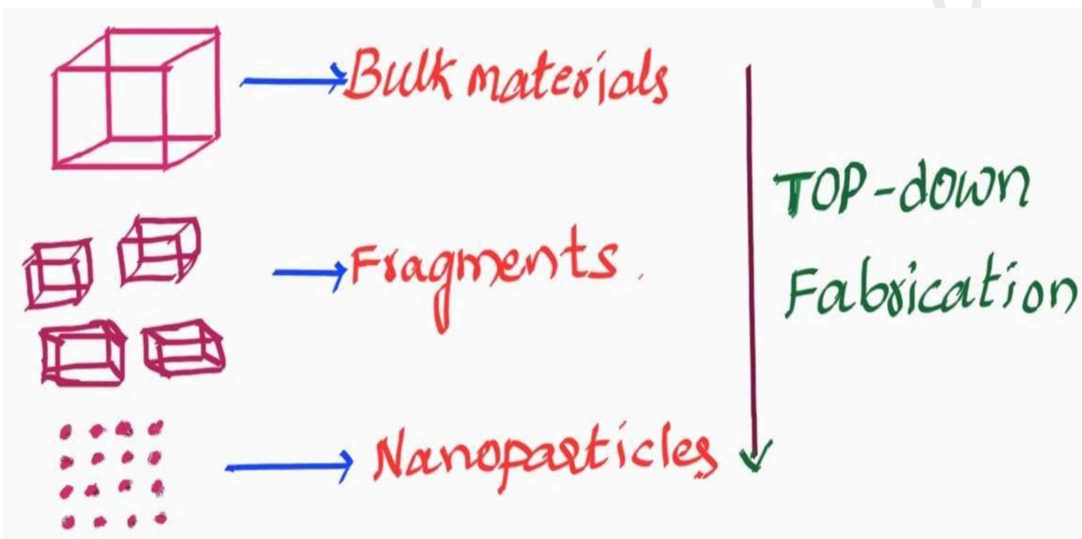
TOP-DOWN FABRICATION

- TOP-DOWN fabrication is a nanotechnology approach that uses physical forces to break-down bulk materials into nano-structures.
- This is the extension technique that has been used for production of micron sized particles.
- This approach/fabrication involves starting with a block of individual materials, converting/etching down into the desired size.
- Here a large scale object is progressively reduced in dimensions.



- In this approach, manufacturing parts are constructed by cutting, carving & moulding.
- The methods used to prepare nanoparticles in top-down fabrication are:

  (i) Ball milling method

  (ii) PVD (Physical Vapour Deposition) method

  (iii) CVD (Chemical Vapour Deposition) method

(i)BALL MILLING / HIGH-ENERGY BALL MILLING

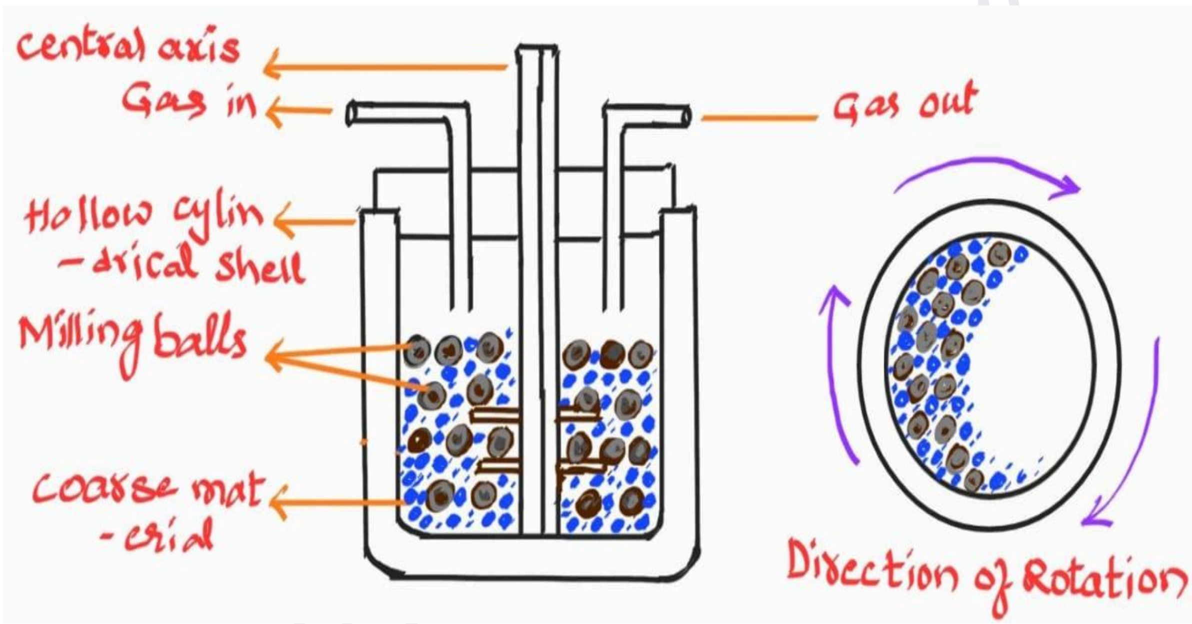
Ball milling :

- Ball milling is a mechanical process of grinding a material into a very fine powder by using a cylindrical device (ball mill) filled with both balls & material.

Principle:

- It works on the principle of Impact & Attrition. Impact force occurs during collision between balls and materials. Attrition force occurs during material grinding which helps in size reduction of material.

Construction:

- It consists of a hollow cylindrical shell rotating about its axis (with horizontal or some angle). This hollow cylindrical shell is filled with balls, made up of steel / tungsten carbide.
- This hollow cylindrical shell is lined with a resistant material such as manganese steel/rubber.
- 

Working process:

- The steps involved in this working process are as follows:

Material Selection and Analysis:

- The first step is to carefully select the material to be milled and understand its properties(such as hardness and abrasiveness). The desired characteristics of the final product, like particle size, shape, and purity.

Ball mill loading:

- Place a desired material of any size along with balls in a cylindrical shell in the ratio of 2:10 and close it with lids.

Process of milling:

- The shell is rotated through a drive gear with speed 60-100 RPM around their own axis as well as around some central axis.
- The speed rotation causes differential moments between the ball & there is a collision between balls and material.
- During this process of impact & attrition coarse material is crushed and reduces its size.

Process Monitoring and Optimization:

- The ball milling process is often monitored to assess the particle size and distribution of the milled material.
- The process can be optimized by adjusting factors like milling speed, duration, and the type of grinding media.
- Ultimately, nanoparticles are formed in the form of fine powder.

Post- treatment:

- The resulting powder may undergo additional treatments such as drying,sieving or surface modification to enhance its properties.

Advantages:

- It is not a time-consuming process.
- Low cost of installation and production
- Grinding medium is cheap/low cost.
- Suitable for both batch & continuous operations.
- It is suitable for materials of all degrees of hardness.
- This method is operated on a large scale.

Disadvantages:

- Low working efficiency and Loud noise.
- Large electricity consumption and Mill feed size
- Contamination by the milling tools & atmosphere can be a problem.

(ii)PVD (PHYSICAL VAPOUR DEPOSITION METHOD)

PVD:

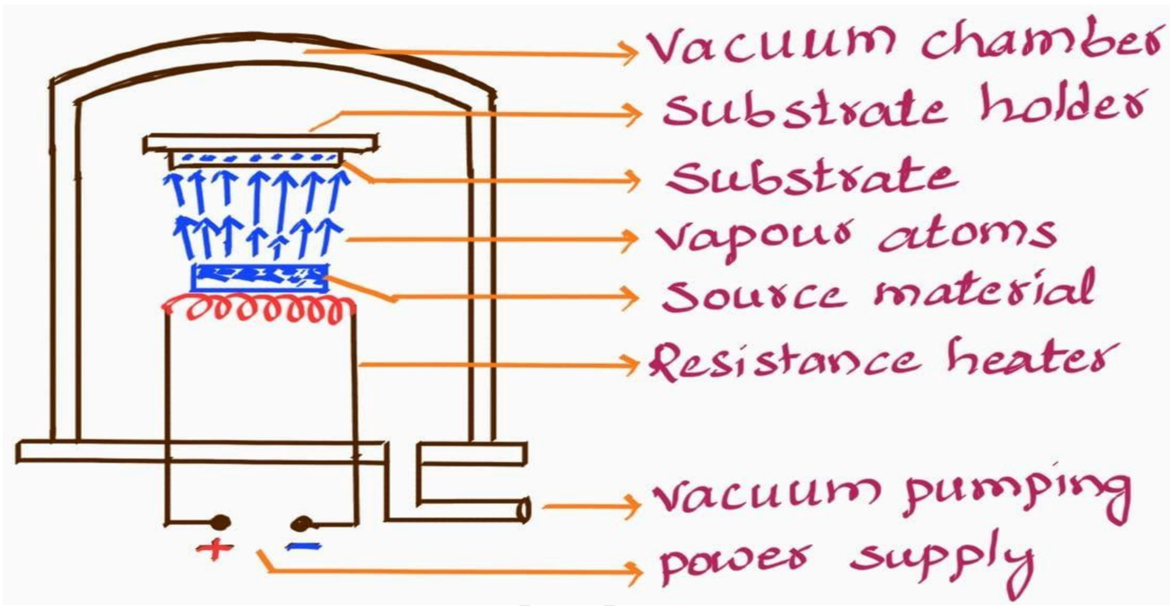
- PVD is a vapour deposition technique on a solid raw material (substrate). This technique deposits thin films onto a solid surface by converting a source material into vapour and then condensing it on the surface.

Principle:

- It works on the principle of deposition/migration of atoms/molecules/ions on a substrate.

Construction/ Chamber setup:

- Connect the vacuum chamber to a vacuum pumping system.
- Load the cleaned substrate into a vacuum chamber.
- Place the source material on a resistance and give the power supply.



WORKING PROCESS:

- The steps involved in this working process are as follows:

Vaporization:

- Once the power supply is given, the source material is heated to a temperature at vacuum and turns to vaporize.

Transport:

- The vaporized atoms/ions from the source material move to the substrate to be coated.

Reaction:

- The transported atoms react with appropriate gas in the transportation stage.

Film Deposition:

- The vaporized material condenses onto the substrate surface, forming a thin film.
- This film grows gradually by the condensation of more deposition of atoms or molecules or ions.

Control and Monitoring:

- By controlling the deposition rate, temperature, pressure to achieve the desired thickness, composition, structure of the deposited film.
- The deposition process continues until the **desired film** thickness is achieved, observed by spectroscopy.

Cooling and Post treatment:

- After getting desired film thickness, substrate & deposited film are allowed to **cool down** at room temperature, further to induce specific microstructures by **annealing** or modification of the surface.

Advantages:

- All types of organic & inorganic materials can be used.
- Environmentally friendly process with High quality films
- High deposition rate, strength & durability.
- Less heating & damage to substrate surface.

Disadvantages:

- Control of film deposition is very difficult.
- Cleaning of the substrate surface is not possible.
- High capital cost & required skilled operators.
- Operates at high vacuum & temperature.

CVD (CHEMICAL VAPOUR DEPOSITION) METHOD

CVD:

- CVD is a vapour deposition technique for growing a solid material (substrate).This fabrication technique deposits thin films onto a solid surface (substrate) by volatile gases (precursors) due to a chemical reaction between substrate & precursors.
- The product of the reaction self-assembles and coats the substrate.

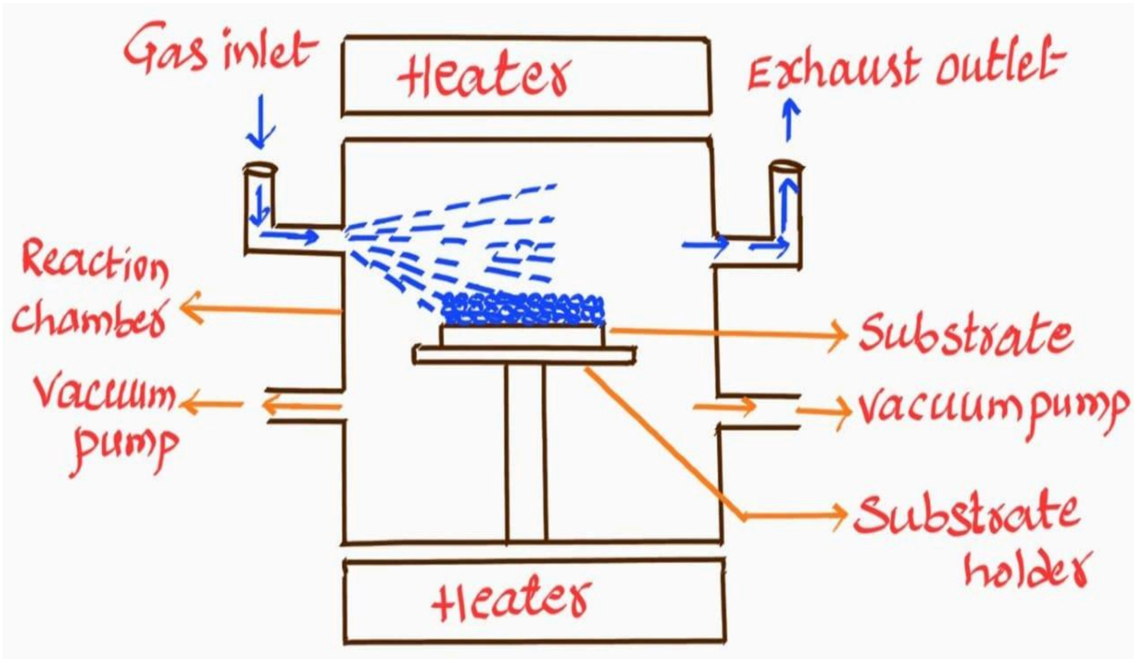
Principle:

- It works on the principle of depositing volatile precursors on a substrate by chemical reaction at high temperature.

Construction/ Chamber setup:

- Place the reaction chamber (muffle furnace) which contains a gas inlet and exhaust outlet at both ends also fixed by a vacuum pump.

❖ Now setup the substrate holder inside the reaction chamber.



WORKING PROCESS:

❖ The steps involved in this working process are as follows:

Heating substrate:

❖ Arrange the substrate on a substrate holder and heat it up to a temperature of a few thousand degree Celsius.

Introducing precursors:

❖ Now introduce the precursor gases into the reaction chamber and allow the gases to flow over the heated substrate.

Chemical reactions:

❖ Then the chemical reaction takes place between precursor gases and the heated substrate. This reactions involve various processes such as decomposition, reduction, oxidation or chemical vapor transport.

Film deposition:

❖ Due to the above chemical process, a thin film is deposited on a substrate.

Growth and Control:

- The thickness of deposition film is controlled by the flow rates of precursor gases, the temperature of substrate, the pressure inside the chamber and the duration of deposition process.

Post treatment:

- Sometimes the process of annealing or some other additional process may be required for the modification of thin film.

Advantages:

- High purity & Scalability
- Uniformity & Fine grained
- Hardness/High density & Forms alloys
- Versatile element/compound deposition
- Economical in production
- Easily modified into desired shapes
- Creep into fibers performs and foam structures

Disadvantages:

- High deposition temperature
- Restriction on the kind of substrate
- High equipment & precursor gas cost
- Potential hazards associated with precursor gases
- Contaminated exhaust gases