Ultra Chemistry Vol. 8(2), 277-281 (2012).

Graphene : A Future Material

K. GOUR and S. M. KEMDEO

Department of Applied Chemistry, J.L. Chaturvedi College of Engineering, Nagpur-09
846,New Nandanvan, Nagpur (INDIA)

(Acceptance Date 16th July, 2012)

Abstract

Graphene has emerged as 21st century material and is potent enough to serve a future science and technologies. Research published in the journal Nature Communication states that graphene, the world's thinnest material at one atom thick and 100 times stronger than steel. Due to other similar versatile physico-chemical properties, graphene and its derivatives are being studied in nearly every field of science and engineering. Recent progress has shown that the graphene-based materials can have a profound impact on electronic and optoelectronic devices, chemical sensors, catalysis and nano-composites and energy storage. In the current article we took a brief review of important scientific properties of graphene and its application in various fields, Along with this, synthesis routes for the respective material is discussed in brief.

Key words : Graphene, nano-composit, graphene-nanosheet, engineering material.

Introduction

In october 2010, two university of Manchester (U.K.) scientists, Andre Geim and Konstantin Novoselov were awarded the 2010 Nobel Prize in physics for their research on graphene. The experimental discovery of graphene completely revolutionized the science world. Graphene is crystals of one atom or molecule thick in the two dimensional plane, i.e. it is flat mono layer of carbon atoms organized into a honeycomb lattice. A monolayer of graphene is around 0.5 nm thick. Graphene is stronger and stiffer than diamond, yet can be stretched by quarter of its length, like rubber. Despite being one atom thick, is so dense even helium cannot pass through it, Fig. 1. Graphene, can carry electricity and heat two fold excess higher than the best metal conductor, viz. silver. On a flat surface, graphene is much harder than even diamond, its allotrope, due to the shorter inter-atomic distance (1.45 Å versus diamond's 1.54 Å).

As a surface, graphene can carry an electrical current density and one hundred times higher than copper. Its surface area is largest known for its weight. Graphene-like nano-plateles are use as filler in composite materials that are used in many engineering applications, given the excellent in-plane mechanical, structural, thermal and electrical properties of graphite[1-4]. It has wide variety of application in super-small transistors, super-dense data storage, energy storage, solar cells, flexible touch screens etc. As a conductor it performs as well as copper, as a conductor of heat it outperforms all the other known materials. While looking at its application in chemical industries, graphene nano-sheet was served as catalyst support for platinum catalyst[5]. Its properties are tested by doping with platinum for electro-catalyst having application in polymer electrolyte membrane fuel cells (PEMFC)[6]. The above findings indicate that graphene nano-sheets can also bring the revolution in the field of catalysis in turn in fuel cell technologies as well.

In view of the understanding this 'Miracle Material', better, here we have focused on some of the important properties and applications of graphene. The synthesis approach is also discussed in brief.

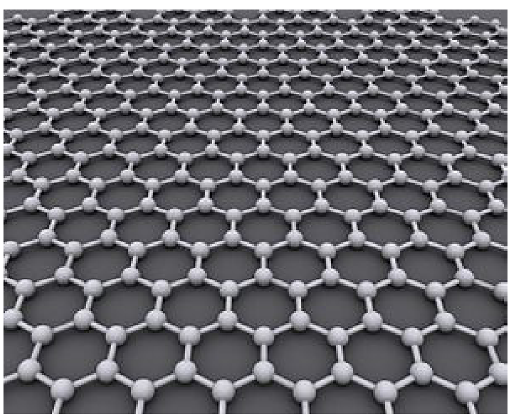

Fig. 1: Structure of Graphene

Discussion

1. Synthesis of graphene :

Unfortunately, large area graphene are not available for industrial applications. However, scientists have obtained small flakes of graphene by stripping them from graphite (e.g. pyrolitic graphite deposited by CVD [7-8]. Scientists also conceived exotic methods for making graphene. For example, graphene was formed during the thermal decomposition of acetylene with iron chloride as catalyst[9]. Graphene may be produced by evaporating silicon atoms out of SiC to force the re-arrangement of carbon atoms left behind. Graphene was also formed by exsoluting saturated carbon atoms in nickel foil[10]. Most graphene samples were extracted by exfoliation of graphite in organic solvent[11]. Some graphene samples were made by reduction of colloidal dispersions of graphene oxide[12].

