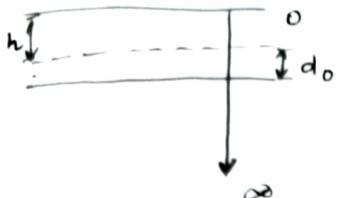


→ semi-infinite block



Total energy = energy of interaction b/w all molecules between  $(0, \infty)$

\* We make a thin slice and place it back.

Total energy

after making the slice = energy of interaction b/w all molecules ( $g_{\text{tot}}$ )

+ [energy required for making the slice (creating interface)]

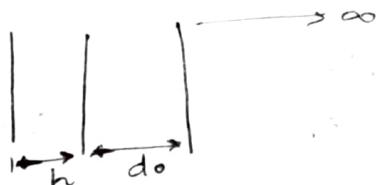
$c_1$  (constant)

$$= \text{Total surface energy} + \text{Total free energy} + G_{\text{interface}}^{100} (h, d_0)$$

$$d_0 \rightarrow \infty \quad d \approx h \quad d \rightarrow d_0$$

$$\therefore \text{Energy of all molecules } (0, h) = G_{\text{film}}^{100}$$

$$G_{\text{film}}^{100} = c_1 - G_{111, \text{interface}}^{100} \quad \dots \quad (1)$$



$$G_{111, \text{interface}}^{100} = -\frac{A_{12}}{12\pi} \left[ \frac{1}{d_0^2} + \frac{1}{(d_0 + h + \infty)^2} - \frac{1}{(d_0 + h)^2} - \frac{1}{(d + \infty)^2} \right]$$

$$G_{111, \text{interface}}^{100} = -\frac{A_{12}}{12\pi} \left[ \frac{1}{d_0^2} - \frac{1}{(d_0 + h)^2} \right]$$

$h + d_0 \approx h$  (order of magnitude analysis)

$$G_{111, \text{interface}}^{100} = -\frac{A_{12}}{12\pi} \left[ \frac{1}{d_0^2} - \frac{1}{h^2} \right]$$

from eqn (1)

$$G_{\text{film}}^{100} = 2r_1^{100} + \frac{A_{12}}{12\pi} \times \frac{1}{d_0^2} - \frac{A_{11}}{12\pi h^2} \quad \dots \quad [\because c_1 = 2r_1^{100}]$$

$$= 4r_1^{100} - \frac{A_{11}}{12\pi h^2}$$

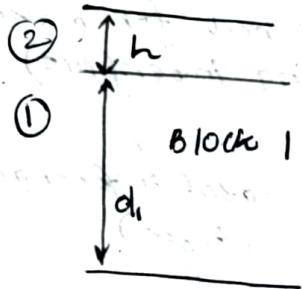
Thin film: it's a film in which  $h$  value is such that

$$G_{\text{film}}^{lw} = f(h).$$

$$G_{\text{film}}^{lw} = 4\gamma^{lw} - \frac{A_{11}}{12\pi h^2}$$

Film of material 1, thickness ' $h$ '.

Supported thin film



Total energy

$$\begin{aligned} &= G_2^{lw} + G_1^{lw} + G_{\text{interface}}^{lw} \\ &= C_2 \frac{A_{22}}{12\pi h^2} + C_1 \frac{A_{11}}{12\pi d_1^2} \quad (C_1 \rightarrow 0) \end{aligned}$$

$$\therefore \text{Total energy} = C_2 \frac{(A_{22} - A_{12})}{12\pi h^2} = C_2 - \frac{A_E}{12\pi h^2} - \frac{A_{12}}{12\pi} \left( \frac{1}{d_1^2} - \frac{1}{h^2} \right)$$

$A_E$  = effective Hamaker constant.

$A_{ii}, A_{ij}$  always positive

BUT sign of  $A_E$  depends upon the conditions.

\* For what  $h$ ,  $G_{\text{film}}^{lw} \neq f(h)$ ? Don't answer this because it also depends on  $A_E$ .  $h$  is somewhere around 100nm.

$$G_{\text{supported film}}^{lw} = C - \frac{A_E}{12\pi h^2}$$

2/25/24

$\frac{P_0}{P_0}$  flat miniscus

Pinside  $\uparrow ?$  curved liq surface at  $\alpha^m$

Pinside  $\neq P_0$

Pinside =  $f''$ (geometry)

Laplace pressure:



$P''$  spherical liq drop.

