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A Mini Review on Graphene - A Wonder Material for New Industrial and Biomedical Applications

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Abstract:

In this mini review we have demonstrated the enormous possibility of next generation electronic and biomedical applications of graphene and its derivatives (graphene oxides). Graphene and its derivatives (graphene oxide, GO, and reduced graphene oxide, rGO) are being evolved as "miracle materials" with manifold applications in different sectors of science and technology (starting from electronics, computer chips energy storage , clean water to tissue engineering in biological science).

1. Introduction

Graphene has unique properties - it is 200 times more stronger than structural steel; the resistivity of the graphene sheet is 10−6 Ohm•cm, which is less than the resistivity of silver - the lowest resistivity substance known at room temperature; it's current carrying capacity is 1000 times greater than copper; it can flex 20 times without damage; it is 97.3% transparent. Graphene may be able to replace semiconductor in computer chips and electronics. It can be added in small amounts to metal and plastics (including polymers) to make stronger and lighter composite materials. Graphene could make better touchscreens- LCD's, LED's & OLED. Graphene may revolutionize data transfer- it can make smaller optical modulators that transfer data at speeds up to 10 times faster than current technology. On the whole Graphene will make a new industrial revolution in future. GO and rGO are being used as conductinve polymer composites for biomedical applications (like drug delivery and tissue engineering scaffolds).In this mini review we have attempted to highlight the importance of graphene and technology to encourage the younger generation.

2. Extraordinary properties of raphene

Graphene is a one-atom-thick (0.335 nm) layer of carbon atoms arranged in a hexagonal lattice. It is a nanomaterial arranged in a two-dimensional layer of carbon atoms with**sp^2**hybridization [1].It is the building-block of Graphite, but graphene is a remarkable substance on its own - with a multitude of astonishing properties which repeatedly earn it the title “wonder material”. Graphene was first made by using scotch tapes and peeling them off from graphite [about 3 million layers of graphene in 1 mm of graphite]. It is the most popularly mentioned (and first discovered 2D) material has seen a lot of positive press since its discovery in Manchester in 2004. Two Russian-émigré scientists at the University of Manchester, Andre Geim and Konstantin Novoselov, were playing about with flakes of carbon graphite in an attempt to investigate its electrical properties when they decided to see if they could make thinner flakes with the help of sticky Scotch tape. They soon realized that by repeatedly sticking and peeling back the Scotch tape they could get down to the thinnest of all possible layers, one atom thick – a material with unique and immensely interesting properties. Like graphene , graphine oxide (GO) was prepared by oxidation of graphite. GO and rGO have got many applications in electronic and biomedical engineering [2].

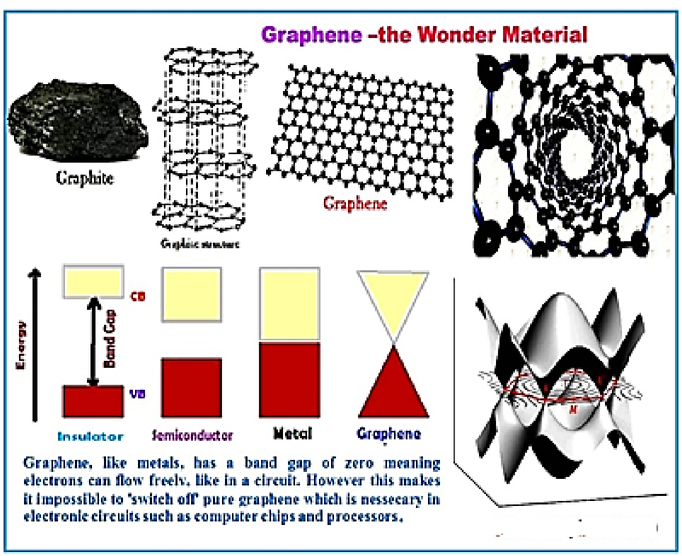

Figure 1: They won Nobel prize in Physics jointly in 2010 for their ground-breaking experiments, the Nobel committee made a point of citing the “playfulness” that was one of the hallmarks of the way they have worked together.With the huge list of superlatives that are

rehearsed almost every time it is mentioned (world's strongest, world's stretchiest, world's most conductive... etc)[3].

Graphene is the thinnest material known to man at one atom thick (0.335 nm), and also incredibly strong - about 200 times stronger than steel. On top of that, graphene is an excellent conductor of heat and electricity and has interesting light absorption abilities. It is truly a material that could change the world, with unlimited potential for integration in almost any industry. Where the horizon of Silicon semiconductors ends, Graphene comes into picture[4].Graphene due to its exclusive and extensive properties along with being cheap and easily accessible can be used in designing and manufacturing of several devices.

3. Applications of graphene and graphene oxides

Graphene has potential applications in batteries, transistors, computer chips, energy generation, supercapacitors, DNA sequencing, water filters, antennas, touchscreens [for LCD or OLED- Organic Light-Emitting Diode displays][5], solar cells, Spintronics-related products etc.Graphene is indeed very exciting, but producing high quality materials is still a challenge.Graphene has led to stampede in research and development and a patent land rush with 31,000 patents and hundreds of thousands of scientific papers.[6]

3.1. Super-light and super-strong material

It was shown that monolayer graphene is, in fact, the strongest solid material ever measured.One needs to apply a tension 100 to 400 times higher on graphene than on steel to break it. Graphene's high breaking strength (42 N/m; for comparison, one-atom-thick-layer of steel has a breaking strength of 0.1-0.4 N/m) is mainly because of the interaction between the atoms of carbon.[7] In graphene, each carbon atom binds to another three via COVALENT BONDS, powerful chemical bonds that involve the sharing of electron pairs between atoms.Despite this, graphite is still incredibly soft and weak. This is because the layers of graphene comprising graphite are held together by van der Waals bonds, which are the weakest form of chemical bonding. Graphene is harder than diamond yet more elastic than rubber; tougher than steel yet lighter than aluminum. Graphene is the strongest known material.