Even with such creative ideas, the practical way out for massive production of graphene is still the most desired thing of current time.

2. Important properties of graphene :

Comparatively better electrical, thermal and mechanical properties make material more useful as an engineering material. In this regards, here we have discussed some of the important properties of graphene and the results of which undoubtedly flourishes the graphene as a future engineering material.

Graphene has excellent electrical properties and can conduct electricity even better than a metal, with the room temperature having resistivity of the order of 1 micro Ohm-cm and extremely high mobility of charge carriers[13].

Graphene is a zero gap semiconductor, so it is a super conductor, electron transfer of graphene is found 100 times faster than silicon[14]. Therefore, graphene based transistors can operate at higher frequencies as compared to silicon based ones. Thermal conductivity defines how well a given material conducts heat. A material's thermal conductivity is measured in the units W/m•K, read as "watts per meter per degree Kelvin." For example, the value of thermal conductivity of silicon, the most important electronic material, is around 145 W/m•K if measured at room temperature. Carbon nanotubes have a typical thermal conductivity range of 3000 to 3500 W/m•K. Diamond, another form of carbon, comes in between 1000 and 2200 W/m•K. The single-layer graphene studied by the UCR researchers displayed a thermal conductivity as high as 5300 W/m•K near room temperature[15].

. Graphene has excellent mechanical properties. It is stronger and stiffer than diamond and yet it has high flexibility. Graphene has record breaking strength (Young's Modulus) of 1000 Gpa which is nearly equal to diamond and many fold excess when compared to that of the steel[16].

Graphene has a perfect two dimensional crystal structure which is remarkable since thermodynamics suggests that 2D crystals are unstable. But 3D rippling (wrinkles) on its surface is believed to be the reason for stabilization of the 2D structure. Due to the 2D structure it has almost 100 % of its atoms on the surface. Thus, it has the highest surface area for its weight; ideally nearly to 2620 m^2/g [17] this favorable property of graphene can simply boost the catalysis research.

Table 1. Comparison of Young's modulus of various materials (Mechanical Strength)

Materials	Young's modulus (*E*) in GPa
Rubber (small strain)	0.01-0.1
PTFE (Teflon)	0.5
Nylon	3-7
Oak wood (along grain)	11
High-strength concrete (under compression)	30
Aluminium alloy	69
Glass	65-90
Titanium (Ti)	105-120
Copper (Cu)	110-130
Wrought iron and steel	150
Silicon (S)	190-210
Tungsten (W)	400-410
Diamond (C)	1,050-1,200
Silicon carbide (SiC)	450
Single walled carbon nanotube	1,000
Graphite/Graphene (within the plane)	1,000

3. Applications of graphene :

Rusting and other corrosion of metals is a serious global problem. In the study conducted by Dhiraj Prasai and colleagues[18] pointed out that, a single layer of graphene provides the same corrosion protection as conventional organic coatings that are more than five times thicker.

Graphene coatings could be ideal corrosion-inhibiting coatings in applications where a thin coating is favorable, such as microelectronic components (e.g., interconnects, aircraft components and implantable devices), say the scientists.

Graphene transistors are predicted to be substantially faster than today's silicon transistors and result in more efficient computers[19]. Graphene cell devices can be incredibly fast, tens to hundreds of times faster than communications in the fastest internet cables, due to the high motility and velocity of the electrons in its structure.

Since it is practically transparent and a good conductor, graphene is suitable for producing transparent touch screens as shown in Fig 2.

When mixed into plastics, graphene can turn them into conductors of electricity while making them more heat resistant and mechanically robust[20]. This resilience can be utilized in new super strong materials, which are also thin, elastic and lightweight. In the future, satellites, airplanes, and cars could be manufactured out of the new composite materials.

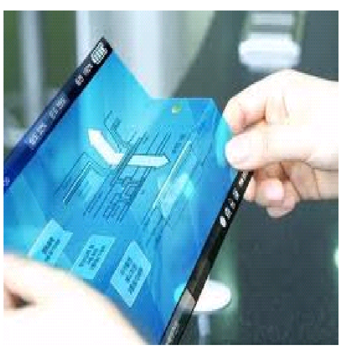

Fig. 2. Flexible touch screen

Research has shown that electrical power can be generated by placing two closely spaced metallic wires on top of graphene and shining light on the structure, making a simple solar cell. light panels, and maybe even solar cells[21].