Spending some energy to increase the radius from  $R$  to  $R+dr$ .

$$\text{Work done} = (P'' - P) \times dV = \Delta P \times 4\pi R^2 dR \quad \dots \textcircled{1}$$

$$V = \frac{4}{3} \pi R^3, dV = 4\pi R^2 dR$$

$$dE_s = r dA$$

$$dE = r dA = r \times d(4\pi R^2) = 8\pi r^2 R dR \quad \dots \textcircled{2}$$

$$2 \cdot 8\pi r^2 R dR = \Delta P \times 4\pi R^2 dR$$

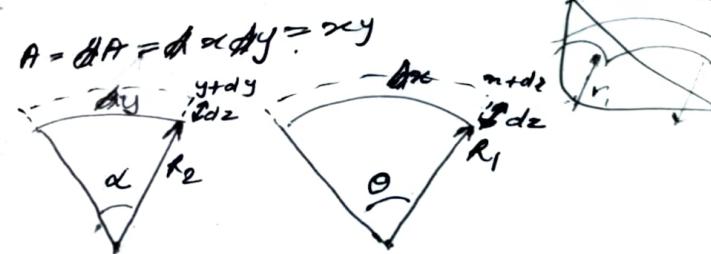
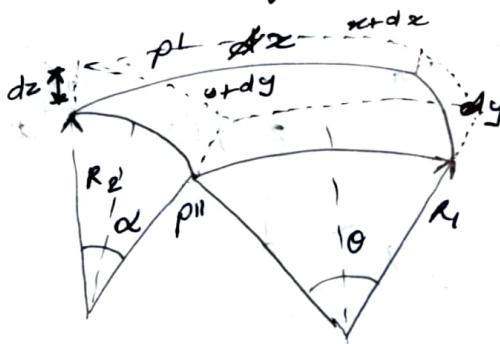
$$\boxed{\Delta P = \frac{2r}{R}}$$

from  $\textcircled{1} \& \textcircled{2}$

expression of Laplace pressure for a drop.

For general shape,

Part of a curved surface  $\rightarrow$



$$dE_s = r dA$$

$$\approx (x dy + y dx) \times r$$

$$d\omega = \Delta P dV = \Delta P \pi y dz$$

$$\Delta P \times \pi y dz = r(x dy + y dx)$$

$$\frac{y+dy}{y} = \frac{R_2 + dz}{R_2};$$

$$\frac{x+dx}{x} = \frac{R_1 + dz}{R_1} \quad \dots \text{similar triangles}$$

$$dy = \frac{y}{R_2} dz$$

$$dx = \frac{x}{R_1} dz$$

isotropic expansion  
[material property]

$$\therefore \Delta P(xy) dz = r(y dx + x dy)$$

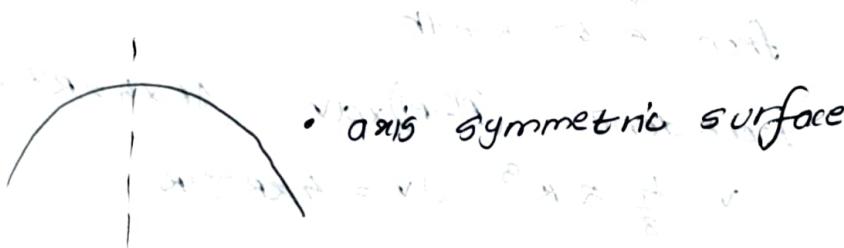
$$= r\left(\frac{xy}{R_2} dz + y \frac{x}{R_1} dz\right)$$

$$\Delta P xy dz = r(xy dz) \times \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

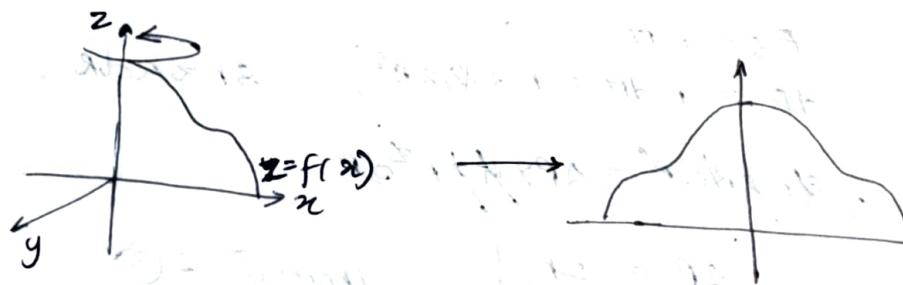
$$\boxed{\Delta P = r \times \left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

Young-Laplace eqn.

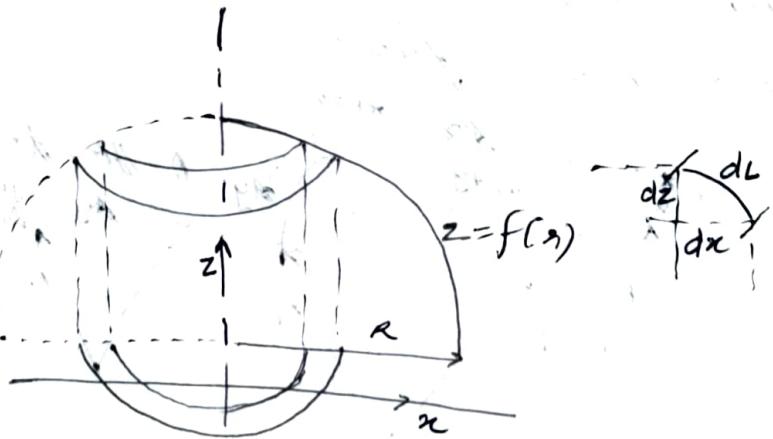
\* for  $\theta_E \uparrow \Rightarrow \Delta P \uparrow$  Reason = less radius of curvature



axis symmetric surface



→ Generalised expression of the Y-L eqn over an axis-symmetric surface:



