KERONE
Kerone Engineering Solutions Limited

# MICROWAVE CHEMICAL VAPOUR DEPOSITION SYSTEM

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ISO 9001:2015 | ISO 14001:2015 | ISO 45001:2018

# ABOUT US

KERONE is now renowned for serving the specialized needs of customers with the best quality and economical process of Heating /cooling and drying products, manufactured in a high-quality environment by a trained and qualified workforce (special purpose machinery)

- 48+ Years Manufacturing Excellence
- Great Sale Support
- Highly Customized Product
- Adherence to Standards
- Sound Infrastructure
- Team of experts Delivering Quality
- Timely Delivery
- Cost Effective Solutions

KERONE is a pioneer in application and implementation engineering with its vast experience and team of professionals.

KERONE is devoteded to serve the industry to optimize its operations both economically and environmentally with its specialized heating and drying solutions.

KERONE is having immense expertise in manufacturing and implementing various types of engineering solutions.

KERONE is possessing employee strength of more than 280+ experts continuously putting efforts for happy industrial engineering solutions.

# WHY CHOOSE US

> “Enhance the value of customer operation through our customer need centric engineering solution.”

With decades of expertise, cutting-edge technology, and a customer-centric approach, Kerone Engineering offers tailor-made heating solutions that prioritize quality, flexibility, and cost-effectiveness. Benefit from our commitment to excellence, post-sales support, and innovative solutions for your unique heating needs. Choose Kerone Engineering for reliability, performance, and unmatched value.

## MISSION

- ✓ To enhance the value of customer operation throughi our customer need centricengineefing solution
- ✓ We are cominitted to provide our customers, unique arid best in class products in Industrial heating drying and cooling segment with strategic tie-up for the technical know-how with renowned leader in the industry specific segment

## VISION

- ✓ Turn into a world leader in providing specialized, top-notch quality and ecological industrial heating, cooling, and drying solutions across the globe.
- ✓ To attain global recognition as the best of quality and environment-friendly engineering solution company.

# Introduction

Chemical vapor deposition may be defined as the deposition of a solid on a heated surface from a chemical reaction in the vapor phase. It belongs to the class of vapor-transfer processes which is atomistic in nature that is the deposition species are atoms or molecules or a combination of these. Besides CVD, they include various physical-vapor deposition processes (PVD) such as evaporation, sputtering, molecular beam epitaxy and ion plating. In its simple incarnation, CVD involves flowing a precursor gas or gases into a chamber containing one or more heated objects to be coated. Chemical reaction occur on and near the hot surfaces, resulting in the deposition of a thin film on the surface. This is accompanied by the production of chemical by-products that are exhausted out of the chamber along with unreacted precursor gases. As would be expected with the large variety of materials deposited and the wide range of applications, there are many variants of CVD. It is done in hot wall reactor and cold wall reactors, at sub-torr total pressores to above atmospheric pressures, with and without carrier gases, and at temperature typically ranging from 200-1600 o c. There are also a variety of CVD processes, which involve the use of plasmas, ions, photons, lasers, hot filaments, or combustion reactions to increase depositon rates and/or lower deposition temperatures.

# CVD Reactor Types

- Hot wall reactor is a high temperature chamber in which the substrate is placed for coating. In this including the substrate, all other parts (inlet and outlet tubes)  inside the chamber get coated.

- Chemical Vapor Deposition (CVD) reactors are used to deposit thin films on substrates through chemical reactions of gaseous precursors. Types include cold-wall and hot-wall reactors for different heating methods, PECVD for low-temperature deposition, LPCVD for precise films at low pressure, APCVD for simpler atmospheric operation, and MOCVD for complex materials like LEDs. Each type is chosen based on application needs.

## Low pressure CVD

A schematic for a hot-wall reactor that has been tailored to low- pressure CVD(LPCVD) batch processing in the microelectronics industry. In this case, a specialized support holds a large number(over a hundred) of closely- spaced silicon wafers for simultaneous processing. In general, hot wall reactors have the advantages of being able to process large batches of substrate, and having relatively uniform substrate temperatures and thus coating thickness.

The primary disadvantages are that the walls get heavily coated,requiring frequent cleaning and causing particle problems, and that it involves higher thermal loads and energy usage.