This material Graphene electrodes used in lithium-ion batteries could reduce the recharge time from two hours to about 10 mins[22]. It is almost completely transparent, yet so dense that even helium, the smallest gas atom cannot pass through its network.

Conclusion

In this article, the preparation, properties, and applications of graphene-based materials have been reviewed. Preparation of high quality graphene materials in a cost effective manner and on the desired scale is essential for many applications. line with its applications, graphene is truly a miracle material for the various fields of science and technology. Graphene possess some extra-ordinary physico-chemical properties favorable in view of its application in formulation of super corrosion-inhibiting coatings, faster silicon transistors, transparent touch screens, ultrafast optical communication and computing, solar cell etc.

This attracted the scientist community towards the research in grephene that enhances the chances of in-depth exploration of the material in upcoming time; in fact we shall only say that a lot remains to be done and that graphene will be an important topic for many years to come.

References

1. Darzal L.T., Fukushima H., *Polym. Prep., 42 (2)*, 42-43 (2001).
2. Darzal L.T., Fukushima H., *Int. Symp. Ex.*, 1635-1642 (2003).
3. Fukushima H., Darzal L.T., *Ann. Tech. Conf-Soc. Plast Eng.*, 2230-2234 (2003).
4. Kelly B.T., *'Physics of Graphite'*, London Applied Science (1981).
5. Su F., Zeng J., Bao X., Yu Y., Lee J.Y., Zhao X.S., *Chem. Mater.*, 17(15), 3960-3967 (2005).
6. Yu X., Ye S., *J. Power Reso., 172 (1)*, 145-154 (2007).
7. Sidorov A.N., Yazdanpanah M.M., Jalilian R., Jouseph P., WCohnl R., Sumanasekera G.U., *IOP PUBLISHING*, 135301 (2007).
8. Banerjee A., Grebel H., *Nanotechnology*, (19), 365303 (2008).
9. Laude T., Kuwahara H., Sato K., *Chemical Physics Letters*, (434), pp.78-8 (2007).
10. Yu Q., Lian J., Siriponglert S., Hao L., Yong P., Pei S.S., *Applied Physics Letters*, (93), 113103 (2008).
11. Hernandex Y., Nicolosi V., Lotya M., Blighe F.M., Sun Z., De S., McGovern I.T., Holland B., Byrne M., Gun'Ko Y.K., Bliand J.J., Niraj P., Duesberg G., Krishnamurthy S., Goodhue R., Hutchison J., Scardaci V., Ferrari A.C., Coleman J.N., *Articles*, 583-588 (2008).
12. Nethravathi C., Rajamathi M., *Carbon*, (46), 1994-1998 (2008).
13. Choi W., Lahiri I., Seelaboyina R., Kang S.Y., *Critical Reviews in Solid State and Materials Sciences*, 35 (1), 52-71 (2010).
14. Tongay S., Lemaitre M., Miao X., Gila B., Appleton B. R., Hebard A. F. (2012), *Physical Review X*, (2), 011002-011007.
15. Balandin A.A., *Nature Materials*, (10), 569-581 (2011).
16. Kevin Ryan, 'Polymer Crystallisation as a Reinforcement Mechanism for Polymer-Carbon Nanotube Composites', *Ph.D. Thesis*, University of Dublin (2005).
17. Stankovich S., Dikin D.A., Dommett GHB, Kohlhaas K.M., Zimney E.J., Stach E.A., *Nature*, 442 (7100), 282-286 (2006).
18. Prasai D., Tuberquia J.C., Harl R.R., Jennings G. K., Bolotin K.I., *ACS Nano., 6 (2)*, 1102–1108 (2012).
19. Lin Y.M., Dimitrakopoulos C., Jenkins K.A., Farmer D. B., Chiu H.Y., Grill A., Avouris., Ph. (2010), *Science* , 327 (5966), 662-662
20. [Link]http://www.specialchem4polymers.com/resources/articles/article.aspx?id=6151
21. Echtermeyer T.J., Britnell L., Jasnos P.K, Lombardo A., Gorbachev R.V., Grigorenko, A.K. Geim A.N., Ferrari A.C., Novoselov K.S. (2011), *Nature Communications*, (2), 458
22. Xiao X., Liu P., Wang J.S., Verbrugge M. W., Balogh M. P. *Electrochemistry Communications, 13(2), 209-212* (*2011*).