For an axis-symmetric surface shape of the meniscus at equilibrium we are going to find out the

$$H = U + PV$$

Gibb's free energy  $G = H - TS$   
 $(P, T \text{ const})$

$$H = G + TS$$

$$U + PV = G + TS$$

$$U = G + TS - PV$$

$$\left. \begin{aligned} &H = U + PV \\ &G = H - TS \\ &U + PV = G + TS \\ &U = G + TS - PV \end{aligned} \right\}$$

Helmoltz free energy  $F = U - TS + \sum r_j A_j$   $j = \text{no. of interface.}$   
 $(V \rightarrow \text{const})$

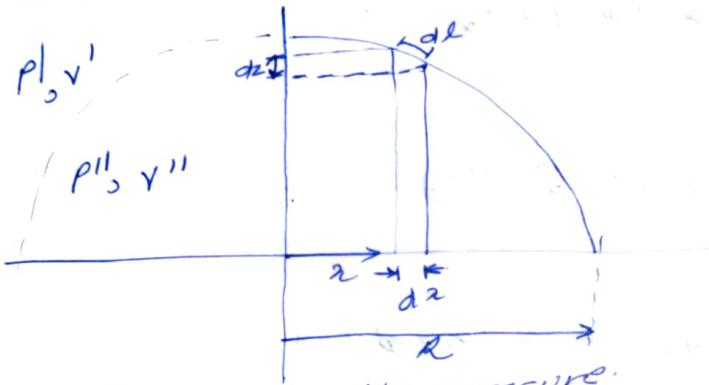
$$F = U - TS + RA$$

$$F = G + \cancel{PV} - PV + RA$$

$$\boxed{F = G - PV + RA}$$

6/08/24

constant vol. system



$P''$  = liquid side pressure.

$P'$  = surrounding pressure.

$P'' = f(\text{curvature})$

Laplace pressure = it is the  $\Delta P$  b/w two sides of a liquid curved surface when mechanical eqm exists.

$$\therefore F = -PV + RA + C_1$$

$$= RA - P'' V'' - P' V' + C_1$$

$$= RA - P'' V'' - P'(V - V'') + C_1$$

$$= RA + (P' - P'') V'' - PV + C_1$$

$$\boxed{F = RA + \Delta P'' V'' + C_2}$$

→ constant volume drops with diff. geometries

$\checkmark_{01}$

$\checkmark_{02}$

$\checkmark_{03}$

• System having  $F_{\min}$  will be the desired geometry.

$$V_{\text{total}} = V = V' + V''$$

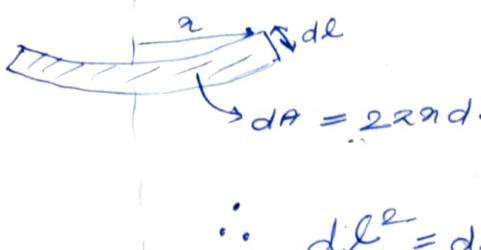
for  $j = \text{no. of interface}$

$$F = U - TS + \sum r_j A_j$$

for  $j = 1$

$$\begin{aligned} F &= U - TS + RA \\ &= G - PV + TS - TS + RA \\ &= \sum \mu_i x_i - PV + RA \\ &\equiv -PV + RA + \text{const.} \end{aligned}$$

Laplace pressure definition.



$$ds^2 = dx^2 \left( 1 + \left( \frac{dz}{dx} \right)^2 \right)$$

$dz, dz$  are small.  
 $\therefore dL = \text{straight line}$

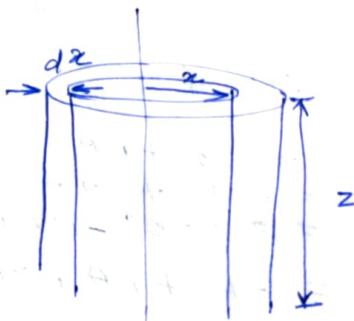
$$d\zeta^2 = dx^2(1+z_x^2)$$

$$d\Omega^2 = dz^2(1+z_x^2)$$

$$dl = dx \sqrt{1 + z_x^2}$$

$$\therefore dA = 2\pi x dx (1 + z_x^2)^{1/2}$$

$$A = \int_0^R 2\pi x (1+z_x^2)^{1/2} dx$$



$$dv = 2\pi x dz \times dz$$

$$dv = 2\pi x z dx$$

$$V' = \int_0^R 2\pi x z dx$$

$$F = -PV'' + rA \text{ f} \text{or} \text{st}$$

$$F = -P \int_0^R 2\pi r z dr + r \int_0^R 2\pi r (1+z^2)^{1/2} dr + \text{const}$$

$$F = \int_0^R f(a_0, z, \frac{dz}{dx}) dx.$$

functional  $\Rightarrow$  falls under 'calculus of variations'

