CARBON NANO TUBES

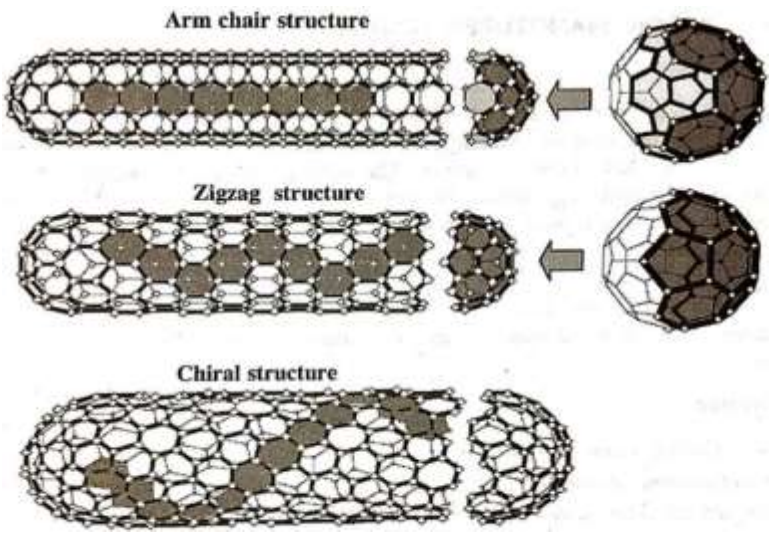
- The discovery of carbon leads to form stable, ordered structures other than graphite and diamond.
- Researchers found that carbon-60 (C_{60}) is used to produce carbon nanotubes (CNT).
- The CNT have remarkable electronic properties and many other unique characteristics.
- **Definition:** Carbon nanotubes (CNT) are molecular-scale tubes of graphitic carbon with outstanding properties. They are among the stiffest and strongest fibers researched till date with remarkable electronic properties and application.

TYPES

- Carbon nano tubes are of three types.
  1. Single walled nano-tubes (SWNTs)
  2. Multi walled nano-tubes (MWNTs)
  3. Single walled nano-horns (SWNHs)

STRUCTURE

- There are three structures based on the rolling of a graphene sheets into tube with different orientations about the axis .
  1. Armchair structure 2. Zig-zag structure 3. Chiral structure



- Here, the armchair and zig-zag structures have a high degree of symmetry.
- The terms “armchair” and “zig-zag” refer to the arrangement of hexagons around the circumference.
- The “chiral” term means that it can exist in two mirror-related forms.

FABRICATION OF CARBON NANOTUBES:

Carbon nano tubes can be fabricated by any one of the following methods.

(i) Pulsed laser deposition (or) laser synthesis

(ii) Carbon Arc method

(iii) Chemical vapour deposition

PULSED LASER DEPOSITION

Principle: The technique of laser heat treatment is used in the preparation of carbon nano tubes

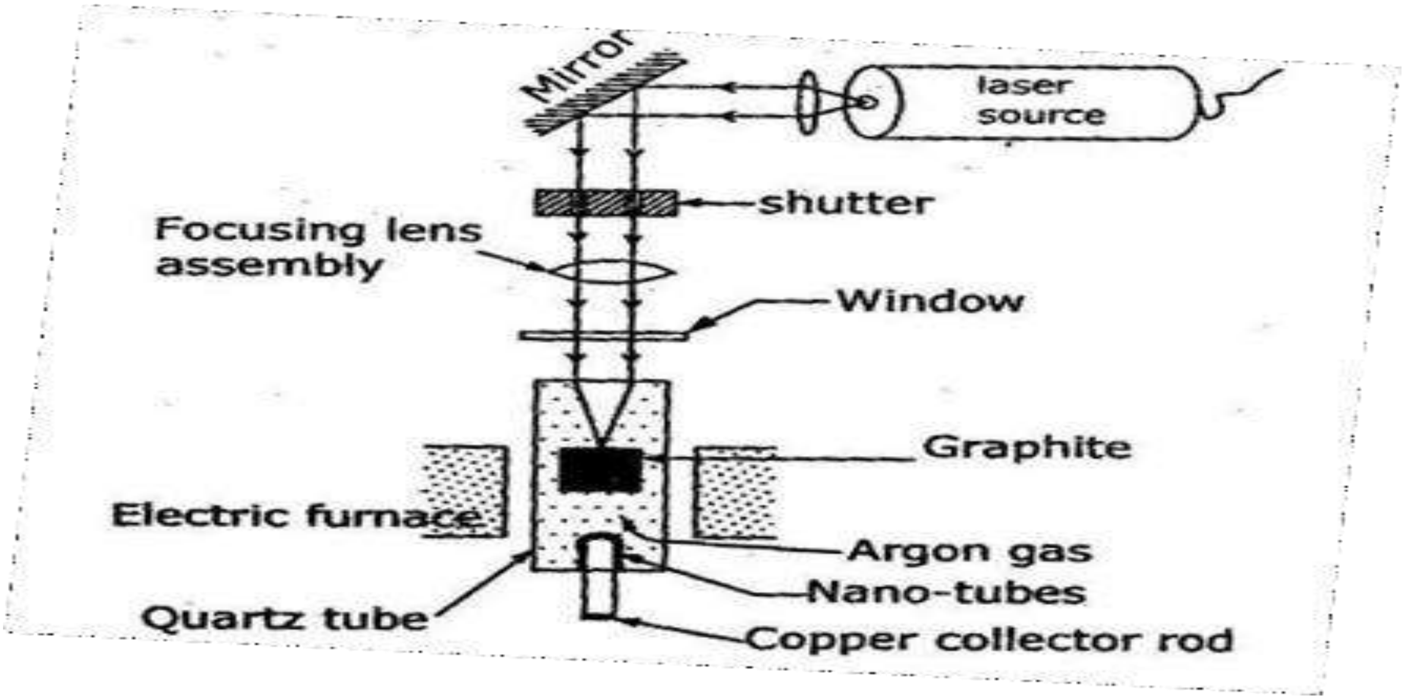
Construction:

