichia coli. This means graphene could be useful in applications such as hygiene products or packaging that will help keep food fresh for longer periods of time [10].

Other Applications

- Graphene nanoribbons
- IR detectors
- Single-molecule gas detection
- Piezoelectric materials
- Energy harvesting
- Composite materials
- Liquid cells for electron microscopy
- Thermal management materials
- Optical modulators
- Chemical sensors

CONCLUSION

The potentialities of graphine composites have been demonstrated in a wide range of scientific works and have fostered broad industrial interest and academic–industry collaborations. The transfer of graphine composites from basic research to commercialization is already ongoing. However, to ensure long-lasting impact, a deeper understanding of the structure and performance of graphine composites will be needed, as well as an extensive evaluation of how these materials perform compared to conventional composites, taking into account performance, cost, and processability. There is practically no limit to the number of 2D composites that can be constructed based on a graphene backbone structure, using chemistry to modify them.

REFERENCES

[1] F. Beckert, S. Bodendorfer, W. Zhang, R. Thomann, R. Mülhaupt. *Macromolecules*. 2014; 47: 7036–42p.
[2] Z.Y. Xia, S. Pezzini, E. Treossi, G. Giambastiani, F. Corticelli, V. Morandi, A. Zanelli, V. Bellani, V. Palermo. *Adv Funct Mater*. 2013; 23: 4684–93p.
[3] F.J. Tölle, K. Gamp, R. Mülhaupt. *Carbon*. 2014; 75: 432–42p. Ciesielski, et al. *Angew Chem, Int Ed*. 2014; 53: 10355–61p.
[4] S. Haar, et al. *Small*. 2015; 11:1691–702p.
a. Ciesielski, P. Samorì. *Chem Soc Rev*. 2014; 43: 381p.
[5] Schlierf, et al. *Nanoscale*. 2013; 5: 4205–16p.
[6] Schlierf, K. Cha, M.G. Schwab, P. Samorì, V. Palermo. *2D Mater*. 2014; 1: 035006p.
[7] Schlierf, P. Samorì, V. Palermo. *J Mater Chem C*. 2014; 2: 3129p.
[8] H. Yang, F. Withers, E. Gebremedhn, E. Lewis, L. Britnell, A. Felten, V. Palermo, S. Haigh, D. Beljonne, C. Casiraghi. *2D Mater*. 2014; 1: 011012p.
[9] Z.Y. Xia, et al. *Chem Plus Chem*. 2014; 79: 439–46p.
[10] Z.Y. Xia, D. Wei, E. Anitowska, V. Bellani, L. Ortolani, V. Morandi, M. Gazzano, A. Zanelli, S. Borini, V. Palermo. *Carbon*. 2015; 84: 254–62p.
[11] K. Parvez, Z.-S. Wu, R. Li, X. Liu, R. Graf, X. Feng, K. Müllen. *J Am Chem Soc*. 2014; 136: 6083–91p.
[12] A.M. Abdelkader, A.J. Cooper, R.A.W. Dryfe, I.A. Kinloch. *Nanoscale*. 2015; 7: 6944–56p.