→ Necessary Condition:

$$\frac{\partial f}{\partial z} - \frac{\partial}{\partial x} \left( \frac{\partial f}{\partial z_x} \right) = 0 \quad \dots \quad (1)$$

$z_{122}$  are treated as if they are separate variables.

$$f = r \times 2\pi z_x (1+z_x^2)^{1/2} + \Delta P(2\pi z_x) dz_x$$

$$\frac{\partial f}{\partial z_x} = \Delta P \times 2\pi z_x.$$

$$\begin{aligned} \frac{\partial f}{\partial z_x} &= r \times 2\pi z_x \times \frac{1}{2} (1+z_x^2)^{-1/2} \times 2\pi z_x \\ &= \frac{2\pi z_x r z_x}{(1+z_x^2)^{1/2}}. \end{aligned}$$

$$\frac{\partial}{\partial z_x} \left( \frac{\partial f}{\partial z_x} \right) = 2\pi r \left[ (z_x z_{xx} + z_x) (1+z_x^2)^{1/2} - z_x z_x \times \frac{1}{2} \times (1+z_x^2)^{-1/2} \times 2\pi z_x \right] / (1+z_x^2)$$

$$= \frac{2\pi r}{(1+z_x^2)} \left[ (z_x z_{xx} + z_x) (1+z_x^2)^{1/2} - \frac{\pi z_x^2 z_{xx}}{(1+z_x^2)^{1/2}} \right]$$

$$= \frac{2\pi r}{(1+z_x^2)^{3/2}} \left[ (z_x z_{xx} + z_x) (1+z_x^2)^{1/2} - \pi z_x^2 z_{xx} \right]$$

$$= \frac{2\pi r}{(1+z_x^2)^{3/2}} \times \left[ z_x z_{xx} + z_x z_{xx} z_x^2 - z_x^2 z_{xx} + z_x + z_x^3 \right]$$

$$= \frac{2\pi r}{(1+z_x^2)^{3/2}} \left[ z_x^3 + z_x + z_x z_{xx} \right] = 2\pi r \left[ \frac{z_x}{(1+z_x^2)^{1/2}} + \frac{z_x z_{xx}}{(1+z_x^2)^{3/2}} \right]$$

Using ①,

$$\therefore \cancel{\Delta P \times 2\pi z_x} - \cancel{\frac{2\pi r}{(1+z_x^2)}} \left[ \frac{z_x}{(1+z_x^2)^{1/2}} + \frac{z_x z_{xx}}{(1+z_x^2)^{3/2}} \right] = 0$$

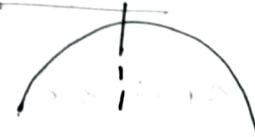
$$\Delta P_x = r \left[ \frac{z_x}{(1+z_x^2)^{1/2}} + \frac{z_x z_{xx}}{(1+z_x^2)^{3/2}} \right]$$

$$\Delta P = r \left[ \frac{z_x}{x(1+z_x^2)^{1/2}} + \frac{z_x z_{xx}}{(1+z_x^2)^{3/2}} \right]$$

Case -1

$$z \mid z = f(x)$$

Case -2



Long wave oscillation.  
 $\frac{dz}{dx} \rightarrow 0$  [small slope]

→ Y-Legn for an anti-symmetric surface that has long wave (small slope)

$$\boxed{\Delta P = r z_{avg}}$$

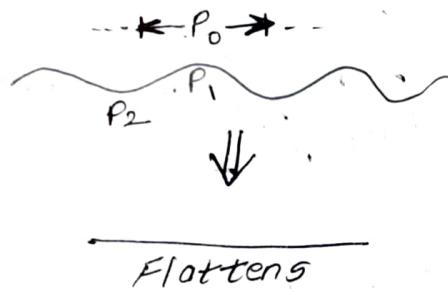
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Supported thin film

Film  
Substrate

$$G_{\text{System}}^{\text{lw}} = G_{1/2 \text{ film}}^{\text{lw}} = -\frac{A_E}{12 \lambda h^2} + C$$

Laplace pressure gradient



$$\Delta G_{\text{System}}^{\text{lw}} = G_{\text{System}}^{\text{lw}} \Big|_{h=h} - G_{\text{System}}^{\text{lw}} \Big|_{h \rightarrow \infty}$$

$$\Delta G_{\text{System}}^{\text{lw}} = -\frac{A_E}{12 \lambda h^2} \quad \left[ \text{excess free energy of the thin film} \right]$$

Is the energy, arising out of the interaction b/w air/film & film/substrate interface.

