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A Study of Graphene Applications

S. Srinivasan [a,*], G. Sanjana [b], P. Abinaya [b]

[a] Assistant Professor, EEE Department, Vivekanandha College of Engineering for women, Tiruchengode, Tamil Nadu, India.

[b] UG Scholar, EEE Department, Vivekanandha College of Engineering for women, Tiruchengode, Tamil Nadu, India.

*Corresponding Author: srivaas131985@gmail.com DOI: https://doi.org/10.34256/bsr1917

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Abstract: Carbon is unique in its own ways, the most special attribute of carbon is that it can make rings and long chain; even life on the earth is possible due to this property of carbon. Graphene is the first two dimensional material and it has many outstanding properties which have resulted in many exciting applications. Graphene is claimed to be so versatile that it will be able to replace present day materials. It is thought to be the perfect two-dimensional carbon crystal as it is the unique blend of properties both mechanical and electronics. Graphene is the thinnest, highly elastic, am bipolar, chemically inert, and hydrophobic, possesses record electron conductivity, high value of mobility, high thermal conductivity, high opacity, low resistivity and shows fractional quantum Hall effect and ballistic conduction and many other interesting properties that are yet be explored. Recently it has been found that the magnetic field of graphene can be switched on and off. In this paper, I have done a comparative study of properties of graphene and tried to produce an application of graphene in two fields which affect us most, that are, Medicine and Electronics.

Keywords: Graphene, Properties, TISSUE engineering, Bio-micro robotics, Drug delivery, Bio-imaging, Transistors, Spin transport device, Hall effect sensors, Transparent conducting electrodes, Conductive ink, Quantum dots, Photo detector, LED, Optical limiters, Touch screen, Teracherts devices.

1. Introduction

GRAPHITE+ENE**=** Graphene is an allotrope of carbon in the form of a single layer of atoms in a two-dimensional hexagonal lattice in which one atom forms each vertex.

1.1 discovery of Miracle Material "Graphene":

The limit for any structure to be called as 2D crystal is less than 10 layers of atomic Planes.

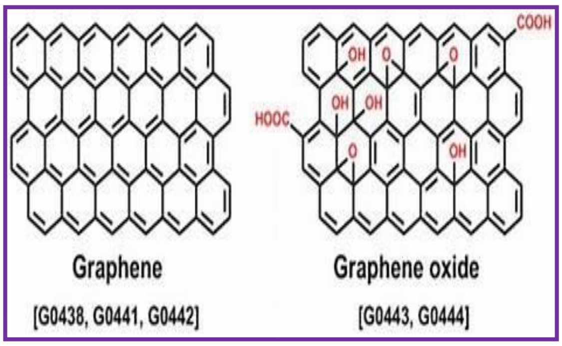

Figure1.1 **(Graphene and Graphene Oxide)**

Above than this limit crystal will be referred to as 3D. Graphene was first made by using scotch tapes and peeling them off from graphite (*Highly Oriented Pyrolytic Graphite - HOPG*). This led to production of flakes containing multi-layers of graphene. It was required to isolate the graphene layers individually for more specific purposes. This was achieved at first by intercalating the graphite mass and separating the graphene layers using different types of atoms or molecules. In spite of this what we got was a 3D layer [1]. After this slowly and gradually there were advancements in production of graphene. Some of the methods used were *CVD (Chemical Vapor Decomposition)* of hydrocarbons on metal surface and Thermal Decomposition of SiC. For more than 60 years Graphene has been studied by various scientists. But since graphene was not available in Free State it was not considered as a practical material that can be used [2]. Graphene as a future fabrication material was understood. It is formed by the thick sheet of carbon atoms bonded by sp2 hybridisation arranged in a hexagonal array [3]. It has gained tremendous fields due to its idiosyncratic electrochemical properties which include high current, density, high thermal conductivity, chemical inertness, optical transmittance. It is the thinnest material produced so far [3].

