A NEW CARBON MATERIAL GRAPHENE AND ITS POTENTIAL APPLICATIONS

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ABSTRACT: The area of Carbon new material graphene tubule research has highly stimulated and attracted the researchers by the discovery of Carbon Nano Tubes. The CNTs can be constructed rolling sheet of a graphene into a cylinder and then doping it by pentagonal carbon rings. Graphene is a newly discovered two-dimensional allotropic form of Carbon. The high quality graphene is very strong, light, inflexible, nearly transparent and excellent conductor of heat and electricity. It has various electronic and optical properties. This article highlights some briefly review of their structure and unique properties.

Keywords: Graphite, Graphene, CNTs, Semi-Metal (Zero-Gap Semiconductor) etc.

1. INTRODUCTION

A groundbreaking experiments was carried out in 2004, by a team of great physicists of Manchester University, UK, led by Andre Geim and Konstantin Novoselov, used three dimensional graphite for their experiment and extracted a single sheet (a monolayer of atoms) of graphite, which was later on known as- 'Graphene'. They were awarded Nobel Prize in physics in 2010, for revolutionary of discovery of graphene. These discoveries led to an explosion of interest in graphene. A Graphene is one of the crystalline forms of carbon, like – Diamond Graphite, CNTs and C_{60}. Graphene is the recently discovered two-dimensional allotropic form of carbon. Prior to its three dimensional (Diamond and Graphite), One dimensional (Carbon nanotubes), Zero-dimensional fullerene (C_{60}). Graphene is a monolayer of carbon planar sheet of sp^2 bounded carbon atoms densely packed into honey-comb crystal structure. The carbon atoms are arranged in planar and hexagonal pattern in graphene. Graphene is easily visualized as an atomic-scale chicken wire made of carbon atoms and their bonds.

The Graphene has two atoms per units' cell. The carbon-carbon bond length in Graphene is approximately 1.42A^o or 0.142nm. Graphene sheets stacks to form graphite with an inter-planar spacing of 0.335 nm. Graphene is that basic structural elements of same carbon allotropes including Graphite, Charcoal, CNTs & C_{60}.

An electrons, in Graphene is behaves as massless and relativistic particles. So, it is called Dirac fermions.The electron-energy is linearly proportional to the wave ector, $E = k\,V_F$ where, $k = \frac{h}{2}$, and h is the Planck's constant, and V_F is the Fermi velocity of electron in Graphene. Recently, it has found that electrons in Graphene move with the velocity of the Fermi velocity V_F ($10^6 ms^{-1}$).

Although, it is a factor of 300 slower than the velocity of electrons in an ordinary conductor $10^{-3} ms^{-1}$.

As for Dirac particles with mass m, there is a gap between the minimal electron energy $E_0 = mc^2$, and the maximal position energy (E), when the electron energy $E \gg E_0$, then the energy is linearly dependent on the wave vector. But for massless Dirac fermions, the gap is zero and it linear dispersion law holds at any energy in this case, there is an intimate relation between the spin and angular motion of the particles.

II. PROPERTIES OF GRAPHENE

(a) ELECTRONIC

The transport measurement show that Graphene has remarkably high electron mobility at room temperature is 15×10^3 $cm^2\,V^{-1}\,S^{-1}$. It is found that motilities greater than 2×10^5 $cm^2\,v^{-1}\,s^{-1}$ are possible if extrinsic disorder can be eliminated, however doping does not influence the carries mobility in Graphene. Even for chemical dopant concentrations in excess of 10^{12} cm^{-2} there is no observable change in the carrier mobility. The corresponding resistivity of the Graphene sheet would be 10^{-6} Ωcm. This is less than the resistivity of the Silver, the lowest resistivity substance known at room temperature. Intrinsic Graphene is a zero gap semiconductor (semi-metal).

Despite the zero carrier density near the Dirac points, Graphene has minimum electrical conductivity of the order $4e^2/h$. The origin of this minimum conductivity is still not clear. However, most measurements are found to be of the order $4e^2/h$ or greater and depends upon impurity concentration. As in several theoretical calculations showed that the minimum electrical conductivity should be $4e^2/h$.

(b) OPTICAL

Graphene has unique optical properties. It produces an unexpected high opacity for atomic monolayer in vacuum, with a startlingly simple value, it absorbs = 2.3% of white light, where is the fine-structure constant. The bard gap ($E_{g)}$ of Graphene can be from 0 to 0.25eV, by applying voltage to a dual gate bi-layer Graphene Field Effect Transistor (FET) at room temperature.

