In an Integrated Circuit Fabrication, many films of different materials are deposited.

These films are of either Metals, Metal-Silicides, and Dielectrics like SiO_2, Si_3N_4.

Requirements of Deposition

i Desired Composition, Low Contaminates

ii Good Electrical properties of films (Desired)

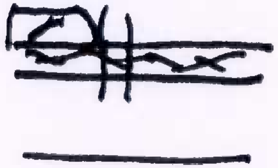
iii Mechanical Properties should also be good.
Adhesion is one such important Property

iv Uniform thickness across Wafer and
· Run to Run.

V. Most important requirement is
Good Step Coverage

vi If 'Interconnect' is desired from metal films, then they should give very low Resistance/length.

vii Better Electromigration resistance



viii Non - Corrosive

$J_c \geq 10^5 Am/$

ix Economical

x Compatible to other processes in IC fabrication.

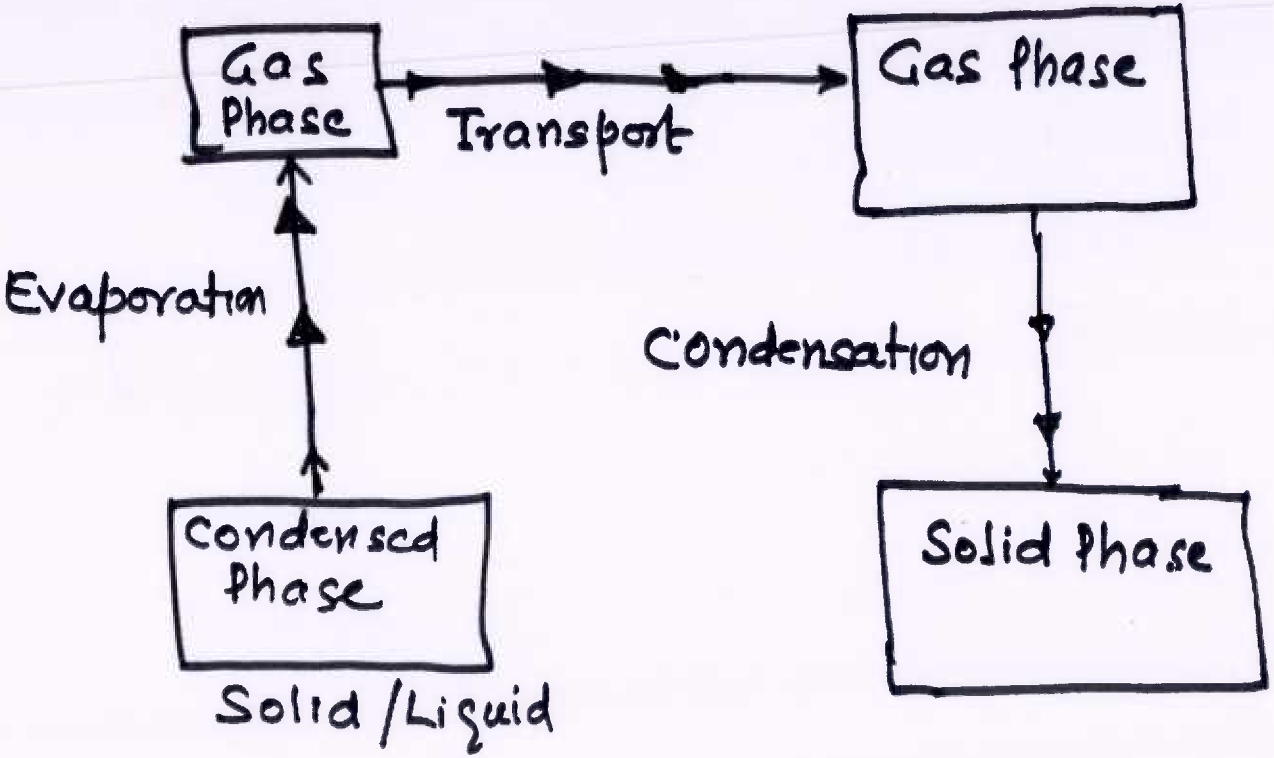
Two Major Deposition Techniques :

1. Physical Vapour Deposition (PVD)
   - (a) Evaporation
   - (b) Sputtering

2. Chemical Vapour Deposition (CVD)
   - a. At. Pressure CVD (APCVD)
   - b. Low Pressure CVD (LPCVD)
   - c. Plasma Enhanced CVD (PECVD)
   - d. Hot-Wire CVD (HWCVD)