- The experimental setup consists of a quartz tube containing a graphite target.
- The tube is surrounded by electric furnace to heat the target.
- Along with this a laser source is used to produce laser beam.
- The intensity of the laser beam is controlled by a shutter and an assembly of lens is

  used to effectively focus the laser beam on to the target.
- The graphite is heated upto 1200°C with the help of electric furnace.Then the laser

  source is switched on.

Diagram:



Working:

- The light reflected by the plane mirror is made to pass through the shutter.
- The intensity of the laser beam is controlled by the shutter.
- The lens assembly focuses the light on to the window and is made to incident on the graphite. Due to laser heating the graphite gets heated and evaporates carbon atoms.
- The argon gas present insides the quartz tube is used to sweep the carbon atoms towards the colder copper collector rod.
- Due to the movement of the carbon atoms from a higher temperature region to lower temperature region it gets condensed and hence carbon nano tubes are formed over the collector rod.

PROPERTIES

1. CNTs have high electrical conductivity.
2. CNTs are good electron field emitters.
3. The energy band gap decreases with increase of diameter of CNTs.
4. CNTs have very high tensile strength.
5. CNTs are highly flexible (can be bent considerably without damage).
6. CNTs are very elastic.
7. CNTs have ability to withstand extreme strain.
8. CNTs provide high resistant to any chemical reaction.
9. CNTs have high thermal conductivity.
10. CNTs have a low thermal expansion coefficient.

APPLICATIONS

1. They are used in aerospace because of its light weight and strength.
2. They are used in the construction of nano scale electronic devices.
3. They are used in battery electrodes, fuel cells and reinforcing fibers.
4. They are used in the development of flat panel displays in television and computer displays.
5. They are used as a light weight shielding materials for protecting electromagnetic radiation.
6. Semiconducting CNTs are used in switching devices.
7. Semiconducting CNTs are used as chemical sensors to detect various gases.
8. They serve as catalyst for some chemical reaction.
9. They are used in military and communication systems for protecting computers and electronic devices.
10. By using CNTs in future it is possible to produce nano-computers, plastic composite, etc.,
11. They are used as interconnects in chip.
12. They are used in the development of fuel cells.

MAGNETIC SEMICONDUCTORS

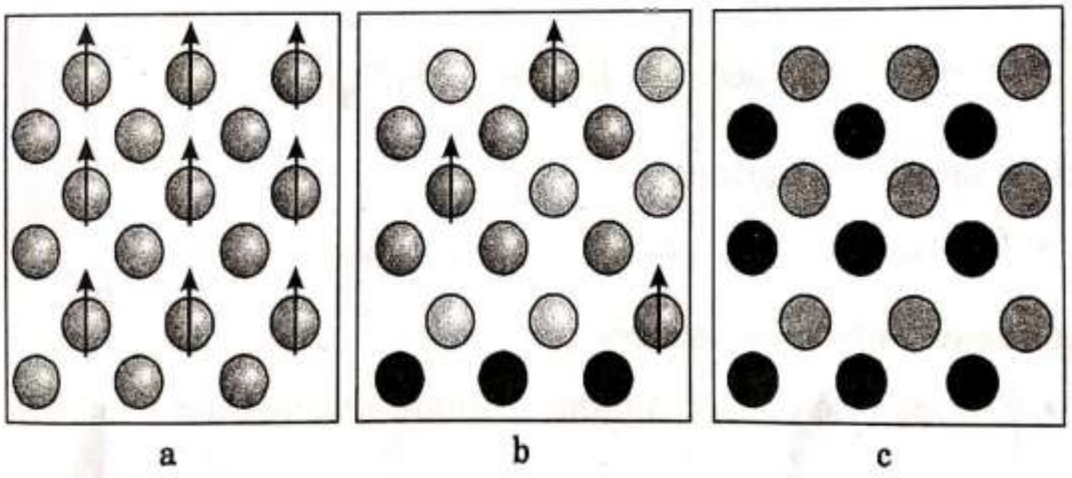
- **Definition:**Magnetic semiconductors are semiconductor materials that exhibit both ferromagnetism (or a similar response) and useful semiconductor properties.
- ***Example:*** Manganese-doped GaAS system,which shows a high Curie temperature upto 200 K.

