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GRAPHENE: CARBON MATERIAL FOR NANOELECTRONICS

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ABSTRACT

The new revolution in semiconductor industry is due to use of carbon allotropes in electronics. Graphene is one of the carbon nanoallotrope that has the potential to replace traditional materials in nanoelectronics. The use of this 2D crystal is nanoelectronics is due to its typical properties that provides improved performance, extended functionality over Silicon era. In this paper, a review is done to study 3D graphite, 0D Fullerenes, 1D Carbon naotubes and Graphene Nanoribbon for which graphene serves as building block along with the applications for which graphene is used.

Keywords: Carbon , Carbon Nanotubes, Fullerenes, Graphene , Graphene Nanoribbon , Nanoelectronics

I. INTRODUCTION

The thinnest element from the carbon family which provide revolutionary in research field of 21st century is Graphene. It is said that "20th century is the age of Plastic whereas 21st century is the age of Graphene". A single atom thick element introduces an outbreak in research field because of its typical properties [1]. The explosion in semiconductor industry due to graphene is because of two great scientists named as Kostya Noveselov and Andre Geim. In 2003, the two scientists started their research in potential for graphene by the motivation provided by Landau and Peierls who in their analysis proposed that 2D crystals are unstable . The key element in their research is one of the basic carbon allotrope i.e. Graphite. Andre and Geim in their experiment took a block of graphite, sticky tape called as scotch tape and applied this tape on the graphite block and when they removed the tape they noticed some flakes. They started collecting these flakes and with consistent efforts they introduced a new material, graphene which is stronger from all other carbon allotropes, thinner than paper and even conductive at best. The main aspect of Graphene is that it is only one atom thick. The pair published their findings in 2004 and for this they

were rewarded by Nobel Prize in 2010 [2]. The two continued their efforts by examining Graphene using different techniques to visualize their properties.

II. GRAPHENE DERIVED STRUCTURE

Graphene is a honeycomb lattice of tightly packed pure carbon atoms arranged in hexagonal shape. This Carbon structure of Graphene is sp^2 hybridised [3]. The 2D structure of Graphene serves as building block to various carbon forms like 0D fullerenes, 3D graphite, 1D Carbon Nanotubes and Graphene Nanoribbons.

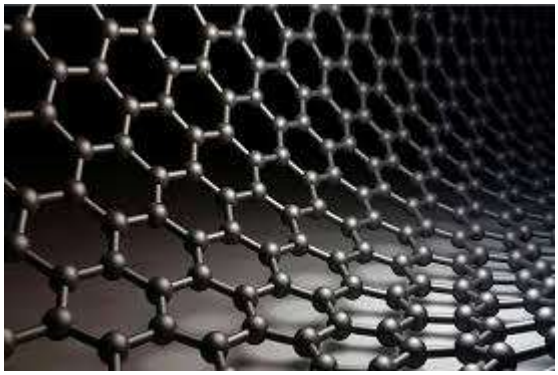

Fig 1: Graphene Sheet

1.1 Graphite

Graphite is one of the allotrope of carbon. It is classified either as natural or synthetic graphite depending on the applications for which it is used. Its natural form is extracted from the metamorphic rock. It can also be formed from the 2D graphene sheets arranged in a stack which means arrangement of grapheme layers one on the other. However graphite is different from graphene. It's three dimensional (3D) structure is useful in various applications like in pencils, batteries, metallurgy, rods and as lubricants [4].

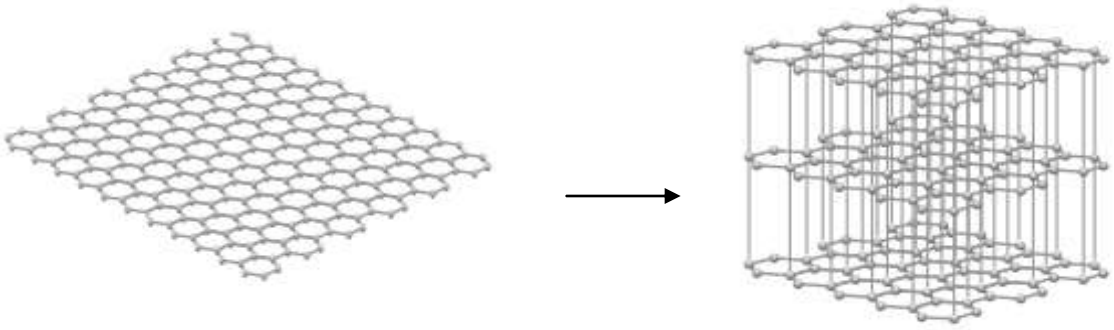

Fig 2: Graphite Formed From Graphene Sheet

1.2 Fullerenes

Fullerenes are the carbon composed allotropes , discovered in 1985. The first ever fullerene molecule is known as Buckminsterfullerene named after Buckminster fuller. Afterwards, another carbon molecule C_{70} (70 carbon atoms), C_{76} (76 carbon atoms), C_{82} (82carbon atoms) are introduced in fullerene family. But Buckminster fullerene remains the most popular one and now known as Bucky ball C_{60} containing 60 carbon atoms [5]. This carbon molecule can be formed from the 3D graphite or 2D graphene. The transformation of graphene sheet to fullerene is on basis of top down mechanism. In which graphene sheet is firstly etched that leads to formation of pentagons in graphene. This flat graphene is then curved to form bowl shaped structure in which open edges are locked to formed closed fullerene [6].