Typical PVD process looks like

a Four Step Process



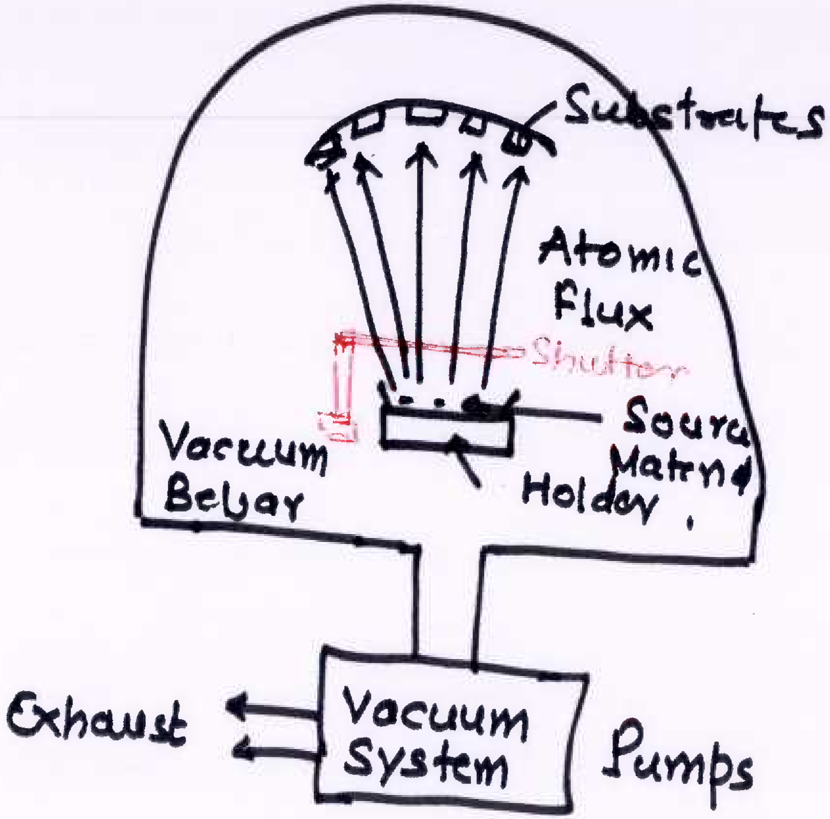
Evaporation System Requirement

1. Vacuum :
   - Need 10^{-6} torr or better vacuum for better quality films.
   - Better vaccum be Ultra High Vacuum which could be around 10^{-9} torr.
2. Heating System
   - Thermal Heating
   - Electron-Beam related

   1-10 kW Power
3. A Bell-Jar to keep vaccum.
4. Thickness Monitor

5. Mechanical Shutter System

Control on evaporating flux reaching substrate



Modeling of Evaporation:

(i) We define p^* as Partial Pressure of a gas in equilibrium with it's Condensed Phase at a given Temperature T.

Generally p^* is only function of Temperature (T).

(ii) p is defined as ambient hydrostatic pressure acting upon evaporant in Condensed State

According to Hertz principle, the evaporation rate is $\propto (p^* - p)$

In vacuum, p is closed to zero

(iii) V_g and V_c are volume of evaporant in Gas Phase and Condensed Phase respectively.

(iv) If we define ΔH_e as enthalpy-change from one phase going to the other, then according to ~~Claesius~~ Clausius Clapeyron Equation

$$\frac{dp^*}{dT} \propto \frac{\Delta He}{T(V_g - V_c)} \cong \frac{\Delta He}{T\,V_g}$$

(Normally $V_g >> V_c$)

$\uparrow$ Clausius - Clapeyron Equation $\downarrow$

By Ideal Gas Laws $p^* V_g = RT$ where R is Universal Gas Constant

$$\therefore \quad \frac{dp^*}{p^*} = \frac{\Delta H_e}{RT^2}\, dT$$

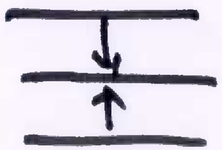
$$\text{or} \quad \ln p^* = -\frac{\Delta H_e}{RT} + c^* \qquad \text{Let } c^* = \ln C_1$$

$$\therefore \quad p^* = C_1\, e^{-\Delta H_e/RT}$$

Clearly p^* is only function of Temperature T

(v) Evaporation Rate R_{ev}

We have two Fluxes:



Evaporant's Vapour Pressure → P dependent

condensed evaporation Rate → p^* dependent

If A is cross-section area of flux coming out of evaporator, then

$$\frac{1}{A}\frac{dN_e}{dt} = \frac{1}{(2\pi m k T)^{1/2}}(p^* - p)$$

where $\frac{1}{A}\frac{dN_e}{dt}$ represents net Evaporation Rate

or $$R_{ev} = \frac{1}{A}\frac{dN_e}{dt} = \frac{1}{(2\pi m k T)^{1/2}}(p^* - p)$$

Hertz - Knudson equation for R_{ev} also takes care of return flux which is decided by α_v called Sticking Coeff for vapour molecules on the surface and thus is written as

$$R_{ev} = \frac{1}{A}\frac{dN_e}{dt} = \alpha_v (2\pi mkT)^{-1/2} (p^* - p)$$

In vacuum, two things are affected

(i) p the pressure due to return flux could be closed to → 0 (zero). Knudsen cell can esure this.

△ (ii) The mean free path of evaporant atoms increases i.e.

$$\lambda = \frac{kT}{\sqrt{2}\,\pi \sigma^2 p}$$

Clearly better vacuum means higher mean free path.

Higher Mean Free Path means, unlikely events of collision between evaporant atoms → Unidirection Flow.