Importance of Magnetic semiconductors

- If it is applied in devices, these materials could provide a new type of control of conduction.
- But, traditional electronics are based on control of charge carriers (*n or p type*).
- Practical magnetic semiconductors would also allow control of quantum spin state (up or down).
- This would theoretically provide near-total spin polarization, which is an important property for spintronics.

Dilute magnetic semiconductor (DMS)

- These are based on traditional semiconductors, but they are doped with transition metals instead of, or in addition to electronically active elements.
- They are of interest because of their unique spintronics properties with possible technological applications.



Examples for magnetic semiconductors

1. Mangenese doped Indium Arsenide and Gallium Arsenide (GaMnAs).
2. Manganese doped Indium Antimonide.
3. Zinc Oxide.
4. Manganese doped Zinc Oxide.
5. n-type Cobalt doped Zinc Oxide.
6. p-type transparent MgO films with cation vacancies.
7. Cobalt doped Titanium Dioxide.
8. Iron doped Titanium Dioxide.
9. Chromium doped Titanium Dioxide.
10. Copper doped Titanium Dioxide.
11. Nickel doped Titanium Dioxide.
12. Manganese doped Tin Dioxide.
13. Iron doped Tin Dioxide.
14. Strontium doped Tin Dioxide ($SrSnO_2$).
15. Chromium doped Aluminium Nitride.

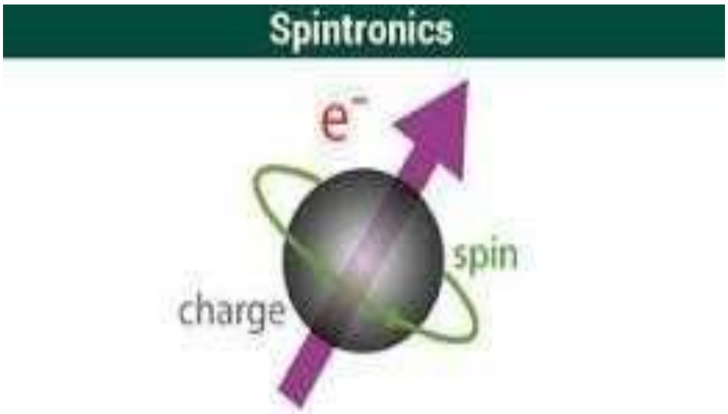
Applications of magnetic semiconductors

1. They are used to make quantum computing architecture using spin polarized electron.
2. They are used in magneto optic applications.
3. They are used to fabricate spin transistors and spin polarized Light Emitting Diodes (LEDs).
4. They are used to exhibit favourable dilute magnetism.

SPINTRONICS

Spintronics – Spin Based Electronics

- **Definition:** Study of the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid state devices.
- Spintronics uses electron spins in addition to or in place of the electron charge.
- The rotational moment creates a small magnetic field.
- Key concept is controlling the spin of electrons.



- Spintronics is intrinsic spin of the electron + its associated magnetic moment + its fundamental electronic charge.

Principle

- Spintronics is based on the spin of electrons rather than its charge.
- Every electron exists in one of the two states- spin up and spin down with spins either positive half or negative half.
- In other words, electrons can rotate either clockwise or anticlockwise around its own axis with constant frequency (as in Figure. 6.22).
- The two possible spin states represent '0' and '1' in logical operations.

Applications

1. Giant magnetoresistance (GMR) in various fields.
2. Spin valve.
3. Solid state non volatile memories.
4. Quantum Information processing and quantum computation.
5. Spin based transistors.

Electonic Devices Vs Spintronic Devices

Sl. No.	Electronic Devices	Spintronic Devices
1	Power failure problem	No power failure problem
2	Boot up waitin problem	No Boot up waitin problem
3	More power consumption	Less power consumption
4	Normal speed	Faster speed
5	Cheaper	Costlier
6	Classical property	Quantum Property
7	Less Compact	Mor Compact
8.	Based on properties of charge of electron	Based on intrinsic property of spin of electron

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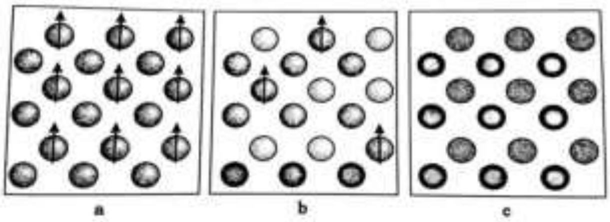

Fig. 5.12 (a) a magnetic semiconductor (e.g. some spinels)
(b) a dilute magnetic semiconductor (e.g. (GaMn) As, (InMn), P, ZnCoO etc)
(c) a non-magnetic semiconductor (e.g. GaAs, InP, Cu_2O, NiO etc)

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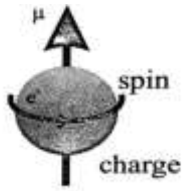

Fig. 6.22
spin of an electron

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