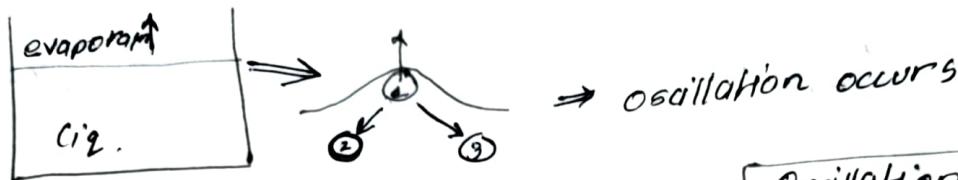
$$\frac{\partial(\Delta G_{\text{sys}}^{\text{lw}})}{\partial h} = \frac{A_E}{62 h^3} \quad \left[ \text{How the excess free energy of the system changes with change in } h. \right]$$

$$\Pi = -\frac{\partial (\Delta G_{sys}^{lw})}{\partial h} = \frac{-AE}{6\pi h^3}$$

(conjoining pressure)

$$\frac{\partial (\Delta G_{sys}^{lw})}{\partial h} = \text{conjoining pressure}$$

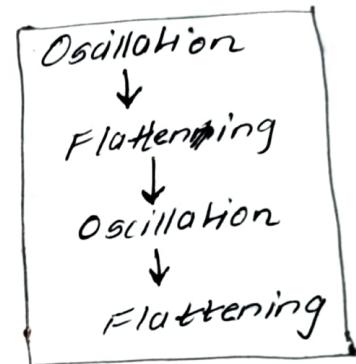
→ In case with reduction in 'h'  $\Delta G_{sys}^{lw}$  also reduces  
 Then -  
 • Thermodynamically favoured reduction in h.



① = trying to escape

②, ③ = keep pulling ①

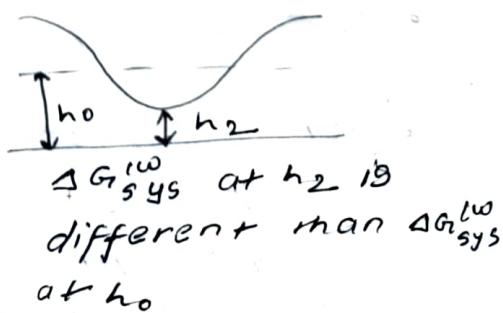
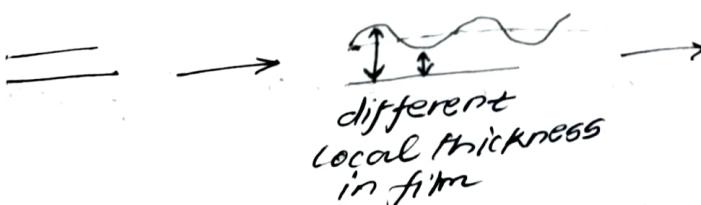
This causes oscillation. This oscillation is low amplitude in nature.



→ thin liquid film

• thin film?  
 → A film which has excess free energy.  $\Delta G_{sys}^{lw} \neq 0$  i.e. active interaction between two interfaces.

	Glass of liq.	thin film of liq.
Same	evaporation	" "
Difference	$\Delta G_{sys}^{lw} = 0$	$\Delta G_{sys}^{lw} \neq 0$



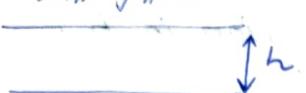
either  $\Delta G_{h_2}^{lw} > \Delta G_{h_0}^{lw}$  or  $\Delta G_{h_2}^{lw} < \Delta G_{h_0}^{lw}$

not thermodynamically favoured

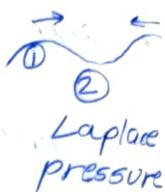
will be thermodynamically favoured

• 13/3/24

Thin film

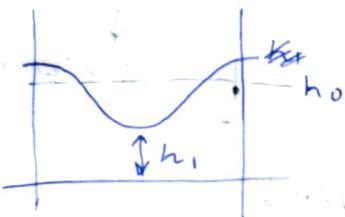


fluctuation over a free liquid surface



$$G_{film}^{lw} = -\frac{AE}{12\pi h^3} + C$$

$$\frac{\partial G_{film}^{lw}}{\partial h} = \frac{AE}{\delta \pi h^3} = \phi \quad [\text{effective interface potential or conjoining pressure}]$$



$$\frac{\partial(\Delta G_{film}^{lw})}{\partial h} = \frac{\text{change in } \Delta G_{film}^{lw}}{\text{change in thickness}}$$

$$= \frac{\Delta G_{film}^{lw}/h_1 - \Delta G_{film}^{lw}/h_0}{h_1 - h_0}$$

$$\Delta G_{film}^{lw}/h_1 > \Delta G_{film}^{lw}/h_0 \Rightarrow$$

growth of fluctuation is not favoured. Thermodynamically unfavoured.

