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Various Useful Available Forms of Carbon Material and their Applications

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Abstract

Carbon material provides a large range of properties suitable for different kind of applications useful in several fields which are directly influencing our life and making ease in our life. A large range of products made using carbon material have been developed by modifying the properties of material and using different forms of carbon material. As the material behaviour can change upon surrounding exposure, therefore the effect of surrounding radiation and change in properties of the material are also interesting to investigate. Most of the research and development work in the field of carbon technology has been carried out in United States of America, Germany, France and England. Considering attractive properties of carbon material, India, China and Korea also have started working in the field of carbon technology. But society can only be benefitted by these products developed so far, if the industries are established to produce cost effective carbon material products. Present paper deals with the study of various forms of carbon material and their applications.

Keywords: Carbon material, graphite, fullerenes, nanotubes, applications.

1. Introduction

Carbon technology being a recent technology in the field of material science is an emerging field of research and development for material applications. Most of the forms of carbon material are developed by controlling processing conditions. Amorphous and crystalline forms of carbon material are obtained using suitable processing steps. Diamond is well known form of carbon material but graphite, fullerenes, carbon nanotubes, carbon nano beads, carbon foam, carbon/carbon composites etc are also important forms of carbon material of 21st century required in various applications. Carbon materials have a wide range of applications ^[1] in the area of electrical, metallurgical, medical science, high-tech aerospace, nuclear reactors and in petroleum refining. Carbon material shows high resistance to chemical attack, low friction and wear etc, good thermal and electrical conductivity, good thermal shock resistance. Carbon fibres are unique material because of non-reacting nature with corrosive environment, except oxygen, at moderately high temperature. A large spectrum of the fibres is available each having unique mechanical properties i.e., high modulus, high strength etc.

Specific properties can be achieved from the carbon fibres when these are used to develop in the form of carbon composites by controlling the manufacturing process and the matrix material. Fibres are used as per the requirement of the final properties of the composites. Obtaining optimum physical properties plays a great role in the development of carbon material that is why various properties i.e., physical, mechanical, thermal and fracture behaviour are required to be measured again and again during research and development work and then further modifications are done in manufacturing process to reach up to the specific properties. Thermal conductivity can be suitably adjusted through the choice of fibre reinforcements, matrix carbon and processing conditions.

2. Methodology and Discussion

Objective of the paper is to discuss various forms of carbon material. Each form of carbon material shows specific properties. Accordingly, these forms are found suitable to make

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variety of products useful in different sectors. Here an attempt has been done to show the scope of carbon material and products of carbon material in India which will be useful for future researcher in this field.

3. Range of carbon material and applications

Carbon material are characterized for Physical, electrical and thermal properties using micro thermal Analysis (MTA), SEM, TEM, Atomic force microscopy (AFM) using optical microscope and X- Ray diffractometer. Table 1 shows few important forms of carbon material and their applications for which detailed discussion is given below-

3.1 Diamond, graphite and graphene

Table 1: Various forms of carbon material and their applications.

Sr. No.	Carbon Material	Application areas
1	Diamond	Jewellery, cutting tools like glass cutter etc.
2	Graphite	Electrodes, used as lubricant
3	Graphene	Electronics, medicine, desalination, coatings
4	Fullerenes	Biomedical field, cosmetic formulations
5	Carbon Nanotubes	Pharmaceutical, Electronics, structural reinforcement
6	Carbon nanobeads	In lithium batteries, provides large surface area for chemical reaction, structural reinforcement
7	Carbon membrane	In semiconductors, dairy food and beverages industry
8	Carbon foam	Energy storage materials, insulation material, adsorbents, catalyst support
9	Carbon fibres	Reinforcement material for making products used in various industries like electronics, telecommunication, entertainment
10	Carbon/carbon composites	Aerospace, defence, sports, infrastructure and transportation etc.

3.2 Fullerenes, nanotubes and nanobeads

Fullerenes are spherical caged molecules with carbon atoms located at the corner of polyhedral structure. Buckminster fullerene C₆₀ has 12 pentagon, 20 hexagons and 30 double bonds on the curved surface.

C₆₀ doped with alkali metals shows superconductivity at low temperatures (approx. 30K). This physical property shows that in future this material can be used to increase the speed of computers for faster data transfer. Physical properties allow it to have the application in medical field. Another use of fullerene is to protect nerve cells from damages caused by stroke, spinal injury, Alzheimer and other disease. Fullerene derivatives can be used in optical devices, gas separation devices, batteries, catalysts, hydrogen storage medium, disintegrating polymers etc.

The discovery of carbon nanotubes by Iijima^[2] created much excitement. This stimulated extensive research into the properties of nanometer scale cylindrical carbon networks. Each layer of carbon nanotube is made of a cylindrical graphene sheet with an interlayer spacing of 3.4 Å. The multiwalled nanotubes have diameter 0.6-11 Å and number of concentric shells 2 to 50. The studies of nanotubes have predicted that they will have unusual mechanical, electrical and magnetic properties of fundamental scientific interest and possibly of technological importance.