The thickness is 0.4-1.7 nm, it is about 1million times thinner than human hair. Its thinness allows to tractile and also conducts heat and electricity. It is the hardest material known to the mankind, even harder than diamond which is 60GPa theoretically 225GPa. (Approximately) Its weight per square meter is 0.77mg. [4] The properties such as biocompatibility, solubility and stability makes the grapheme oxide multi-functional for various biological and medical applications. Due to its effective interactions with drug molecules, Graphene oxide is a being studied for the use in biological and medical applications Graphene and Graphene oxide are ideal nano carriers for effective gene and drug delivery. Graphene oxide used for drug delivery is about one-two nanometer thick, with size staring from a few to 100s of nm. Drug delivery applications of graphene and graphene oxide include delivery of anti-cancer drugs, as a drug carrier for the treatment of subarachnoid hemorrhage, poorly soluble drugs, peptides, antibiotics, antibodies, DNA, RNA, genes.

Others nano-carriers lack ability to achieve high targeting concentration and efficiency at tumor sites, have limited drug loading capacity, a low degree of functionality, insufficient cell uptake, leads to nonspecific accumulation of the drug in normal cells, which further decreasing the therapeutic efficacy of the drug. Graphene and graphene oxide, on the other hand, are used to prevent unsought drug release into the blood stream during drug transportation and is therefore used for the effective drug transportation of anti-tumor drugs in tumor cells or tissue. They have flexibility and capability to design complex multifunctional drug systems for combined therapies.

They have high drug loading capacity. Both covalent and non-covalent modifications can be used to give specific biological activity to G and GO, and also to improve the bio-compatibility and colloidal stability [5] Graphene and Graphene Oxide act as catalyst are in growth, differentiation, and maturation of stem cells. Graphene and graphene oxide are soft membranes which allow stem cell attachment and growth and increase estrogenic differentiation. Thus they act as a transferable and implantable platform for growth of stem cells. Therefore, G and GO can be thought to act as an alternative material for bone regeneration. Graphene-based materials enhance stem cell differentiation. [5].

2. Proposed System

2.1.1 Bio-Micro Robotics

Medical micro-robots are being studied for their applications in targeted drug delivery, surgical accuracy, biopsy, radioactive therapy, scaffolding, surgical ablation in living bodies, sensing, marking and in hospital housekeeping. Such tasks are preferred to be carried out with micro robots because they are least invasive and precisely targeted.

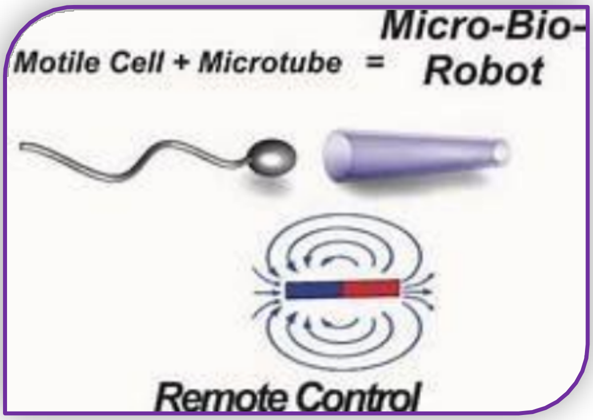

Figure 2.1.1 (Bio micro Robotics)

Temperature responsive hydrogel-Graphene oxide nano-composite bi-layers closely resemble to the shape of Jellyfish and have physical and chemical properties similar to biological tissues. These polymer networks have unique capability to reversible volume change in presence of external stimuli.

2.1.2 Bio-Imaging

Bio-imaging is a method that helps us to visualize biological processes with the aim to interfere as little as possible with biological processes. It is used to gain in vivo and in-vitro imaging on the 3-D structure. In also includes methods visualizing biological material that has been fixed for observation. Quantum confinement and edge effects of grapheme have shown to induce photoluminescence.

Isolated poly aromatic structures surface defects contribute to the fluorescence of Graphene Quantum Dots. Graphene Quantum Dots are fluorescent carbon-based nano-material that can be used to make effective fluorescent probes for bio-imaging due to their chemical inertia and non-toxicity [6].