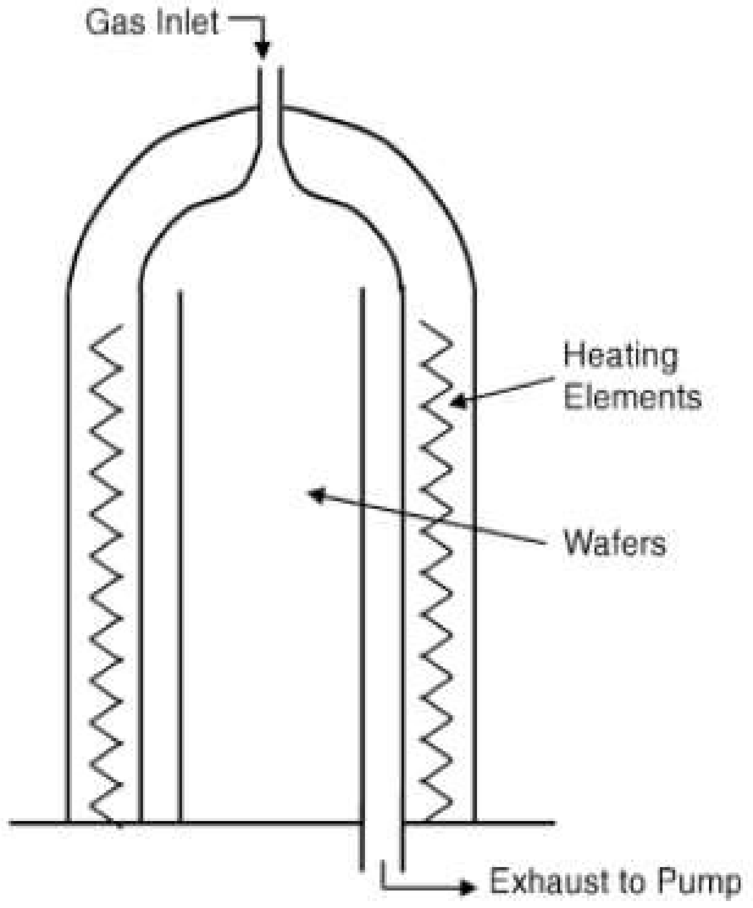


**Fig. 8:** Schematic drawing of LPCVD furnace for batch processing of multiple silicon wafers.

## Rotating disk CVD

On the other hand, in a Cold-wall reactor only the substrate is heated, either resistively or inductively. In such systems, the substrates are heated but the walls are cooled. Cold wall reactor often run at relatively high pressures, several hundred torr to atmospheric total pressure, and usually have reactive precursors diluted in a carrier gas.Figure 9 shows an example of a Cold wall rotating disk CVD reactor. This system has water-cooled quartz walls, with a rotating holder for(silicon or compound semiconductor) wafers that is resistively heated. Most compound semiconductor CVD processes use reactors of this type. Cold wall reactors have the advantages of reduced deposition of material on the walls, which means less cleaning, lower thermal loads on the substrates because of faster heat-up and the avoidance of vacuum equipment. The primary disadvantages are larger temperature non-uniformities on the substrate, which may lead to film thickness non- uniformities, the smaller batch sizes.