Flattening will occur: 1. Laplace pressure

2. repulsion b/w surface and interface

$\phi \rightarrow -ve$  is possible for  $AE \rightarrow -ve$

case:

for  $\phi \rightarrow +ve$  growth of fluctuations is favoured.  
 $AE \rightarrow +ve$

Laplace pressure is trying to flatten out  
Whereas conjoining pressure favours growth in film

$$\phi = \frac{A_E}{6\pi h^3}$$

-ve  $\rightarrow$  Growth not favoured,  $A_E$  ve-

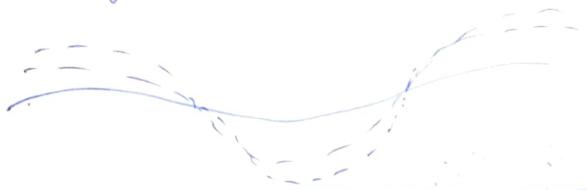
+ve  $\rightarrow$  Growth favoured,  $A_E$  ve-

<p style="margin: 0;">film will flatten</p>	<p style="margin: 0;">film may or may not flatten</p>
---------------------------------------------	-----------------------------------------------------------

Intefacial interaction  
repulsion

interfaical interaction  
attractive

$\Rightarrow$  for favoured growth



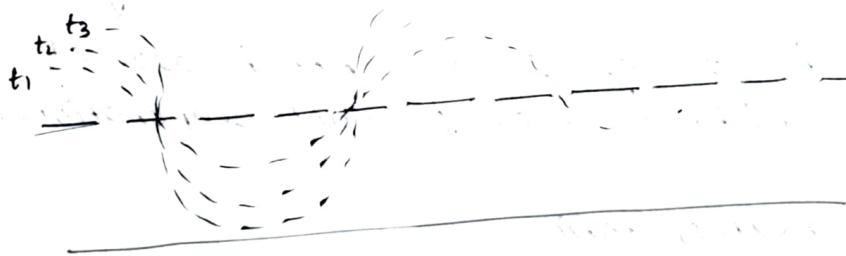
$R$  (curvature) ↓  
 $\therefore$  Laplace pressure ↑  
 but  
 as local thickness ↓  
 Conjoining pressure ↑

$$15/8/2^4. \quad \phi = \frac{\partial \Delta G_{\text{film}}^{\text{lw}}}{\partial h} = \frac{A_E}{6\pi h^3}$$

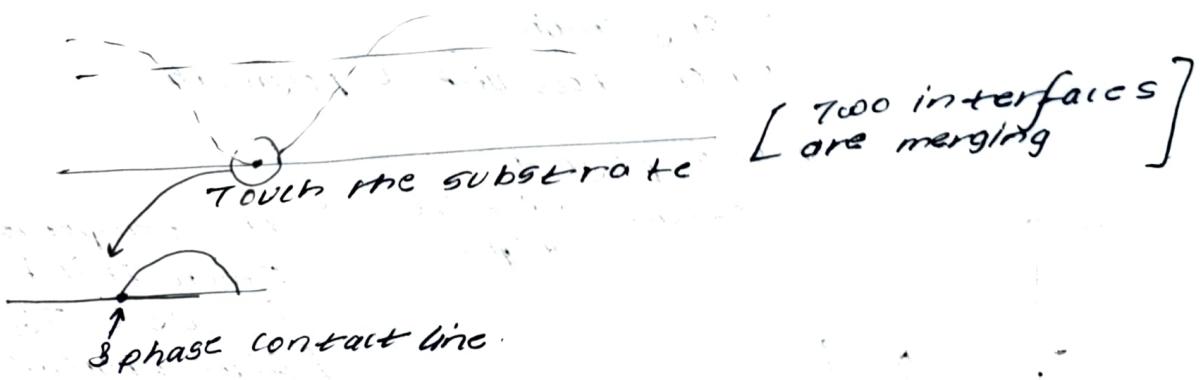
$$\Delta G_{\text{film}}^{\text{lw}} = -\frac{A_E}{12\pi h^3}$$

+ve  $\phi \rightarrow A_E$  +ve  $\rightarrow$  Growth favoured

-ve  $\phi \rightarrow A_E$  -ve  $\rightarrow$  Growth not favoured  
 [Stable film]



$\Leftrightarrow \phi \propto \text{laplace pressure}$

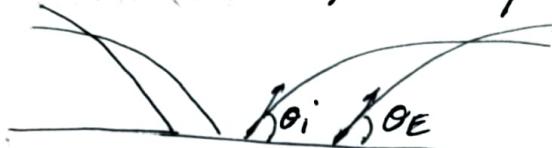


Growth of undulation

$$(1\theta_1) > (1\theta_1)$$

Leads to merging of two interfaces.

Formation of hole / 3 phase contact line formation



After hole formation,

intrinsic contact angle in  $\theta_i$ ,

Subsequently contact line retracts so that  $\theta_i \rightarrow \theta_E$

→ After film ruptures surface tension increases the undulation whereas surface tension has opposing growth before rupturing of film.