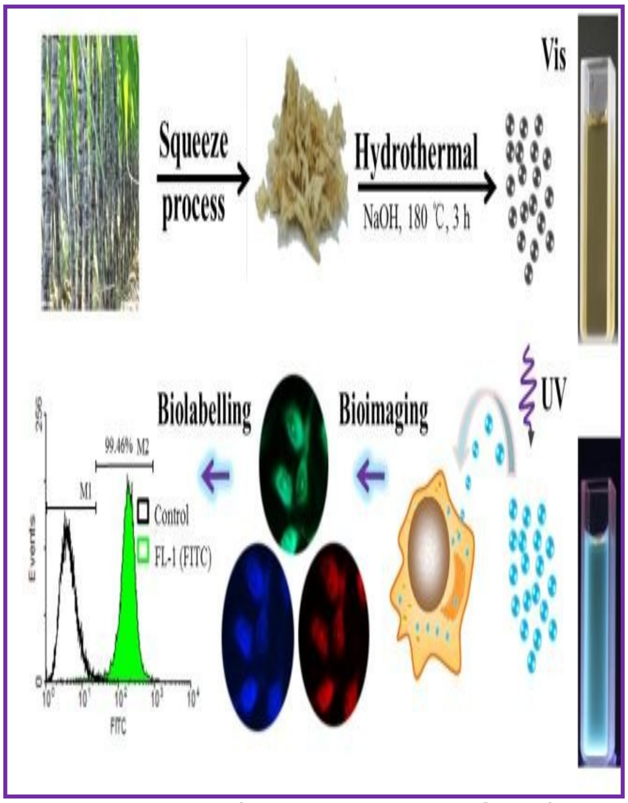

Figure 2.1.2 **(**Bio-imaging Graphene)

2.2.1 Elecronics

2.2.2 (1) FET Transistor:

Field-effect transistor (FET) is a three terminal device. These terminals are called source, drain and gate. It is one of the most broadly researched applications of graphene. Its valance band and conduction band meet at Dirac point (a point where electric field and charge carrier concentration are zero). Thus graphene is a zero band-gap semi-metal. 2D Few-Layer graphene shows a strong am bipolar electric field effect, high carrier mobility and large nano-electronic conductance. All these characteristics make it useful for graphene based field effect transistor. Here graphene is used to make the channel. Under the effect of electric field, electrons can be converted into holes and holes into electrons. Under positive gate bias, grapheme behave as an electron conductor and under negative gate bias, it behave as a whole conductor [7].

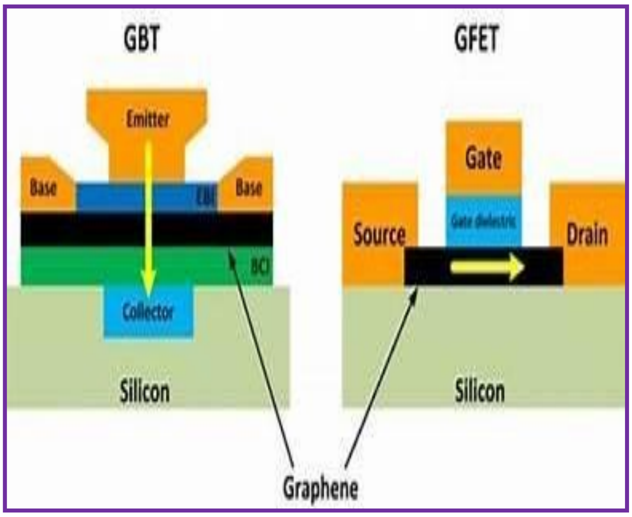

Figure 2.1.2 (Graphene FET)

2.2.3 (2) Single-Electron Transistor

A single electron transistor is same as a normal transistor except the channel is replaced by a quantum dot and the dot is separated from source and drain by thin insulators. The biggest challenge in utilizing graphene in transistor is that it has no band gap. But it can cause bilayer graphene using electrostatic gates. Electronic states can be change by injecting an electron into it. That structure is called quantum dot. The electronic states of a quantum dot can be controlled also by controlling the electric potential of the quantum dot.

