Types :

1. Atmospheric Pressure CVD : APCVD
2. Low Pressure CVD : LPCVD
3. At. Pressure Low Temperature CVD
4. Plasma Enhanced CVD : PECVD
5. Atomic Layer Deposition : ALD
6. MBE : Molecular Beam CVD

In VLSI, we need to deposite

1. Dielectric Films : SiO_2, Si_3N_4, HfO_2 etc
2. Polysilicon Films : Self Aligned Gate and also for small Interconnect
3. Metal films of Ti, W, Ta, Mo etc.

Further we also need At. Pressure CVD for growing Epitaxial Films.

Thermal Budget and Quality of films desired decide the choice of Process.

CVD Chemical Reactions

$SiH_4(gas) + O_2(gas) \rightarrow SiO_2(solid) + 2H_2(gas)$

$SiH_4(gas) + H_2(gas) + SiH_2(gas) \rightarrow 2H_2(gas) + \text{Polysilicon (solid)}$

Continuous gas flow

Diffusion of reactants

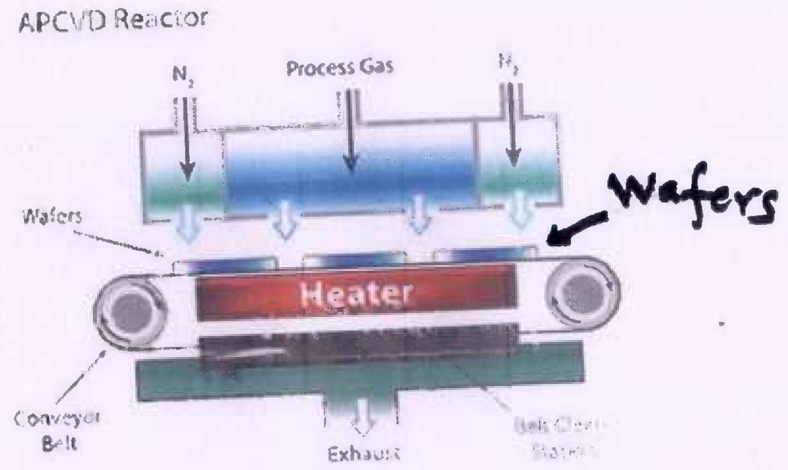
Boundary layer

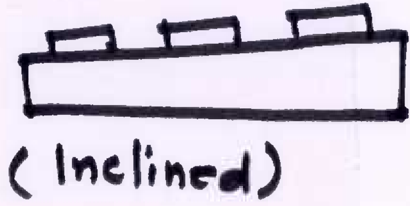
Deposited film

Silicon substrate

CDEEP
IIT Bombay

EE 669 L 26 / Slide 18





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Steps in APCVD :—

ⓐ Reactants reaches deposition region where Substrates are horizontally kept.

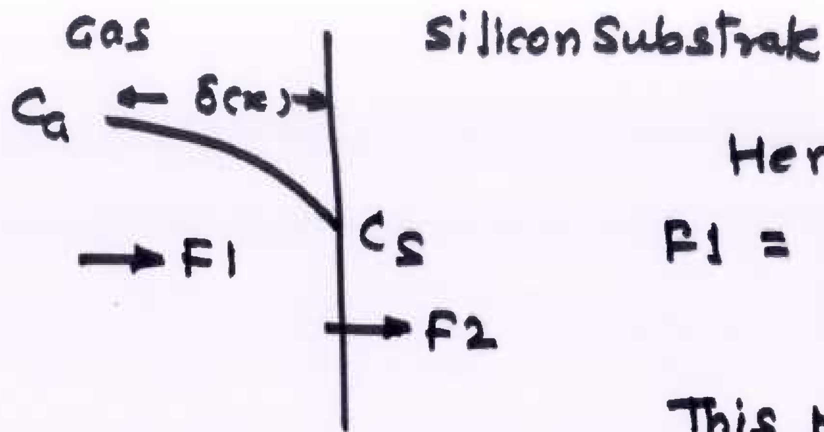
ⓑ From ambient Gas Stream the reactants diffused through Boundary Layer (Stagnant layer)

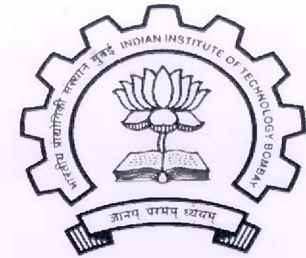
(c) Reactants are then adsorbed at wafer surface.

(d) Surface Reactions occure. Here chemical reactions takes place, and deposition occures conformally. Simultaniously emission and re-deposition too occures

(e) Un reacted reactants & Byproducts are desorbed. They transport through Boundary-Layer and are exhaust out of system.

We can have kinetics of such deposition, similar like Grove-Deal model for oxide growth.