Spontaneous Instability in an ultra thin liquid film.

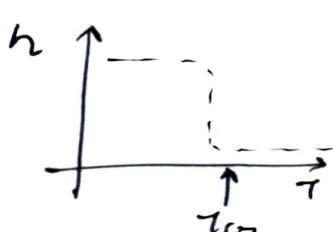
Note- Though the experiment of spontaneous instability can be done on a regular liquid, ~~but~~ we do not use regular liquids. We use polymers with less volatility in order to make sure that the growth of undulation is occurring because of  $\phi$  and not because of reduction in thickness bcoz of fast evaporation.

Polymer → thermoplastic

- long chain

- non-cross linked polymers

Heat polymer:



softens / viscosity drops  $\Rightarrow$  the temperature at which this happens

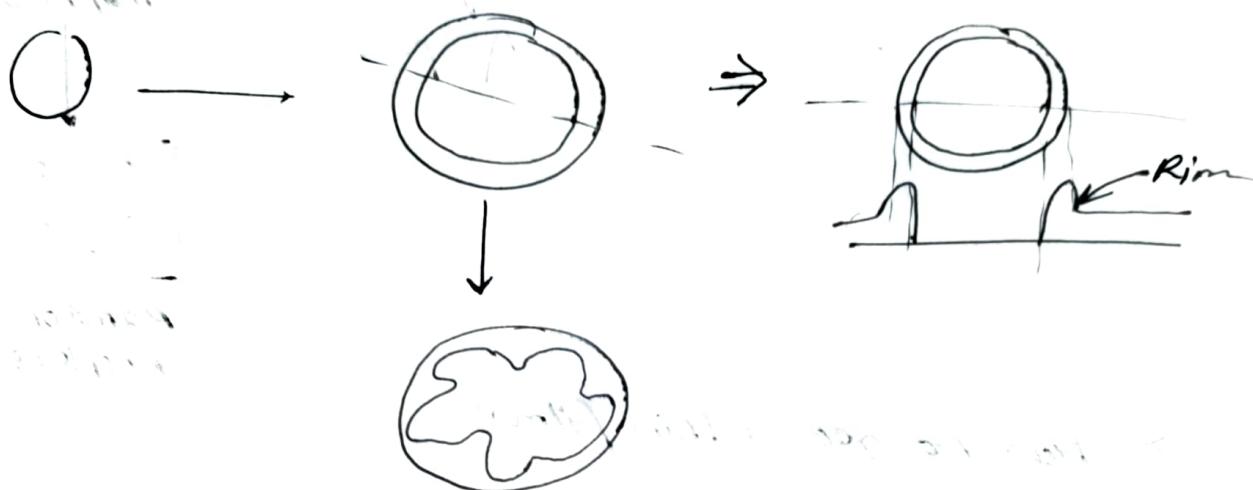
is called  $T_g$   
[glass transition temperature]

61065 → amorphous ⇒ resembles liquid.

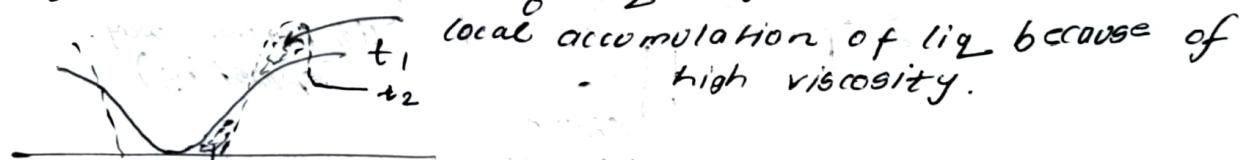
↳ frozen liquid.

↳ structurally analogous to a liquid.

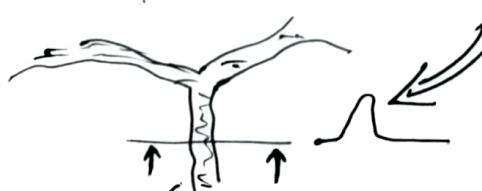
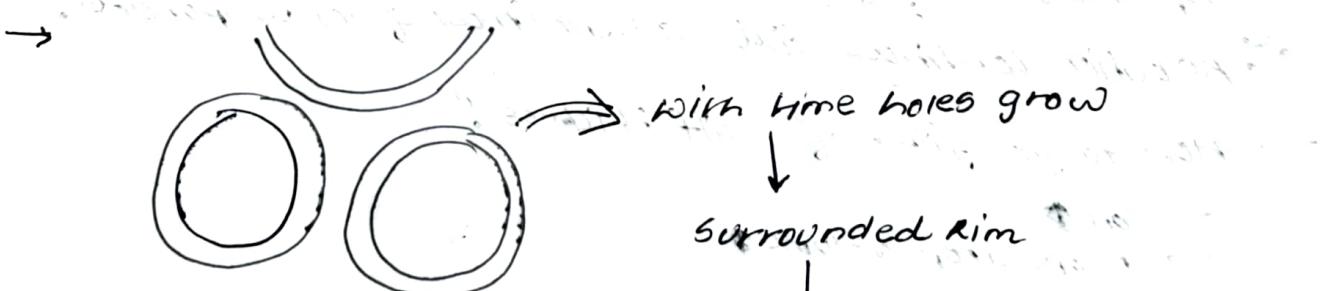
changes in hole formed with time