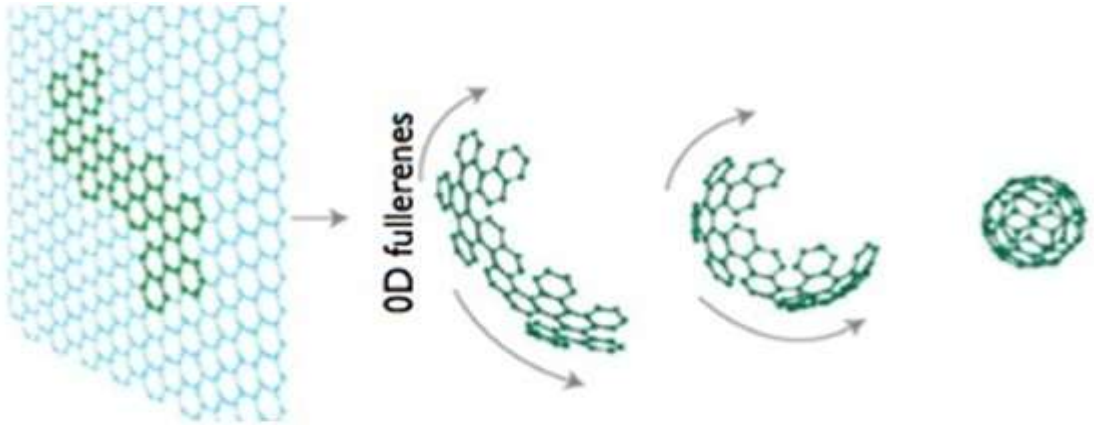

Fig 3: Formation of Fullerene from Graphene

1.3 Carbon Nanotubes

A new candidate in carbon family that provides its use in Nanoelectronics, Science and Optics is one dimensional carbon nanotubes. These 1D CNT's are invented in 1991. For these structures, graphene serves as a building block. The CNT's structures are formed by rolling up of graphene sheet into carbon cylinder [7]. The wrapping of one sheet of graphene forms a Single Wall Carbon Nanotube (SWNT) that has properties of both metals and semiconductor based on the diameter of the seamless cylinder. However, rolling of multi-layers of graphene forms MWNT characterized as either Russian Doll Model in which graphene sheet forms concentric cylinders of varying diameter or Parchment Model in which graphene sheet is rolled around itself [8].

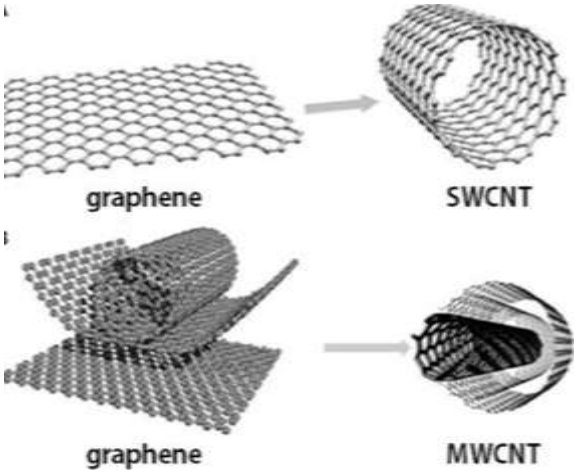

Fig 4: Single and Multiwall Carbon Nanotubes

1.4 Graphene Nanoribbon

Graphene Nanoribbons are the thin width strips of graphene that are formed to study characteristics of graphene at the nanoscale. These 1D carbon crystals are classified as either Zigzag GNR or Armchair GNR depending on the Edge structures. The both types of GNR's exhibits different electronic states that is dependent on the width of the strip [9]. Thus on the virtue of these states that is either metallic or semiconducting, these are used in different electronic applications.

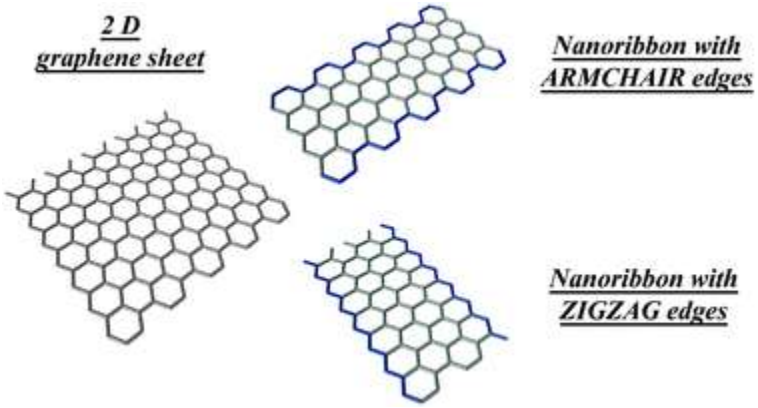

Fig 5: Zigzag and Armchair GNR

III. GRAPHENE BASED ELECTRONICS

Graphene is an important electronic component because of its unique properties. The 2D crystal has high conductivity, more strength than that of steel , high elasticity and stiffness [10]. Its potential applications in electronics includes its use in Mobile touch screens which replaces costly indium based electrodes and make devices

more ecofriendly. To save the power consumption it is widely used in batteries as graphene anode that provides faster recharge capacity. Graphene also has the capability to replace traditional Silicon from the integrated circuits . The research is still going on to use graphene in designing of high frequency transistors and logic transistors. Graphene is also suitable for photo electronic devices. Its wide spectral range provides its use for photodetectors and optical modulators [11].

IV. CONCLUSION

The future electronics is based on the Nanoelectronics. Graphene serves as a promising candidate for nanoelectronics devices. Various nanomaterials like CNTs, Fullerenes and GNRs can be formed from graphene. It is widely used in electronic applications because of its typical mechanical and electrical properties. But the researchers are still working to make it more efficient so that it can replace silicon because miniaturization of silicon is not possible at nanoscale.

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