3.2. Heat transporter

Carbon has the highest-known ambient transition point of all the elements on the Periodic Table. To change it from solid directly to vapour, it is necessary to heat it at almost 4000K(~3600ºC/6600ºF) at room temperature and 1 atmosphere. Graphene itself shares this property. Besides, this material is very effective at transporting heat. With a thermal conductivity of 5000W/mK, graphite trumps copper (~500W/mK) by one order of magnitude.[8]

3.3. Electrical Conductivity

Graphene possesses amazing characteristics- it has high electron mobility is 100x faster than silicon.Grapheneelectrical conductivity is roughly 50% higher than copper.Graphene can also work as a semiconductor.Graphene is a "zero-gap" semiconductor because no energy gap exists between the conducting and valence energy bands of the carbon atoms comprising graphene.

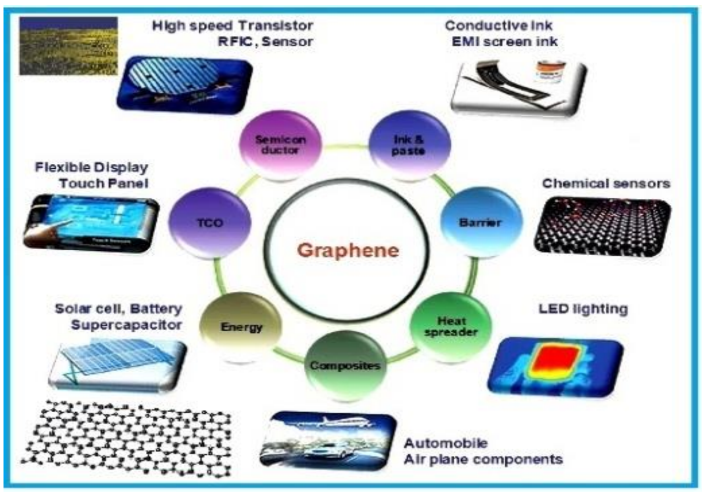

Fig 2: Use of Graphene in various electronic instruments

Graphene has yet another area as capacitors. Depending on design (the base that the graphene rests on, or lack thereof, can affect its electrical properties) and stimulation from electronic frequencies (graphene's permittivity varies with input frequency, becoming more insulating as frequency increases), graphene can become either a conductor or an insulator. Theoretically, this material can be used to create ultra-compact capacitors that can store stupendous amounts of electrical energy.[9]

3.4. Potential newly found properties of graphene

Graphene already exhibit notable traits, surpassing most other known materials. Its primary interest lies in super-compact electronics and super-light materials, stronger than any synthetic polymer or known metal-alloy. What if it could also give humanity free energy? It is possible to convert the Brownian motion of a graphene sheet into an—albeit minimal—amount of electrical power.[8] In other words, this material could become a sort-of free-energy generator.

Electronics appear to be the holy grail of graphene research. Unfortunately, the promises of superconducting wires, ultrafast processing chips for computers, advanced batteries and super-efficient power generation are not going to become a reality any time soon. There are two big obstacles that are preventing these discoveries:

(a)Graphene needs to be completely pure and defect free to have the extremely high conductivity that would make these systems possible. Unfortunately, now no process has been developed that allows the bulk manufacturing of pure graphene at an economical price.

(b)Computer chips need to have a band gap to function (it is the band gap that allows chips to either be 1, on, or 0, off). Introducing a band gap to graphene reduces its conductivity. Researchers are currently trying to develop a method that retains the high conductivity of graphene whilst allowing it to function as a semiconductor.[3]

3.5. Clean Water

Creating reliable sources of clean water might be one of its most important uses; e.g, next-generation membranes based on graphene for water desalination.[19] If superfine graphene mesh filters can be scaled up it could transform billions of lives.

3.6. Graphene safety

Graphene is incredibly thin, light and strong and has numerous potential applications showing a direction to new industrial revolution. But based on the current knowledge on hazards of nanomaterials, a number of characteristics can be identified that may be relevant for hazards assessment of graphene. The surface functionalization of graphene will dictate the dispersion stability, the surface reactivity, and the degradation behavior, of all of which will contribute to the overall toxicity of the material.[11]

3.7. Graphene oxides as biomaterials

Graphene derivatives (GO and rGO) are important nanofiller materials for making biopolymer composites which are found to be bioactive antbacterial and biocompatible for applications in tissue engineering and regenerative medicine [2,12,13].

4. Conclusion

Graphene is a peculiar material and can combine with other elements to produce different materials showing superior properties for desired applications. Researchers worldwide continue to constant studies to learn its various properties and possible applications, which include: batteries, transistors, computer chips, energy generation , supercapacitors, DNA sequencing, water filters, antennas, LCD or OLED displays, solar cells and spintronics-related products. Moreover, graphene and its derivative oxide (GO and rGO) are the next generation nano materials for various applications in all branches of science and technology. However , large scale preparation of graphene sheet is still challenging. Predation new smart composites with novel properties is an immerging field of research.

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