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# Graphene: Carbon Based Nanomaterial for Dentistry

**Dr. Japneet Randhawa**
BDS
Dr Harvansh Singh Judge Institute of Dental Sciences & Hospital
Panjab University,Chandigarh

## ABSTRACT

*The new revolution in dental materials is due to use of nanomaterials in dentistry. Graphene is one of the carbon nanoallotrope that has the potential to enhance properties of materials used in dentistry. The use of this 2D crystal is dentistry is virtue to its typical properties that provides improved performance, extended functionality in materials. In this paper, a review is done to study 3D graphite, 0D Fullerenes, 1D Carbon nanotubes 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 , Dentistry***

## I. INTRODUCTION

The thinnest element from the carbon family which provide revolutionary in research field of 21$^{st}$ century is Graphene. It is said that "20$^{th}$ century is the age of Plastic whereas 21$^{st}$ 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 material science 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.Recently, biomedical researchers have begun to exploit these unique properties of graphene and its derivative materials, opening a totally new research avenues in biomaterials, tissue engineering, and regenerative medicine [1,2]. In this perspective article, we will highlight the graphene-based materials for applications in dentistry and suggest perspective on potential future directions.

## II. GRAPHENE 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.

### 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].

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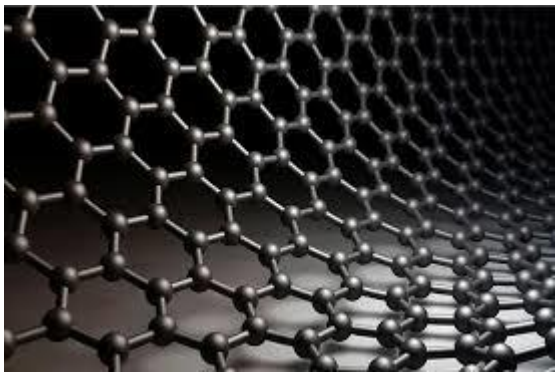

Fig 1: Graphene Sheet

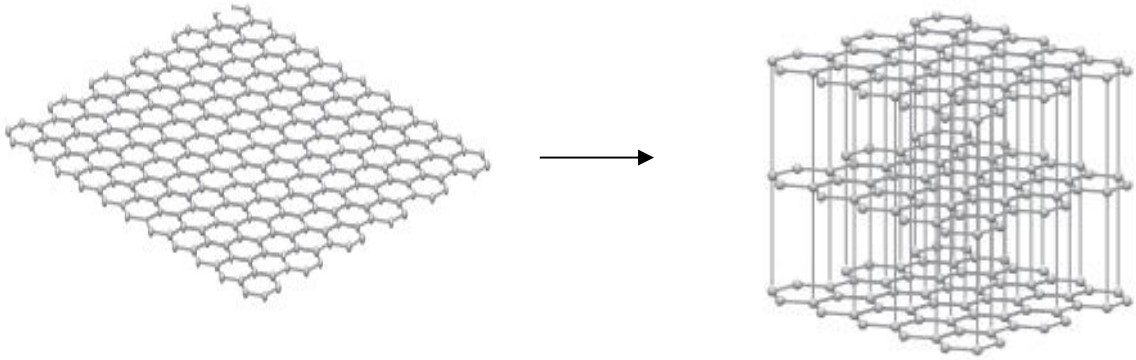

Fig 2: Graphite formed from Graphene Sheet

**1.2 Fullerenes**

Fullerenes are the carbon composed allotropes , discovered in 1985. The first ever fullerene molecule is known as Buckminsterfullerene named after Buckminster fullerene. 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].

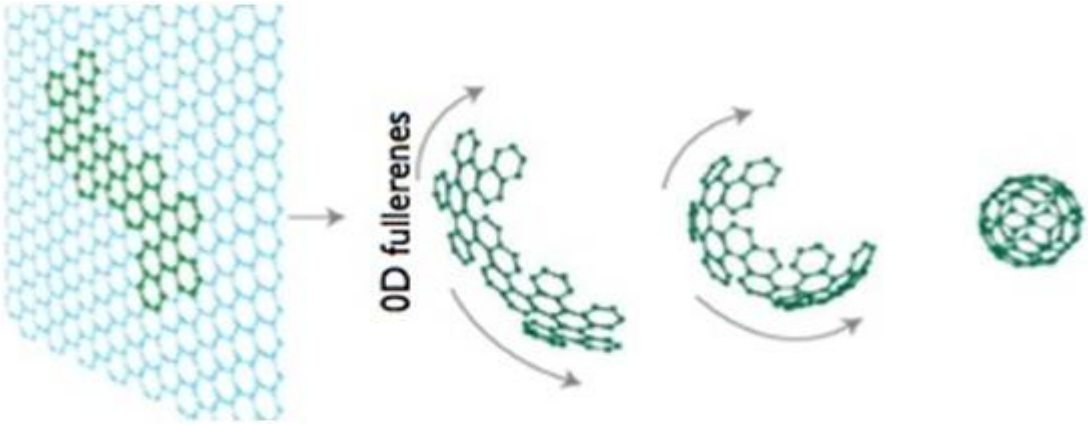


Fig 3: Formation of Fullerene from Graphene

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### 1.3 Carbon Nanotubes

A new candidate in carbon family that provides its use in dentistry 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].