→ local accumulation of liquid:

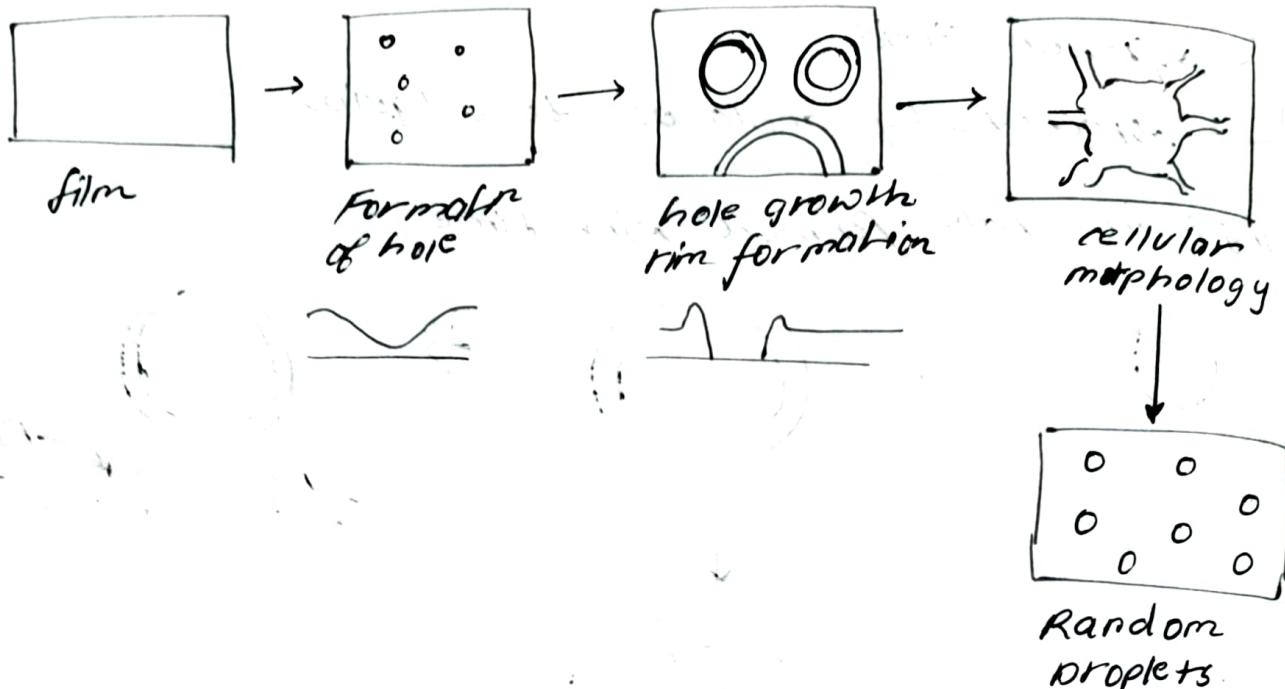


↳ liq. dislocated from here



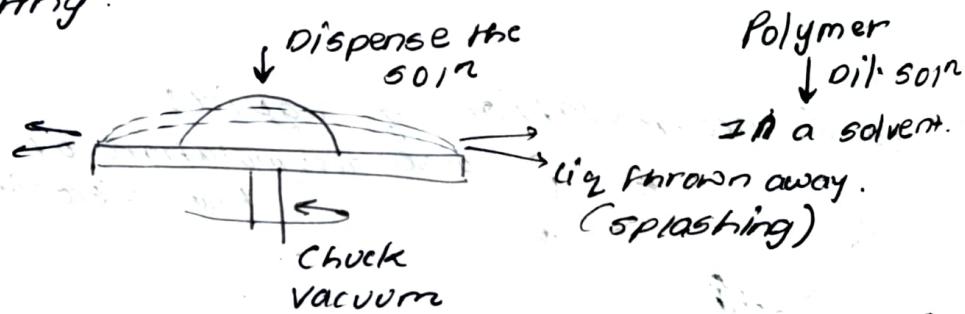
↳ droplets because of surface tension.

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→ How to get a thin film?

- Spin coating:



→ as rotation continues, evaporation of solvent occurs → concentration increases → after saturation point is reached → polymer deposits on wafer.

\* • Rotation continues till solvent (most of it) evaporates.

→ How to get films of diff thickness?

- