Nanorods:

Nanostructures which are shaped like long sticks or rods with diameter in nanoscale and a length very much longer.

Nanotubes:

The carbon nanotubes are the wires of pure carbon like rolled sheets of graphite or like soda straws.

Nanowires:

Nanowires are nanorods which especially conduct electricity.

Fullerenes:

A form of carbon having a large molecule consisting of an empty cage of 60 or more carbon atoms.

Nanocomposites:

Composite structures whose characteristic dimensions are found at nanoscale.

Cluster:

A collection of units (atoms or reactive molecules) upto about 50 units.

Colloids:

A stable liquid phase containing particles of size 1-1000 nm range.

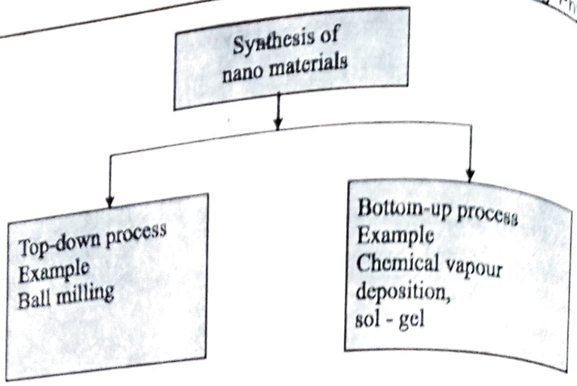
A number of metals, alloys, intermetallics, ceramics, polymers as well as composites are synthesized in nano form.

Synthesis of Nanomaterials

The methods for the synthesis of nanomaterials are broadly classified into two ways

(i) Top-down process

(ii) Bottom-up process



(a) Top down process

In this process, the bulk materials are broken into nano sized particle as shown in fig 7.1

Fig. 7.1 Synthesis from bulk materials.

It is an example of solid-state processing of materials

Example: Mechanical alloying (or) Ball milling

(b) Bottom-up process

In this process, nano materials are produced by building of atom by an atom as shown in fig 7.2

Fig. 7.2 Synthesis from individual atoms

Example: Chemical vapour deposition

7.2 PREPARATION OF NANOMATERIALS

There are few widely known methods to produce nanomaterials. They are

(i) **Ball milling**

(ii) **Plasma arcing**

(iii) **Chemical vapour deposition**

(iv) **Sol-Gels.**

(v) **Electro-deposition**

(vi) **Laser synthesis**

(vii) **Inert gas condensation**

Using the above techniques it is possible to produce nano-materials in the form of nano-powders, nano-crystals, nano-films, nano-wires, nano-tube, nano-dots, etc. From these methods, let us discuss the few methods briefly.

PULSED LASER DEPOSITION

rinciple

The laser pulse of high intensity and energy is used to evaporate carbon from graphite. These evaporated carbon atoms are condensed to form nanotubes.

Description

The experimental arrangement of pulsed laser deposition is shown in fig. 7.3. A quartz tube which contains a graphite target is kept inside a high temperature muffle furnace.

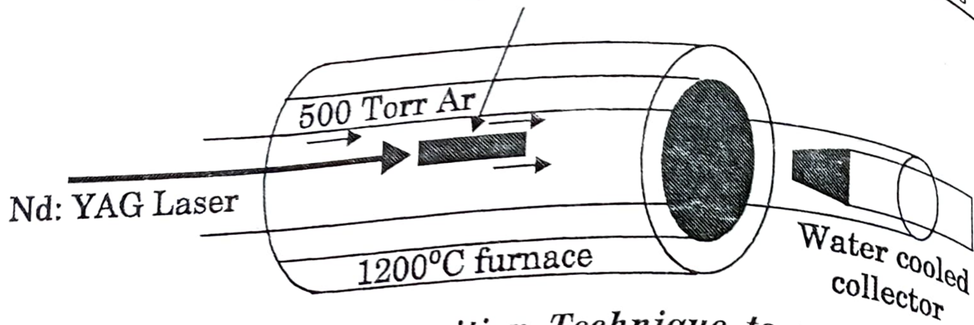


Fig. 7.3 Pulsed Laser Deposition Technique to produce CNT

This quartz tube is filled with argon gas and it is heated to 1473 K. A water cooled copper collector is fitted at the other end of the tube. The target material graphite contains small amount of nickel and cobalt as a catalyst to nucleate the formation of nanotubes.

Working

When an intense pulse of laser beam is incident on the target, it evaporates the carbon from the graphite. The evaporated carbon atoms are **swept** from the high temperature region to the cold copper collector by argon gas.

When the carbon atoms reach the colder copper collector, they condense into nanotubes.

