## Given Problem:—

For Physical Vapour Deposition:—

Assumptions:—

- 1D growth:— Crystal grows only in the $+x$ direction from $x = 0$ to $x = L(t)$.
- Instantaneous crystallization:— every molecule arriving at the interface freezes with 100% efficiency.
- Isothermal interface:— Interface temperature $T_{int}(t)$ is prescribed.
- Constant properties
- Negligible vapor-side resistance: mass flux $J_m(t)$ is taken as known (or damped to an empirical growth rate).

## Governing Equations:—

- Heat conduction of the solid:—

$$\rho_s c_s \frac{\partial T}{\partial t} = k_s \frac{\partial^2 T}{\partial x^2}, \quad 0 < x < L(t)$$

- Stefan (energy) condition at $x = L(t)$

$$\rho_s \Delta H \frac{dL}{dt} = -k_s \frac{\partial T}{\partial x}\bigg|_{x=L(t)}$$

• Kinematic growth law :-

$$\rho_s \frac{dL}{dt} = J_n(t) M$$

Boundary & initial conditions :-

• At the seed $z=0$ :- $T(0,t) = T_{seed}$

• At the interface $z = L(t)$ :-

$$T(L(t), t) = T_{int}(t)$$

• Initial State at $t=0$ :-

$$L(0) = L_0 ; \quad T(z,0) = T_{init}(z)$$

Chemical Vapor Deposition :-

Assumption :-

1) 1D Boundary Layer :- gas-phase concentration varies only in $0 < z < \delta$

2) Steady gas flow :- velocity u constant; convection

3) First-order surface reaction :- deposition flux proportional to surface concentration

4) Instant array in corporation :- every reacted molecule becomes solid.

5) Constant properties :- $\rho_s, c_s, k_s, \Delta H, D_g$, $u_g$, $k_{chem}$ constant.

Governing equations:-

• Gas-phase convection-diffusion $(0<x<\delta)$

$$u \frac{\partial c_g}{\partial x} = D_g \frac{\partial^2 c_g}{\partial x^2}$$

• Surface reaction flux at $x=0$:-

$$J_{surf}(t) = k_{chem}\, c_g(0,t)$$

• Film heat conduction:-

$$\rho_s c_s \frac{\partial T}{\partial t} = k_s \frac{\partial^2 T}{\partial x^2}$$

• Energy (stefan) balance at the growing surface
$x=0$:-

$$\rho_s \Delta H \frac{dL}{dt} = -k_s \frac{\partial T}{\partial x}\Big|_{x=0}$$

• Kinematic growth law:-

$$\rho_s \frac{dL}{dt} = J_{surf}(t)\, M_{film}$$

Boundary and initial conductions:-

Gas layer:- $c_g(\delta,t) = c_\infty$

Film temperature:-

$$T(L(t),t) = T_{sub}\ ,\ -k_s T_x(0,t) = h_T\,[T(0,t) - T_\infty]$$

Initial state at $t=0$:-

$$L(0)=0;\ T(x,0) = T_{init}(x),\ c_g(x,0) = c_\infty$$