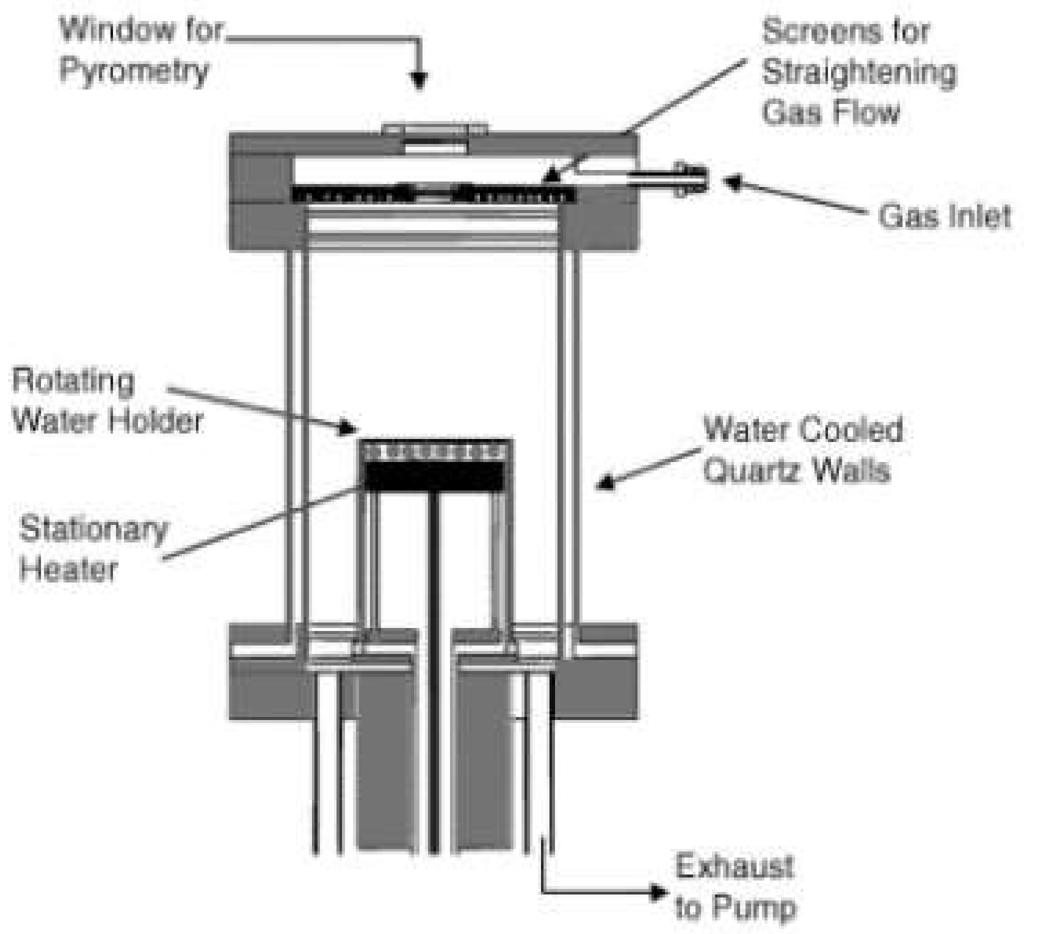
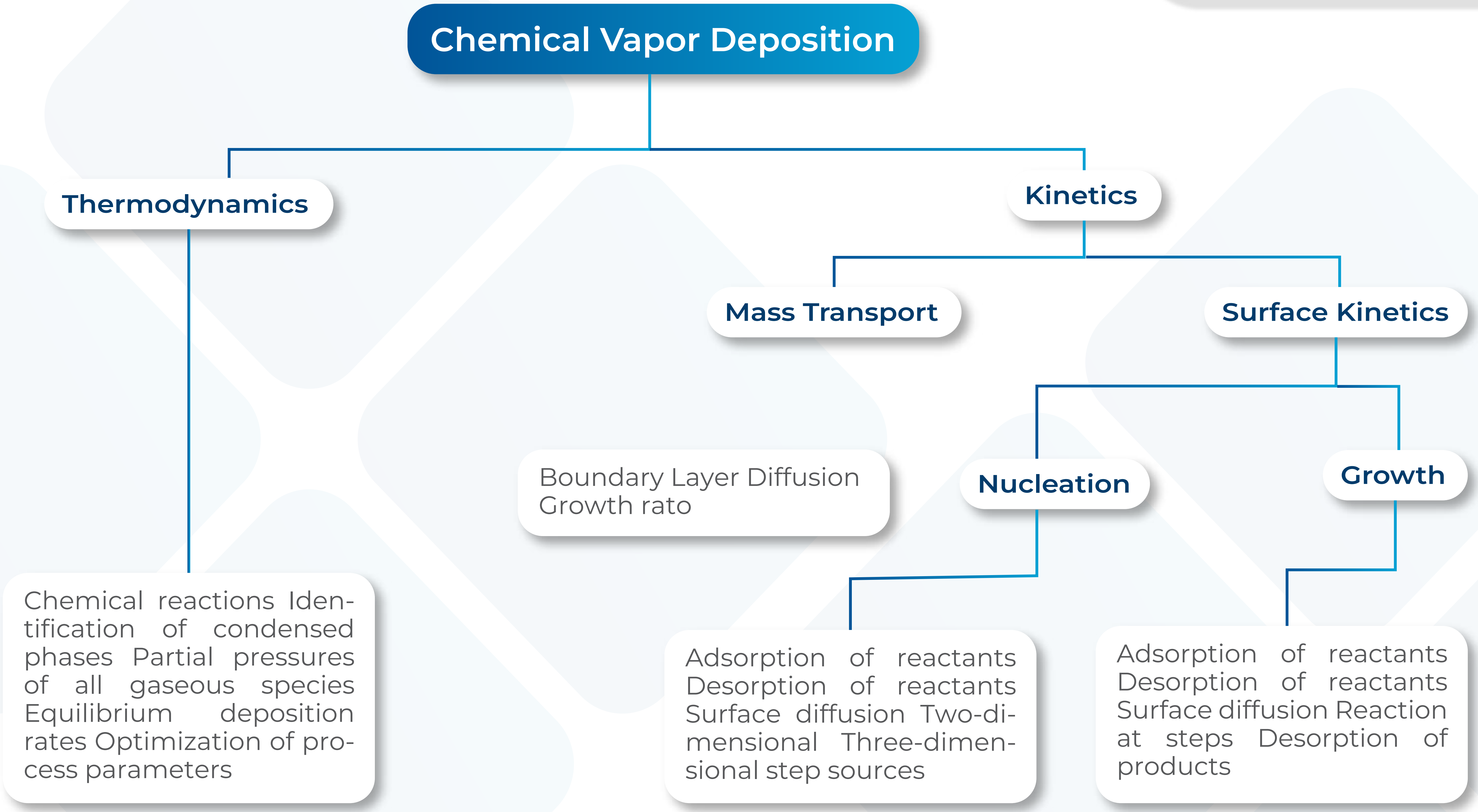