Advantages

1. Single walled carbon nanotubes of 10 - 20 nm diameter and 100 micrometer long can be produced by this technique.
2. In this technique more than 85% of graphite is converted into carbon nano tube.
3. The presence of catalyst prevents the growth of fullerenes and a selective growth of nanotube is achieved.
4. The nanotube diameter can be controlled by the reaction temperature.

Note: Apart from CNT, nanostructures of many materials in the form of thin film can also be produced by this PLD.

Vapour phase deposition method

Vapour phase deposition technique is used to fabricate thin films, multilayers, nanotubes, nanofilaments and nanosized particles of different materials. These materials can be organic or inorganic. There are generally two types of vapour phase deposition techniques. They are

(i) **Physical Vapour Deposition (PVD)** and

(ii) **Chemical Vapour Deposition (CVD)**

PVD involves the direct deposition of gaseous phase on the substrate surfaces. CVD on the other hand involves diffusion with chemical reactions at the substrate surfaces. CVD is a complex process than PVD.

7.4 CHEMICAL VAPOUR DEPOSITION

The deposition of nano films from gaseous phase by chemical reaction on high temperature is known as **chemical vapour deposition**.

This method is used to prepare **nano-powder**.

Principle

In this technique, initially the material is heated to gaseous state and then it is deposited on a solid surface under vacuum condition to form nano powder by chemical reaction at the substrate.

Description and Working

The CVD reactor built to perform CVD processes is shown in fig.7.4.

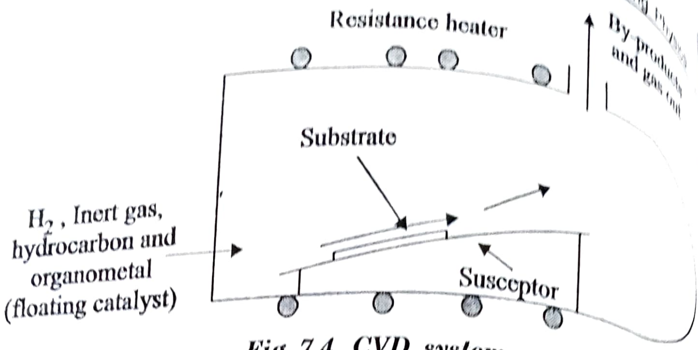


Fig 7.4 CVD system

Chemical vapour deposition (CVD) involves the flow of a gas with diffused reactants (substances to be deposited in the vapour) over a hot substrate surface. The gas that carries the reactants is called the carrier gas.

While the gas flows over the hot solid surface, the heat energy increases chemical reactions of the reactants that form film during and after the reactions.

The byproduct of the chemical reactions are then removed. The thin film of desired composition can thus be formed over the surface of the substrate.

Advantages

(i) The CVD method is used to produce defect free nanoparticles.

(ii) Due to the simplicity of the experiment, the scaling up of the unit for mass production in industry is achieved without any major difficulties.

Properties of Nanophase Particles

The mechanical, electrical, chemical, magnetic, optical and structural properties of nanophase materials change with the reduction in the particle size of the material.

(a) Physical properties

Variation of physical properties with geometry

Starting from the bulk, the first effect of reducing the particle size is to create more surface sites. This in turn changes surface pressure and interparticle spacing.

(i) Interparticle spacing decreases with decrease in grain size for metal clusters. For example in copper, it decreases from 2.52 (cluster size - 50Å) to 2.23Å (Cu dimer) fig. 7.5.

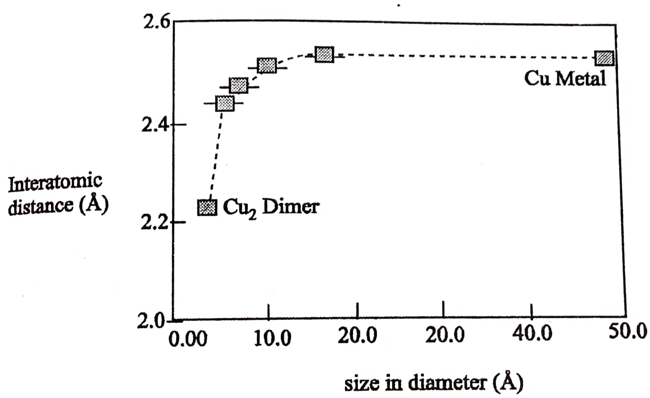


Fig. 7.5 Interatomic distance in Cu_n as a function of grain size

The change in interparticle spacing and large surface to the volume ratio in particles have a combined effect on material properties. Therefore, the nanophase materials have very high strength and super hardness.

Because of the cluster of grains, the nanophase materials are mostly free from dislocations and stronger than conventional metals.

(ii) Melting point reduces with decrease in cluster size

The melting point of gold in nano phase (Au_n) varies as a function of particle size (fig. 7.6).