Here

F1 = Diffusion Flux of Reactant to the wafer

This process is Mass Transfer process

F2 = Flux of Reactant consumed by Surface reaction

Thus this process is Reaction rate limited

We have

$$F1 = h_a (C_a - C_s)$$

h_a is Mass Transfer Coeff (cm/sec)

and

$$F_2 = k_s C_s$$

In Steady State $F = F_1 = F_2$

or $h_a(C_a - C_s) = k_s C_s$

or $h_a C_a = (h_a + k_s) C_s$

or $C_s = \dfrac{h_a}{h_a + k_s} C_a = \dfrac{1}{1 + \dfrac{k_s}{h_a}} C_a$

or $C_s = \left(1 + \dfrac{k_s}{h_a}\right)^{-1} C_a$

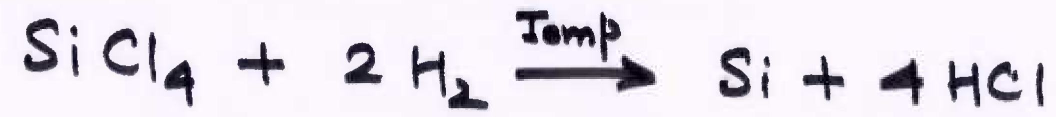
The Growth rate $V_y = \dfrac{F}{N}$ N is no of atoms incorporated on surface

$\therefore V_y = k_s \left(1 + \dfrac{k_s}{h_a}\right)^{-1} \dfrac{C_a}{N}$

If C_T denotes Conc. of all Molecules in Gas Phase then C_a is fraction of C_T or Mole fraction $Y = C_a / C_T$,

$$Y = \frac{C_G}{C_T} = \frac{p_G}{p_T} = \frac{P_{G\,SiCl_4}}{P_{G\,SiCl_4} + P_{H_2}}$$

Reaction used here is



$$SiCl_4 + 2H_2 \xrightarrow{Temp} Si + 4HCl$$

$\Delta G = \Delta H - T\Delta S$ is Thermodynamic Statement

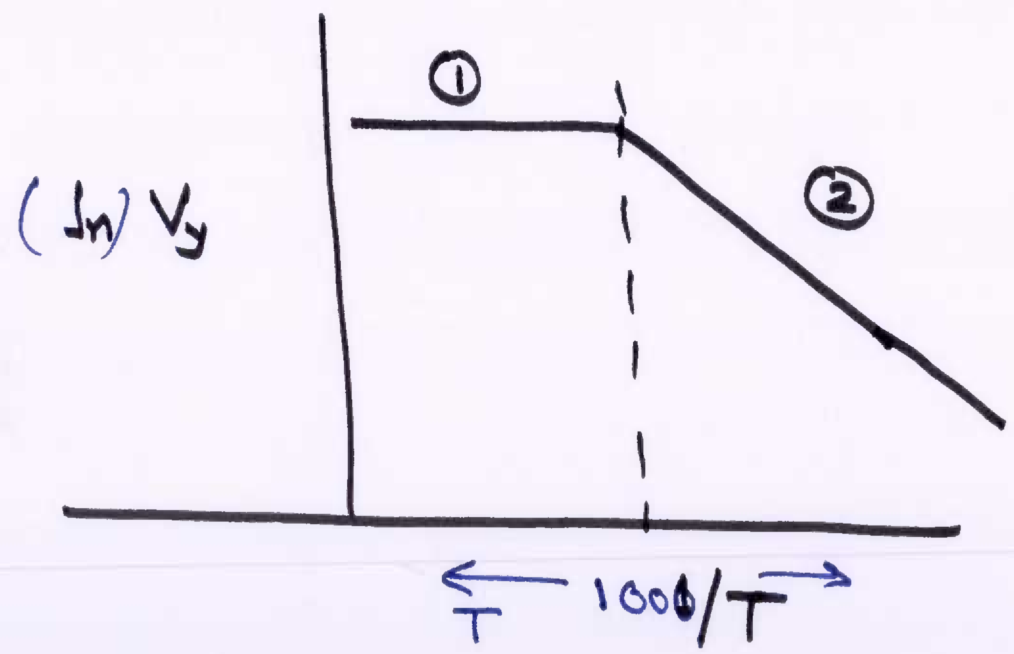
The Growth rate V_y is therefor written as

$$V_y = \frac{k_s h_G}{k_s + h_G} \cdot \frac{C_T}{N} \cdot Y \qquad \frac{1}{\left(\frac{1}{k_s} + \frac{1}{h_G}\right)}$$

Two cases :– ① $k_s \ll h_G$, then $V_y = \frac{k_s C_T Y}{N}$ — (A)

② If $h_G \ll k_s$, then $V_y = \frac{h_G C_T Y}{N}$ — (B)

Deposition rate (V_y, k) in CVD is a function of Temperature



① Mass Transfer limited

② Reaction Rate Limited

We know reaction rate Constant

$$k_s = k_0 \exp(-E_s/kT)$$

or k_s is strong (exponential) function of T

However Mass Transfer Coefficient h_G is related to gas stream Pressure and its diffusivity through Boundary layer. Hence h_G is very weak function of Temp. and treated constant.

Clearly at Lower temperatures, we can have $k_s << h_G$ and V_y will show exponential temperature dependance.

However at higher Temperature $k_s >> h_G$, and then V_y becomes constant with temperature.

APCVD and LPCVD uses these two cases in their system