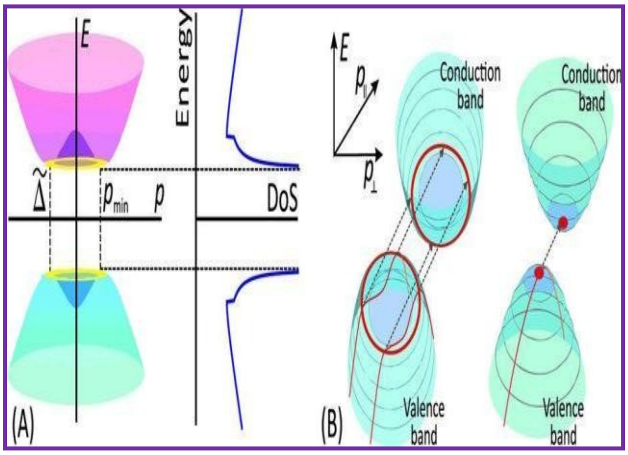

Figure 2.2.3 (2) (A) Electron spectr (B) bi-layer Graphene

Graphene quantum dots can be easily formed by etching because graphene is a single atomic layer thick. But fabrication with precision is still challenging. Single Electron Transistors consist of a sub-micron sized island coupled weakly to source and drain contacts.

1. The Coulomb energy $e2/C$ should be greater than the thermal energy. A size of the dot should be either small (<10 nm at 300K) or it should be cold (< 1K for a mu sized dot).

$$Ec>kbT$$

2. The residence time µt=RC of an electron on the dot needs to be so long that the corresponding energy uncertainty µE=h/µt = h/RC is less than the Coulomb energy $e2/C$. That leads to a condition for the tunnel resistance between the dot and source/drain:

$$R>h/e2$$

Where, $h/e2$ mu 26 kµ [8]

1. Electrical Properties

The freely available electrons (pi-electrons) that do not get bonded are the reason for electrical conduction to take place. Graphene thus behaves as a semiconductor just like the Silicon and Germanium. But since the cause of conduction in graphene is different from that of other semiconductor materials, it exhibits many unique properties. One such property is the electron mobility. The electron mobility of graphene in its pristine form is more than 200,000 cm2/Vs. The sheet resistance of graphene is about 30 ohms [9] Graphene atoms behave much similar to photons.

4. Scope for Development

4.1 Graphene's amazing properties bring scope of various future applications in following fields

❖ Biological engineering

- Optical electronics
- Composite materials
- Ultra filtration
- Composite materials
- Photovoltaic cells
- Super capacitors

The research on Graphene is in its initial stage. Graphene needs a lot of attention and research to fully discover its potential applications. The trick with Graphene is that it is so thin, it takes almost no current to heat it, but equally it cools in an instant. Pumping audio-frequency current through a sheet of Graphene- going well into the ultrasound- generates sound waves without the need for any moving parts.

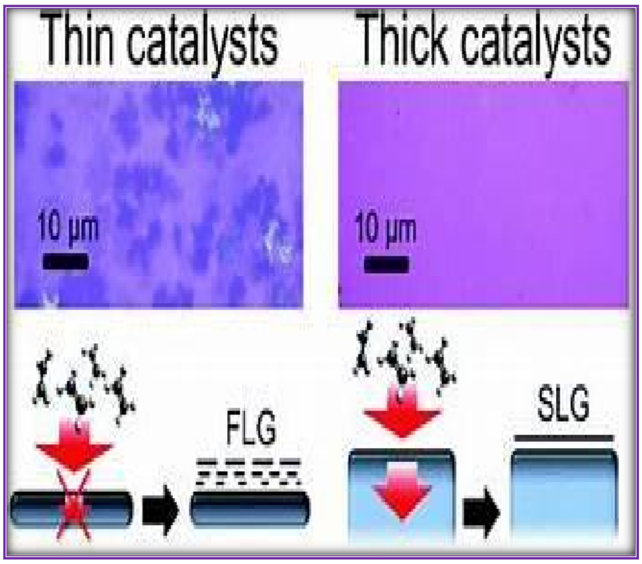

Figure 4.1 (a) **We can also able to convert thin catalysis to thick catalysis.**

Figure 4.1 (b) **By this development we can make anything very flexible. Until 2025, the development of the graphene is shown in the below graph.**