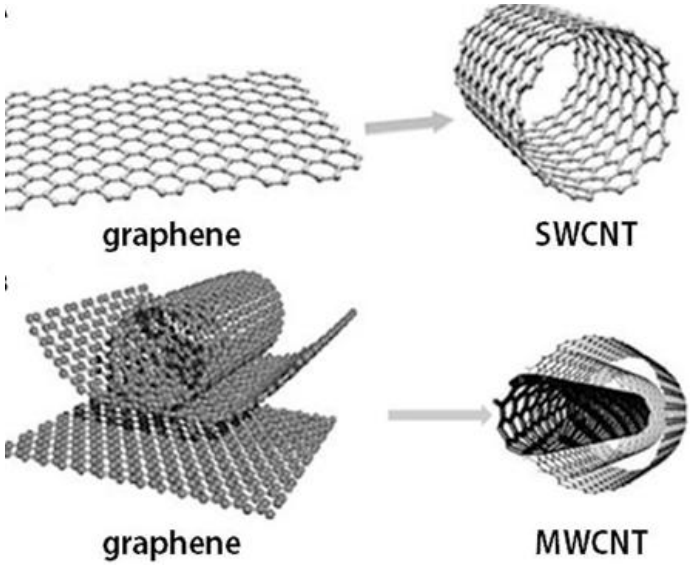


Fig 4: Single and Multiwall Carbon Nanotubes

### 1.4 Graphene Nanoribbon

Graphene Nanoribbons are the thin 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.

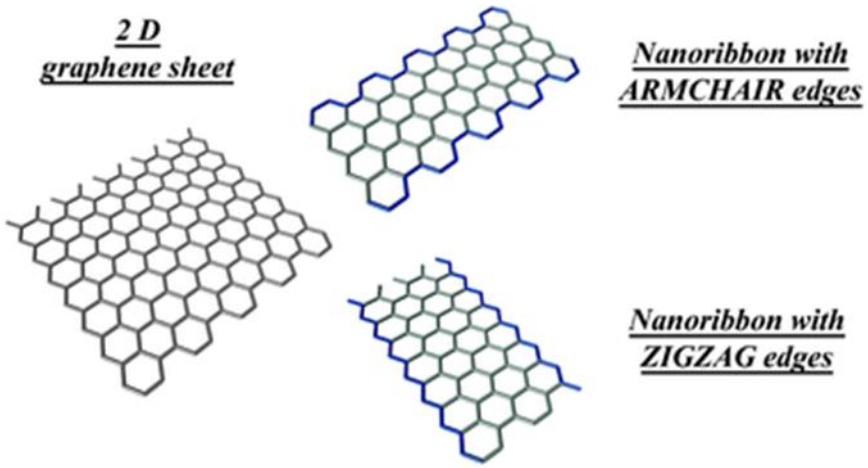


Fig 5: Zigzag and Armchair GNR

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## III. GRAPHENE IN DENTISTRY

A fundamental aspect in the fabrication of dental materials is the appropriate measure for preventing mechanical failure. Studies have examined the effect of graphene-related carbon allotropes on implant mechanical properties. It was shown that silicatized titanium (Ti) plates had higher bond strength and good adhesion with carbon-graphite fiber-reinforced (CGFR) polymer than the sandblasted counterpart [10]. Another important challenge in the dental materials is the formation of oral biofilms and aggregation of primary etiological agents on the implant surface. To overcome this hindrance, researchers have attempted various surface coatings to achieve antibacterial properties. One recent study pursued graphene-based surface coating, i.e., coating of artificial acrylic teeth surface with non-toxic graphene/zinc oxide nanocomposite, and observed a substantial decrease in the deposition of the carcinogenic S. mutans bacteria and biofilm formation [11]. Recent studies have evidenced that graphene and related materials, e.g., graphene oxide (GO) and reduced graphene oxide (rGO), may provide excellent blends in dental materials to improve osteointegration.

## IV. CONCLUSION

The future dentistry is based on the blending of nanomaterials with dental materials to enhance their properties. Graphene serves as a promising nanomaterial to improve performance of dental materials. Various nanomaterials like CNTs, Fullerenes and GNRs can be formed from graphene. It will be widely used as dental material because of its typical mechanical and chemical properties. Self-assembling and biocompatible carbon based nanomaterials can be used as dental fillers, implant coatings and bone substitution. They also form basis of innovation of smart materials that stimulate growth and differentiation. While studies highlighted above strongly suggest that graphene and related derivative materials would become high performance coating materials for dental and orthopaedic implants, it is still in the very early stage in both underlying science and practical applications with several issues to be explored.

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