**Fig. 9:** Schematic diagram of a cold-wall rotating disk CVD reactor used for depositing thin films on semiconductor wafers.



**Chemical Vapor Deposition**

**Thermodynamics**

Chemical reactions Identification of condensed phases Partial pressures of all gaseous species Equilibrium deposition rates Optimization of process parameters

**Kinetics**

**Mass Transport**

Boundary Layer Diffusion
Growth rato

**Surface Kinetics**

**Nucleation**

Adsorption of reactants Desorption of reactants Surface diffusion Two-dimensional Three-dimensional step sources

**Growth**

Adsorption of reactants Desorption of reactants Surface diffusion Reaction at steps Desorption of products

FIG 1: Various fundamental aspects involved in a chemical vapor deposition process.

# Deposition Mechanism

The manner in which a film is formed on a surface by CVD is still a matter of controversy and several theories have been advanced to describe the phenomena. Figure 10 shows the seven mechanistic steps that have been hypothesized to occur during a vapor deposition process.

**These steps include:**

- Transport of reactant gases into the reaction chamber,
- Intermediate reactants form from reactant gases,
- Diffusion of reactant gases through the gaseous boundary layer to the substrate,
- Absorption of gases onto the substrate surface,
- Single or multi-step reactions at the substrate surface,
- Desorption of product gases from the substrate surface, and
- Forced exit of product gases from the system.