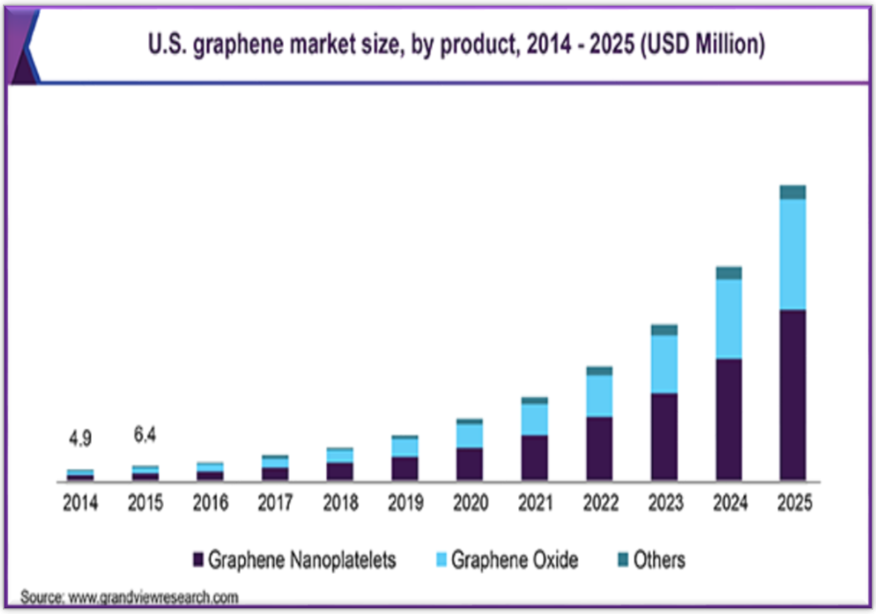

Figure 4.1 (c) **(development graph)**

This makes devices simpler and cheaper and opens up the possibility of new applications. Graphene may also replace electrical wires in the near future. We may no longer need separate ducts for wiring. It will surely prove to be a 'future material'.

4. Result and Discussion

Graphene is a promising material for new types of systems, circuits and devices where several functionalities can be combined into a single material. Presently, highly critical issues with the extensive use of Graphene in electronics are related to manufacturing. Although growth on copper surfaces has made bulk manufacture of large area Graphene layers possible, there are number of technical challenges to be overcome both in terms of cost and quality before the first consumer products using Graphene are actually commercialized. Graphene is thought to be perfect two-dimensional crystal due to intriguing properties. Versatility of graphene lies in its properties from physical to electronic. Due to these properties graphene can be used in many applications. Graphene has almost negligible band gap that increases its importance in electronics domain. Though synthesis of graphene is tedious job but producing it in large quantities for industrial purposes will reduce the cost and increase the ease of production of graphene. Some of the properties of graphene are:

- High tensile strength
- High Young's Modulus (about 1TPa)
- High intrinsic strength (about 130GPa)
- High elasticity

It also has potential to replace present day benchmark materials like silicon in transistor, steel as a building material (graphene is 100 times stronger than steel). But the question is, are properties of graphene can actually be used in present day applications.

5. Conclusions

In this paper, we have tried to explain, how graphene out of its excellent properties is going to revolutionize the electronics industry in near future. In next 20-30 years the key component of electronics industry will be graphene. It has come out to be exhibiting very unique and fascinating properties in all mechanical, chemical, and electrical domains which is a foresight of how it is going to replace all its contenders in future. Here we firstly study the mechanical properties of various interlayers and intra layer crosslink via first-principles calculations and then perform continuum model analysis for the overall mechanical properties of graphene-based papers. We find that there is a characteristic length scale $l0$, defined as $Dh0$ / $4G$, where D is the stiffness of the graphene sheet, $h0$ and G are the height of interlayer crosslink and shear modulus respectively. When the size of the graphene sheets exceeds $3l0$, the tension-shear (TS) chain model that are widely used for nano composites fails to predict the overall mechanical properties of the graphene-based papers. The DTS is then applied to predict the mechanics of graphene-based paper materials under tensile loading. According to the results we thus obtain, optimal design strategies are provided for designing graphene papers with ultrahigh stiffness, strength and toughness. We discuss some aspects of how graphene could be used in mainstream electronic devices.

The main focus is on signal processing applications in high-volume, industrially manufactured battery-powered devices, e.g. mobile phones and laptop computers, but we will also discuss applicability to other components like interconnects, wireless communication antennae and camera sensors, as well as novel types of signal processing devices, based on the unique physical properties of graphene.

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