

**Nano structured materials-synthesis, properties, self assembly and applications  
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**MODULE 3 (LECTURE 1, 2, 3): Carbon nanotubes and fullerenes**

***Problem :***

1. What are the different forms of carbon.
2. C<sub>60</sub> was predicted first time by....
3. C<sub>60</sub> was discovered by.....
4. What are the different types of fullerenes.
5. What is the structure of C<sub>60</sub>.
6. What is Euler's polyhedron formula.
7. What are the different techniques used in synthesis of fullerene.
8. What would fit inside a buckyball.
9. Define endohedral and exohedral compounds.
10. Properties of fullerenes.
11. What are the commercial and biological applications of fullerenes.
12. What are carbon nanotubes.
13. Carbon nanotubes are made of.....
14. Differentiate between graphite and graphene.
15. CNTs composed of sp<sup>2</sup> bonds(T/F).
16. How naming of CNTs are done.
17. Define arm-chair, zig-zag and chiral nanotubes.
18. What are the properties of CNTs.
19. What is the general rules of metallicity of SWNTs.
20. What are the different techniques for synthesis of CNTs.
21. Potential applications of CNTs

## MODULE 3 (LECTURE 1, 2, 3): Carbon nanotubes and fullerenes

### **Solution :**

1. Diamond, graphite and amorphous (non-crystalline carbon)
2. Eiji Osawa from Toyohashi University of Technology in 1970
3. Harold Kroto, James R. Heath, Sean O'Brien, Robert Curl and Richard Smalley from Rice University in 1985.
4. Buckyball clusters, nanotubes, megatubes, fullerene rings, nano onions, linked ball and chain dimers.
5. Three dimensional network of carbon atoms containing pentagonal and hexagonal rings in which no two pentagons share an edge. Each atom is bonded by two single bonds and one double bond.
6.  $V - E + F = 2$  (V, E, F are the numbers of vertices, edges, and faces).
7. Soot from vaporizing graphite with laser, arc discharge method, pyrolysis of aromatic compounds.
8. Particle size smaller than 0.12 nm will fit inside a buckyball.
9. Fullerenes with material inside are called endohedral compounds. Exohedral compounds are organic or inorganic groups present exterior to the cage.
10. Bounce back to their original shape after subjected to pressure, good material as catalyst, possess interesting electrical properties, drug delivery.
11. Commercial and biological applications: sunscreens, antibacterials, superconducting materials.
12. Allotropes of carbon with a cylindrical nanostructure.
13. Composed of one atom thick sheets of carbon, called graphene.
14. Graphene, two-dimensional material, is a one atom thick plane of graphite. Graphite, three-dimensional material, is a stack of graphene planes sitting one on top of each other.
15. True.
16. There is a straightforward labelling convention to distinguish differently wrapped tubes from one another. The mapping specifies the number of unit vectors required to connect two atoms in the planar hexagonal lattice to form a seamless tube. These numbers specify a "vector" for the mapping, commonly expressed as (m,n), where m and n are integers. These numbers constitute a unique "name" for a tube.
17. Any tube "named" (n,0) has carbon-carbon bonds that are parallel to the tube axis, and form at an open end a "zig-zag" pattern, these tubes are referred to as "zig-zag" tubes. Tubes named (n,n), where the two integers are equal, have carbon-carbon bonds that are perpendicular to the tube axis, and are called "armchair" tubes. These two basic types are achiral, meaning they do not have a distinct mirror-image, like left and right hands. All the other tubes, named (m,n), where m does not equal n, and neither is 0, are chiral, and have left-and-right-handed variants.
18. Very high current carrying capacity, excellent field emitter, high electrical conductivity.
19. (n,n) tubes are metal

(n,m) tubes with  $n-m = 3j$ , where  $j$  is a non-zero integer, tiny gap semiconductors

All others large gap semiconductors

20. Arc discharge, laser ablation, chemical vapour deposition, high pressure carbon monoxide
21. Field effect transistors, logic gates, conductive plastics, textile industry, gas storage, antifouling paint etc