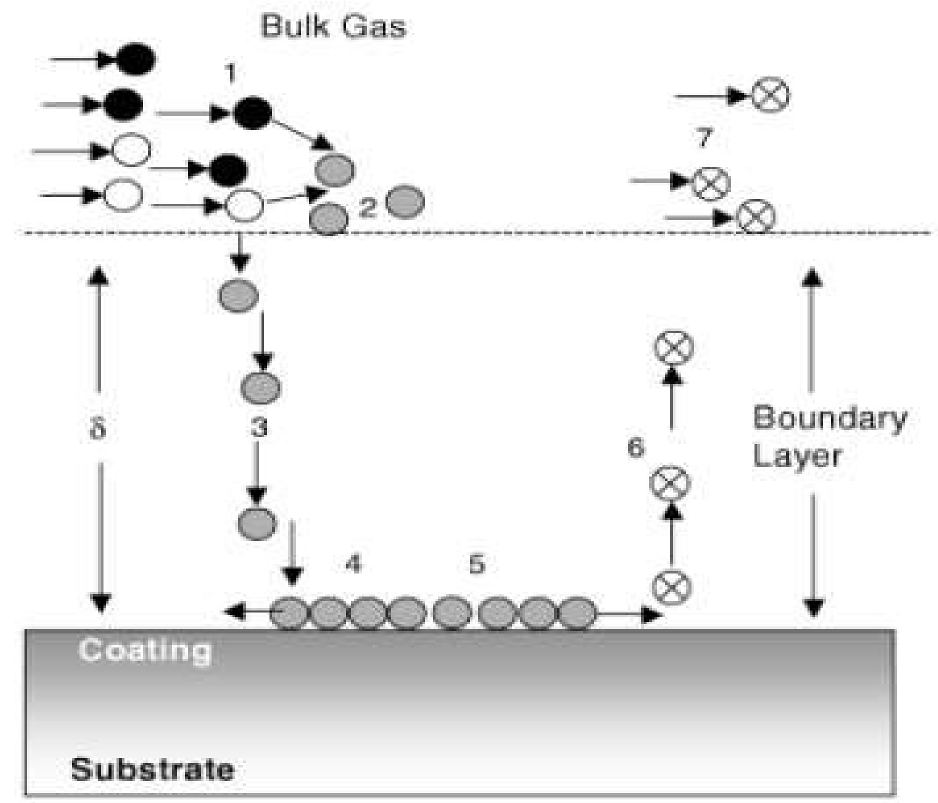


**Fig. 10:** Schematic diagram of the mechanistic steps that occur during the CVD process.

In this model, the steps can be classified into two categories, mass transport and surface reaction steps.2,4,5 and 6 The lowest of these steps determines if the process is mass transport or surface reaction limited. As the temperature increases, the surface reaction rate rises exponentially, resulting in a mass transport limited because transport becomes the slowest step in the series deposition steps.

A thermodynamics theory proposes that a solid nucleus is formed from supersaturated vapor as a result of the difference between the surface free energy and the bulk free energy of the nucleus. Another and new theory is based on atomistic nucleation and combines chemical bonding of solid surfaces and statistical mechanics.

There are however, three important factors that control the nature and properties of the deposit to some degree which must be reviewed at this time: epitaxy, gas-phase precipitation, and thermal Expansion.

- **Epitaxy:**
  A specific case is that of epitaxy where the structure of the substrate essentially controls the structure of the deposit.2 Epitaxy can be defined as the growth of a crystalline film on a crystalline substrate, with the substrate acting as a seed crystal. When both substrate and deposit are of the same material(for instance silicon on silicon) or when their crystalline structure(lattice parameters) are identical or close, the phenomena is known as homoepitaxy. When the lattice parameters are different, it is heteropitaxy. Epitaxial growth can’t occur if these structural differences are too great.

## Gas Phase Precipitation:

As mentioned previously, a CVD reaction may occur in the gas phase instead of at the substrate surface if the super saturation of the reactive gases and the temperature are sufficiently high. This is generally detrimental because gas-phase precipitated particles, in the form of soot, become incorporated in the deposit, causing non-uniformity in the structure, surface roughness and poor adhesion. In some cases, gas-phase precipitation is used purposely, such as in the production of extremely fine powders.

## Thermal Expansion:

Large stress can be generated in a CVD coating during the cooling period from deposition temperature to room temperature, if there is a substantial difference between the coefficient of thermal expansion (CTE) of the deposit and that of the substrate. These stresses may cause cracking and spalling of the coating. If differences are large, it may be necessary to use a buffer coating with in intermediate CTE or with high ductility. Deposition processes which do not require high temperatures, such as MOCVD or plasma CVD, should also be considered.

