CHEMICAL VAPOR DEPOSITION (CVD):

- CVD can be defined as a process in which the gaseous chemical reactants are transported to the reaction chamber, activated thermally (conventional CVD) or by other than thermal means (plasma assisted CVD or laser induced CVD), in the vicinity of the substrate, and made to react to form a solid deposit on the substrate surface.

- It is possible to deposit films of uniform thickness and low porosity even on substrates of complicated shape in this process.

Conventional CVD (Thermal CVD):

- In conventional CVD (CCVD), the gaseous reactants are activated thermally in the vicinity of the heated substrate, and react to form a film on the substrate.

- A simple schematic representation of CVD is shown in Fig. 1

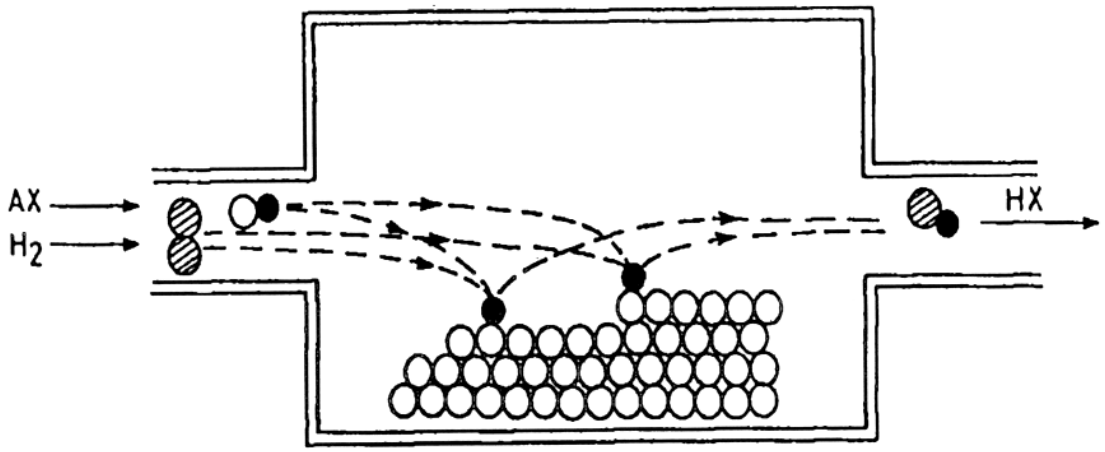

Fig. 1 Schematic of the chemical vapor deposition (CVD) process

Various heating sources are used in CVD.

1. *Hot plate.* The substrate is in direct contact with the hot plate which is either resistively or inductively heated.

2. *Radiant heat.* The substrate is heated by a thermal radiation technique or optical technique (tungsten filament lamp or laser).
3. *Heating of a conductive substrate.* Conductive substrates can be heated resistively or by RF induction.

Classification of CVD Reactions:

CVD reactions fall into four general categories.

1. ***Thermal decomposition reactions (pyrolytic reactions).*** This reaction is characterized by

$$AX_{(g)} \rightarrow A_{(s)} + X_{(g)}$$

Where *AX* is a gaseous compound, *A* a solid material, and *B* a gaseous reaction product.

Some examples of these reactions are:

$$B_2H_{6\,(g)} \rightarrow B_{(s)} + 3H_{2(g)}$$
$$SiH_{4\,(g)} \rightarrow Si_{(s)} + 2H_{2(g)}$$
$$W\,(CO)_{6(g)} \rightarrow W_{(s)} + 6CO_{(g)}$$

2. ***Reduction reactions.*** In this reaction, a gaseous compound is reduced by a reducing agent (usually hydrogen).

$$2AX_{(g)} + H_{2(g)} \rightarrow 2A_{(s)} + 2HX_{(g)}$$

Examples of some reduction reactions are given below:

$$2BCl_{3(g)} + 3H_{2(g)} \rightarrow 2B_{(s)} + 6HCl_{(g)}$$
$$SiCl_{4(g)} + 2H_{2(g)} \rightarrow Si_{(s)} + 4HCl_{(g)}$$

3. ***Displacement reactions.*** These reactions are also known as exchange reactions. In the molecule *AX*, *X* is replaced by another element *B*.

$$AX_{(g)} + B_{(g)} \rightarrow AB_{(s)} + X_{(g)}$$

Some representative reactions are:

$$Zn_{(g)} + H_2S_{(g)} \rightarrow ZnS_{(s)} + H_{2(g)}$$

$$SiCl_{4(g)} + CH_4 \rightarrow SiC_{(s)} + 4HCl_{(g)}$$
$$CrCl_{2(g)} + Fe_{(s)} \rightarrow \text{Cr-Fe alloy} + FeCl_{2(g)}$$