Atomic Force Microscope (AFM) revealed that Graphene sheets are held together by Vander Waals forces. It is found that Graphene has a spring constant of the order 1-5 Nm^{-1} and its young's modulus was 0.5T Pa. These high values make Graphene very strong and rigid. These unique properties could lead to using it in applications as – pressure sensors & resonators.

(c) THERMAL

Thermal conductivity of Graphene is found to be between (4.84 -0.44) ×103 to (5.30 -0.48) ×103 $Wm^{-1}K^{-1}$ at room temperature. There measured values are greater than those measured for CNTs or diamond. This value is a factor of 100 larger than the thermal conductivity of Graphite.

(d) MECHANICAL

The Graphene is one of the strongest materials ever tested. Because, its breaking strength greater than 100 times than a hypothetical steel of same thickness with a tensile modulus of IT Pa. Graphene is very light weighing only 0.77 mg m^{-2}. The $1m^2$ Graphene hammock would support a 4 kg. cat.

III. POTENTIAL APPLICATIONS

A Graphene has several potential applications under development and many more have been proposed due to it peculiar properties like– light weight, strong, rigid, thin, flexibility etc. these applications are discuss as

(a) INTEGRATED CIRCUITS (ICs)

Graphene has the unique properties to be an excellent component of ICs. Graphene has a very high carrier mobility as well as low noise. The Graphene epitaxial grown on Silicon Carbon (SiC) is suitable for mass production of ICs. The Graphene-based ICs can handle frequencies up to 10 GHz, also up to temperature 127^0C.

(b) TRANSISTORS

Graphene can be used to make excellent transistors. The Graphene-based transistors can run at higher frequencies and more efficiently than silicon transistors. Graphene can be used to create world's smallest transistor.

(c) GAS SENSOR

Graphene can make an excellent sensor due to it 2D–structure. Since gaseous molecules cannot be readily absorbed onto Graphene surface, so intrinsically Graphene is insensitive. The sensitivity of graphene can be dramatically enhanced by coating with thin film of certain polymers. This thin polymer layer can acts like concentrator, which absorbs gaseous molecules. Thus, Graphene can be used to make gas sensor.

(d) FREQUENCY MULTIPLIER

Graphene can build a Graphene frequency multipliers that can take an incoming signal of a certain frequency and outputs a signal at a multiple of that frequency.

(e) ULTRA CAPACITORS

Graphene can be used to make ultra capacitors, due to its extremely high surface area to mass, so it its one of the application in the conductive plates ultra capacitors with greater energy storage density than currently available.

(f) MOLECULAR NET (SIEVES)

The open honeycomb structure of Graphene can be possible to use it as a net (Sieve) for atoms and small molecules. As only small objects of this size can be able to fit through the lattice. So it can be used in a way analogous to a filter paper, trapping large molecules and allowing smaller on to pass.

(g) TRANSPARENT CONDUCTING ELECTRODES

Graphene has high electrical conductivity and high optical transparency. So it can make use in making for transparent conducting electrodes which is required for applications in touch screens, liquid Crystal displays, Organic photovoltaic cells, Organic LEDs.

(h) SOLAR CELLS

Graphene has a unique combination of high electrical conductivity, so these properties make it a good candidate for the use in solar cells. The study found that unlike silicon, which generates only one current – driving electron for each photon it absorbs, graphene can produce multiple electrons. Thus, Solar made from graphene could have efficiency more than 60%, as silicon-based solar cells have efficiency about 30%.

IV. CONCLUSION

Graphene is the first 2D- Allotrope of Carbon. It is the absolutely new carbon materials. It has various peculiar properties. It is a fascinating class of materials with a variety of applications. It has some specific characteristics. It is a gapless semiconductor with a linear energy spectrum. The study of Graphene is a very challenging and fascinating both theoretically and experimentally in condensed matter physics as well as quantum field theory.

But due to its very promising applications and versatile characteristics the future of the Graphene looks very bright. Thus, Graphene provide a showcase in which the science and applications go side by side. Many physicists and researchers are working in this field; some new results may come in the half of this 21st Century. The day is not far when the Graphene will prove to be worthy companions to human beings.

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