Structure,texture, electrochemical properties of carbon materials-I

Introduction

Carbon materials have always played important roles for human beings, charcoal as heat source and adsorbent since prehistoric era, flaky natural graphite powder as pencil lead, soots in black ink for the development of communication techniques, graphite electrodes for steel production, carbon blacks for reinforcing the tires in order to develop motorization, membrane switches for making computers and control panels thinner and lighter, etc. In electrochemistry, electric conductive carbon roads and carbon blacks support the development of primary battaries; a compound of graphite with fluorine, graphite fluoride, improved the performance of primary batteries; and the reaction of lithium intercalation/deintercalation into the galleries of graphite was greatly promoting the developed of lithium-ion rechargeable batteries. Carbon nanotubes and fullerenes developed recently are promoting the development of nanotechnology in various fields of science and engineering.

Historical and Chemical Background of Some Carbon Allotropes

Carbon materials are predominantly composed of carbon atoms, only one kind of element, but they have largely diverse structures and properties. Diamond has a three-dimentional structure and graphite has a two-dimensional nature, whereas carbon nanotubes are one-dimensional and buckminsterfullerene C_{60} is zero-dimensional. Fullerenes behave as molecules, although other carbon materials do not. Graphite is an good electric conductor, whereas diamond is completely insulating. Diamond which is the hardest material is used for cutting tools, and graphite is so soft that it can be used as a lubricant.

For a very long period of time, carbon is conventionally known to exist in two natural crystalline allotropic forms commonly known as graphite and diamond. However, the chemistry of these two substances differs more importantly in crystal structures and properties. Chemically speaking, many other allotropes can be formed due to the valence of carbon atoms. This occurred when carbon atoms form covalent bonds with another carbon atom. To easily understand this phenomenon, allotropes are elements which are chemically identical but vary strikingly in their physical properties. Therefore, when the atoms in substance that have only one type of atom are organized in a different way than an allotrope is established.

For this reason, several other allotropes and forms of carbon were discovered (Figure 1) such as grapheme, fullerene, carbon nanotubes etc., hence making carbon to have the highest number of identified allotropes when compared to any other material.

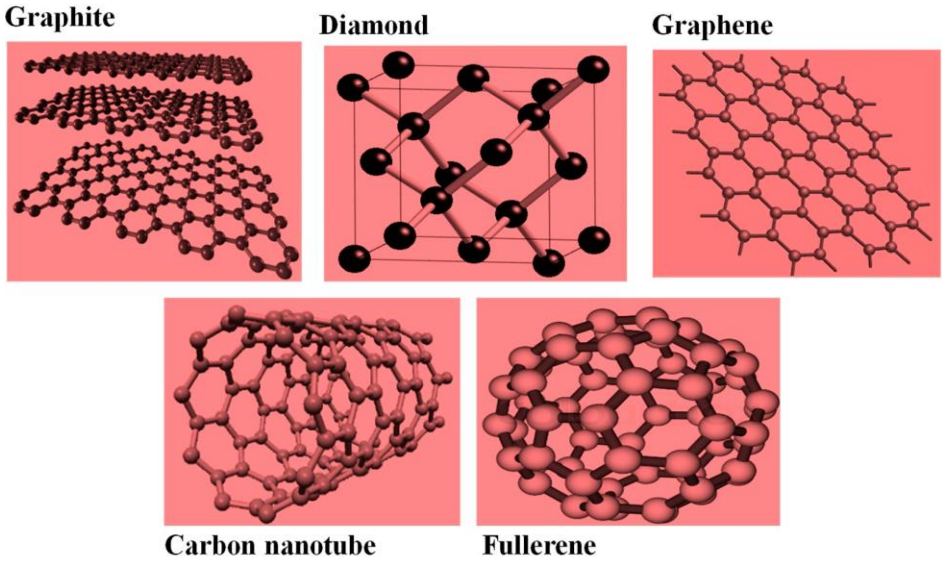

Fig.1. Structural illustration of some 0-, 1-, 2- and 3-dimensional carbon nanomaterials with sp^2 and sp^3 hybridization allotropes occurring in different crystallographic form

Graphite

The word graphite was reported to have been derived from the primordial Greek word 'graphein' It was named by Abraham Gottlob Werner in 1789 and consists of carbon atoms connected together in huge flat networks that are piled on top of each other. This allotrope of carbon is an excellent electrical conductor making it a very good material for electrode in an electrical arc lamp. The ability to conduct electricity occurs as a result of delocalization of π-electrons of the carbon atoms in graphite, a phenomenon that is not feasible in diamond. Hence, diamond cannot conduct electricity due to the restricted movement of the electrons in its lattice arrangement. It has been established that graphite is the most stable form of carbon under standard conditions. The first synthetic graphite was produced by an American scientist, Edward Acheson in 1896.

The material (graphite) is characterized with a marked lustrous black sheen feature and experimentally tested to be very flexible but non-elastic. It is also known to possess the properties of both metals and non-metals, with high thermal and electrical conductivity, chemically inert and physically greyish-black and opaque in nature. The basis for all of the aforementioned remarkable properties could be attributed to its crystal structure. It is interesting to also note that the carbon atoms in graphite are structurally arranged hexagonally in a planar condensed ring system.

Moreover, the layers are piled parallel to each other and a covalent bond strongly held the atoms together within the rings. On the contrary, the layers are slackly bonded together by van der Waals forces. Based on this inter-layer weakness caused by the attractive part of the van der Waals forces, the layers are therefore capable to move past each other and this is the reason for soft and slippery physical property of graphite, which in effect make it a good lubricating material in dynamos and electric motors. In summary, graphite can be found mainly with a flaky morphology. Despite the difficulty of preparing graphite nanoparticles or nanosheets, however, in 2002 a new process was successfully developed that was effectively used to exfoliate natural flake graphite into nanosheets with thickness ranging from 30 to 80 nm.

References

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