4. ***Disproportionation reactions.*** In these reactions, the oxidation number of an element both increases and decreases through the formation of two new species. Some typical examples are:

$$2GeI_{2(g)} \rightarrow Ge_{(s)} + GeI_{4(g)}$$
$$TiCl_{2(g)} \rightarrow Ti_{(s)} + TiCl_{4(g)}$$

Several types of reactions can be involved simultaneously in some CVD coating processes. An example of these reactions is:

$$2AlCl_{3(g)} + 3CO_{2(g)} + 3H_{2(g)} \rightarrow Al_2O_{3(s)} + 3CO_{2(g)} + 6HCl_{(g)}$$

In this reaction, water produced from

$$CO_{2(g)} + H_{2(g)} \rightarrow CO_{(g)} + H_2O_{(g)}$$

is used to form Al_2O_3 by the following reaction

$$AlCl_{3(g)} + 3H_2O_{(g)} \rightarrow Al_2O_{3(s)} + 6HCl_{(g)}$$

Reactors:

- There are two kinds of reactors most frequently used in the CVD processes, *hot wall reactor* (Fig. 2) and *cold wall reactor* (Fig. 3).

- In the former reactor, the reactor tube is surrounded by a tube furnace making the substrate, and the reactor wall to be the same temperature. A large number of substrates can be coated in this type of reactor.

- A major drawback of this type of reactor is deposition on the reactor wall and possible contamination in the system from chemical reactions between the reactor wall, and the vapor due to the high temperature of the reactor wall.

- Therefore, the hot wall reactor is ideal for the case where the reaction is exothermic, since the high wall temperature prevents undesirable deposition on the reactor walls.

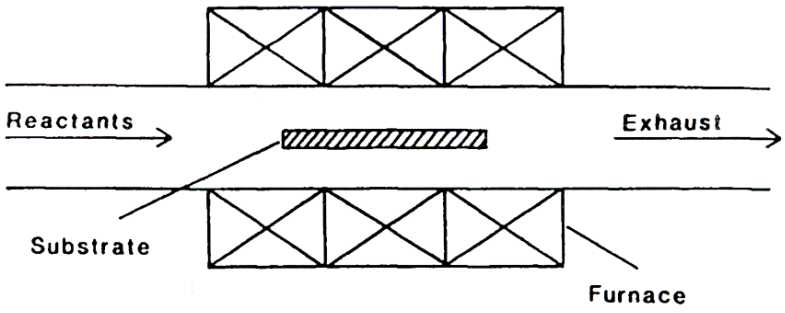

Fig. 2 Hot wall CVD reactor

- In the cold wall reactor, only the susceptor where the substrates are placed is intentionally heated by RF induction, or high radiation lamps.

- This type of reactor is predominantly used for the deposition reaction which is endothermic, such as Si deposition from the halides. Since the substrates have a higher temperature than the reactor wall, the reaction will proceed most readily on the hot surface of the substrate.

- In this reactor type, contamination due to the interaction between the reactor wall and the vapor can be greatly reduced. Very frequently, the walls are water-cooled to further prevent deposition on the wall or reactions between walls and vapor.

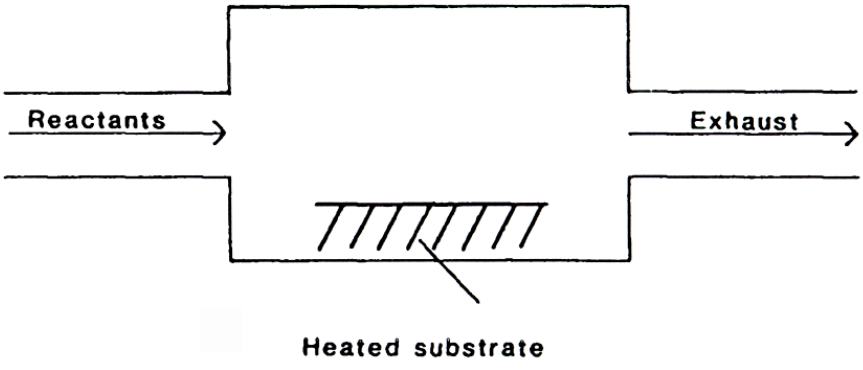

Fig. 3 Cold wall CVD reactor