Spin Coating
Reviewing Bornside et al, 1991

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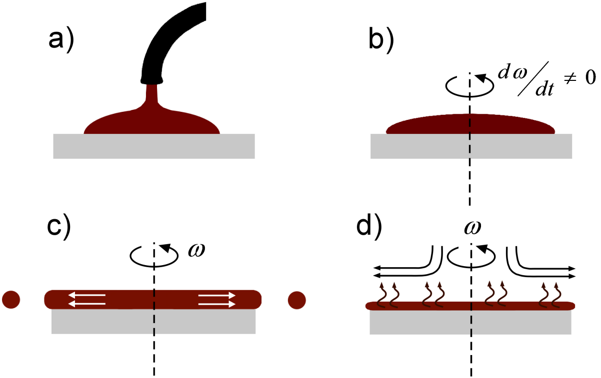
Outline

What is Spin Coating ?

- Spin coating is a widely used technique for creating uniform thin films on flat substrates. The process involves depositing a liquid solution onto a spinning substrate where centrifugal forces spread the liquid radially outward, thinning the film. As the solvent evaporates then the film solidifies.



Why Spin Coating ?

Spin coating is a common technique for applying thin films to surfaces because it's easy to use, inexpensive and versatile. It's used in a variety of applications including:

- **Widespread Applications :** Semiconductors, Biomedical Devices.
- **Key Benefits :** Simplicity and Speed.
- **Challenges :** Need to take care of the evaporation and coupling.

Problem

The **problem** lies in predicting and controlling the final film thickness h_f which depends on several interconnected factors:

- Fluid properties (viscosity, density, surface tension)
- Spin speed
- Solvent evaporation rate
- Polymer solvent interactions.

Model

comparison

- The main focus is to modify Mayerhofer's model.
- **Why?** Because the evaporation rate is an unknown parameter in the Mayerhofer's model.

Aspect	Meyerhofer's Model	Modified Model by Bornside, 1991
Evaporation rate in the solvent	Unknown Parameter	Computed
Viscosity assumptions	Assumed constant during convective stage	Assumed constant during convective stage
Coupling between stages	None:Independent	None

Convective outflow rate $= \frac{2\rho\omega^2 h^3}{3\eta_0}$

1. r momentum: $\frac{\partial^2 V_r}{\partial z^2} = -\frac{\omega^2 r}{\nu}$
2. Integrate and apply NO SLIP and NO SHEAR boundary conditions.
3. Radial flow rate, $q = \int_0^h V_r dz$
4. I - O + C + G = A
5. Output + Accumulation = 0
6. $2\pi r q \rho + \frac{d[\rho\pi r^2 h]}{dt} = 0$

Evaporation rate $= k(x_A^0 - x_{A\infty})$

1. Fick's law : $J = D\frac{C_s - C_\infty}{\delta}$
2. Ideal gas, $C = \frac{P_A}{RT}$
3. $\dot{m} = \frac{DM_A}{RT}\frac{P_A - P_{A\infty}}{\delta}$
4. Raoult's law, $P_A = x_A P_{A,sat}$
5. $\dot{m} = \frac{DM_A}{RT}\frac{P_{A,sat}(x_A^0 - x_\infty^0)}{\delta}$
6. J: molar flux, $\dot{m}$: mass flux, $P_{A,sat}$: solvent saturation pressure, M_A: molecular weight, x_A: solvent's mole fraction.

Model

wet film thickness

Convective Outflow Rate = Evaporation Rate

$$\frac{2\rho\omega^2 h^3}{3\eta_0} = k(x_A^0 - x_{A\infty})$$

$$\boxed{h_{wet} = \left[\left(\frac{3\eta_0}{2\rho\omega^2}\right) k(x_A^0 - x_{A\infty})\right]^{\frac{1}{3}}}$$

where

- k = mass transfer coefficient
- x_A^0 = initial concentration of solvent in the coating liquid
- $x_{A\infty}$ = mass fraction of solvent in the coating liquid
- h_{wet} = wet film thickness
- ρ = density of the liquid
- ω = angular velocity

- Assumes that the density of the solid dominates, $h_{wet} = \frac{m_{solid}+m_{solvent}}{\rho_{solid}A}$
- $A =$ Unit Area
- After solvent evaporates, $h_f = \frac{m_{solid}}{\rho_{solid}} = \left(\frac{m_{solid}+m_{solvent}}{\rho_{solid}}\right)\left(\frac{m_{solid}}{m_{solid}+m_{solvent}}\right)$
- Solvent mass fraction, $x_A^0 = \left(\frac{m_{solvent}}{m_{solid}+m_{solid}}\right)$
- $$\boxed{h_f = h_{wet}\left(1 - x_A^0\right)}$$

Model

dry film thickness

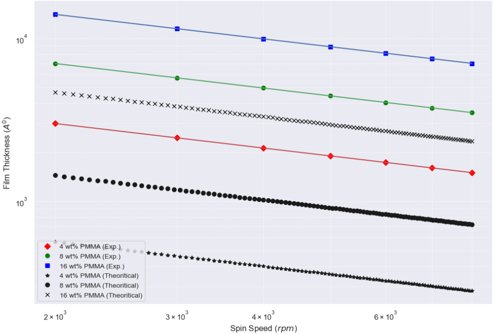
k and $\bar{k}$ are defined as $k = \bar{k}\omega^{1/2}$ and $\bar{k}$ is given constant

$$h_{wet} = \left[\left(\frac{3\eta_0}{2\rho\omega^{3/2}} \right) \bar{k}(x_A^0 - x_{A\infty}) \right]^{\frac{1}{3}}$$

$$\boxed{h_f = (1 - x_A^0) \left[\left(\frac{3\eta_0}{2\rho} \right) \bar{k}(x_A^0 - x_{A\infty}) \right]^{\frac{1}{3}} \frac{1}{\omega^{1/2}}}$$

Results and Conclusions

Results :



Conclusions : Spin coating is a vital process for producing thin films. Its widespread use and importance make it crucial to develop accurate models for predicting film thickness and understanding the underlying physics. This paper addresses some of the limitations in Mayerhofer's model and validates the theoretical model. Future works will be needed for coupling two stages.

Thank you!

Questions?