Potential application for them as one-dimensional conductors, reinforcing fibres, super strong composite materials, adsorption material for gases such as hydrogen have been suggested. Due to strength and other attractive properties nanotubes can be used with other material to make composite material for sports equipment. Carbon nanotubes and carbon nanobeads both can be synthesized by chemical vapor deposition. Carbon nanobeads are also

Diamond and graphite are made of carbon atoms but due to difference in processing mechanism and surrounding conditions both shows unique properties. Diamond is the hardest material whereas graphite is the softest carbon material. Diamond is insulator to the electrical conduction whereas graphite is good conductor of electricity. Diamond is used in jewellery, drilling tools, cutting and polishing whereas graphite is used in nuclear reactors, stationery, industries etc. Graphite retains its dimensional stability at very high temperatures (approx.3000 degree Celsius). Graphene structure consists arrangement of single layer of carbon atoms which are joined by covalent bonds. It is actually a single layer of graphite. Graphene is used in electronics, medicine, desalination, coatings etc.

nano sized particles which are used in lithium batteries, provides large surface area for chemical reaction and is used as structural reinforcement.

3.3 Carbon molecular sieves (CMS)

Another amorphous form of carbon material is known as carbon molecular sieves which have micro pores similar to the critical dimension of small molecules. Pore size in this material when measured is found from 3 to 12 Å. Pore volumes 0.2 to 0.5 cm³/g and surface areas from 300 to 500 m²/g. Due to this, CMS has the ability to separate the absorbing molecules on the basis of size and shapes. Shape selectivity offer potential as adsorbent^[3], catalyst and catalyst support. Indian Institute of Petroleum, Dehradun has been working on pitch based advanced and futuristic carbon material.

3.4 Carbon Membrane

Carbon membrane^[4] may find their applications in semiconductors, dairy food and beverages industry also. Carbon membrane has several inherent advantages over conventional polymeric membrane like superior thermal stability, chemical inertness, core dimensions and superior absorptivity.

3.5 Carbon foam

Carbon foam^[5] can be a good substitute of metals as it is four to five times more conductive than copper and aluminium. The high thermal conductivity of carbon foam can be exploited for its use as heat exchanger for car radiator. It also has open porosity and gives large surface area (>20 m²/g) for better heat transfer management.

3.6 Carbon fibre and composites

Carbon fibres are produced from polyacrylonitrile (PAN)^[6], petroleum pitch or from rayon. The organic polymers are converted in forms of fibres then these fibres are heat treated up to different temperatures in inert atmosphere to obtain carbon fibres. Carbon fibres exhibit even a slight increase in strength at temperature upto 2200-2800°C depending on the precursor material and the heat treatment temperature used during manufacturing. Carbon fibres demonstrate a unique combination of properties and are ideally suited for making products used in various industries like electronics, telecommunication, entertainment, sports, infrastructure and transportation. Carbon fibre-based plastic housing used for cell phone, electronic gadgets, laptop, computers has the shielding capability required to withstand electromagnetic and radio frequency interference.

Carbon fibre composites^[7] are stronger than steel, lighter than aluminium and have superior fatigue properties. Various ceramic matrix composites containing carbon fibres can be used at very high operating temperature without much property degradation.

Carbon fibre reinforced aluminium matrix composites are very attractive for structural applications due to their high specific strength, high modulus and zero Coefficient of Thermal Expansion (CTE).

Few special types of composites are as: -

1. Carbon fibre reinforced polymer composites
2. Carbon-Carbon composites
3. Metal matrix composites
4. Ceramic matrix composites

Industrial application of carbon composites are increasing day by day in India. Aggressive expansion of aircraft and space applications are another field in which carbon material is used in large scale. Emerging application of carbon fibre composites have increased Indian Carbon fibre market in recent time; but there are various major challenges which restricts the use of carbon fibre which are as follows-

- Harmful emissions from carbon fibre.
- Lack of technological expertise.
- Lack of skilled labour.
- Increasing raw material price.

Indian carbon fibre market is also influenced by crude oil prices, automobile industries, urban population in India and GDP per capita each year.

3.7 Carbon black

Carbon black is also amorphous form of carbon material available in powder form. It is widely used in tire industry and rubber industry. Carbon black is also used in inks, paints, plastics. It is used in photocopier and laser printer toner.

National Physical Laboratory (NPL) New Delhi, Graphite India Limited Bhopal and Bangalore in India have basic research and development facilities to develop carbon material products. These Research and development centres have contributed a lot in this field.

4. Conclusions

There are a large range of carbon material. Development of different forms of carbon material has direct correlation

with the processing conditions. Physics provides techniques and devices to measure the various properties of carbon material. Without proper measurement it is not possible to develop the material according to the application. There are opportunities to develop cheap carbon material and technology to manufacture products to be useful for the common citizen. Awareness of technology is necessary to the common citizen to start the thought process and to get the suitable area of application.

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