Example; As an example, one can consider the deposition of tungsten on the interior wall of a graphite tube by the hydrogen reduction of the fluoride as follows,

$$WF_6 + 3H_2 \rightarrow W + 6HF$$

# CVD Process

A sequence of physic-chemical process steps take place in a CVD process. First the reagents have to the surface being coated. The zone between the bulk of the flowing gas and the substrate surface is the location of the 1st kinetics barrier, which has to be crossed by diffusion of gaseous species. Next the species are adsorbed on the substrate surface, and migrate, react and the product to be deposited is formed to form nuclei.

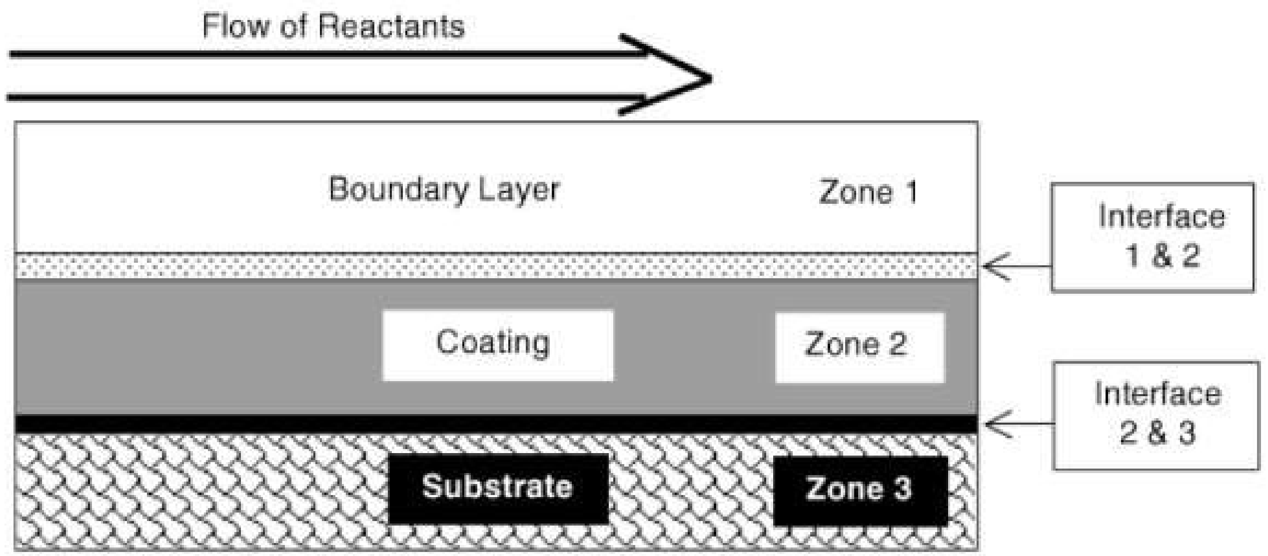


**Fig. 2:** A schematic diagram of the boundary layer model showing the reaction zones for $Al_2O_3$ coating.

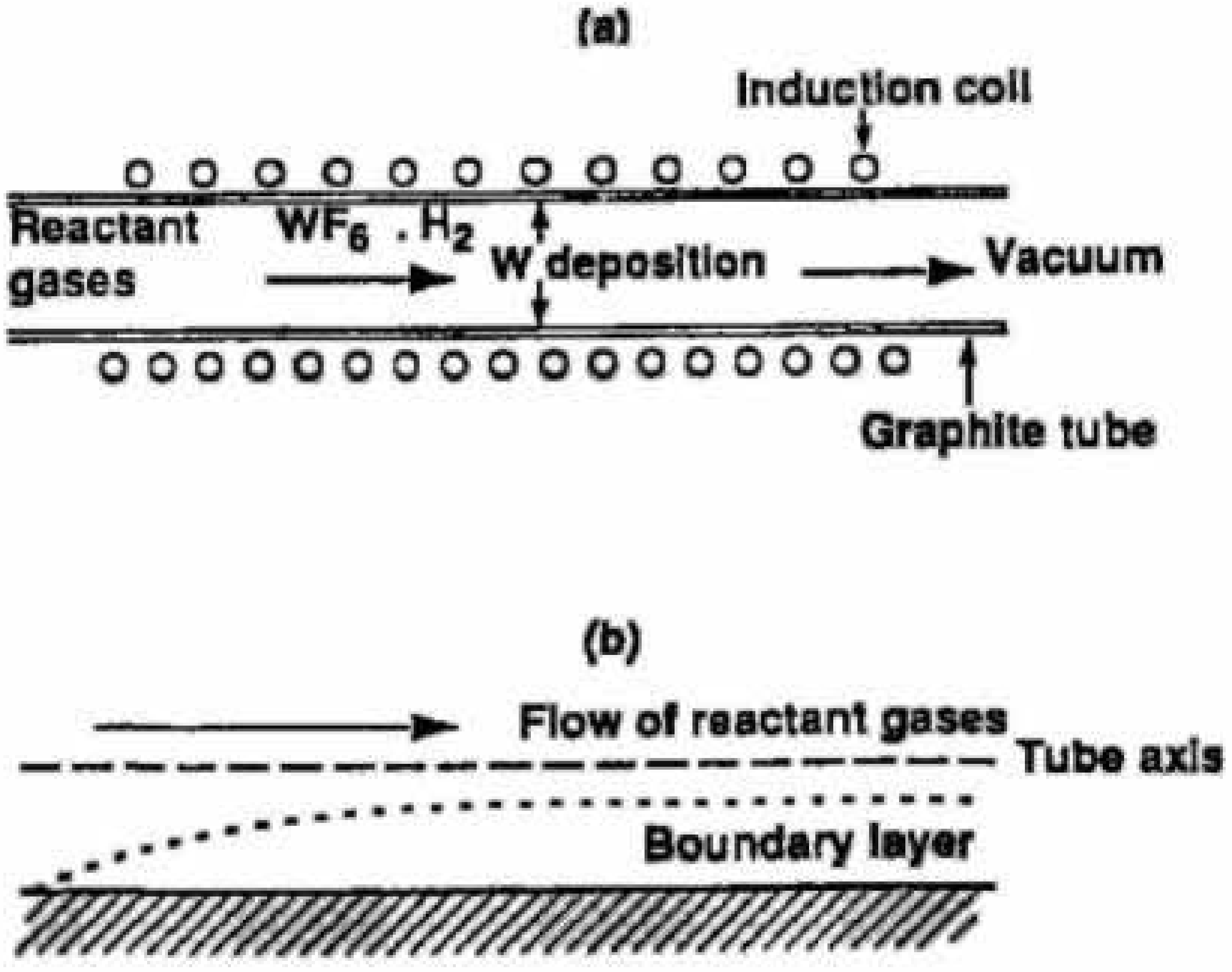


**Figure 2.4.** *(a)* Tungsten deposition in a tubular reactor, *(b)* boundary layer conditions.

In laminar flow, gas velocity is zero at the substrate surface and increases to the bulk flow velocity with distance. Boundary layer theory (BLT) explains the coupling of chemical and mass transport near the heated substrate, where a stagnant boundary layer forms. During coating, gaseous reactants and products cross the reaction zone, with homogeneous nucleation in the vapor potentially causing issues.

Undesirable reactions can cause flaky or non-adherent coatings, while growth-controlling heterogeneous reactions occur at the vapor/coating interface. High CVD temperatures lead to solid-state reactions like phase transformations and grain growth in the coating and substrate. Diffusion at their interface forms intermediate phases critical for coating adherence.

**Advantages:**

CVD has a number of advantages as a method for depositing thin films. One of the primary advantages is that the film thickness on the sidewalls of features is comparable to the thickness on the top. This means that films can be applied to elaborately shaped pieces, including the insides and undersides of features. Another advantage of CVD is that, in addition to the wide variety of materials that can be deposited, they can be deposited with very high purity. Other advantage include relatively high depositionrates, and the fact that CVD often doesn't require as high a vacuum as PVD processes.

**Disadvantages:**

CVD also has number of disadvantages. One of the primary disadvantage lies in the properties of the precursors. CVD precursors can also be highly toxic, explosive, or corrosive. The byproducts of CVD reactions can also be hazardous. The major disadvantage is the fact that the films are usually deposited at elevated temperatures. This put some restrictions on the kind of substrates that can be coated.

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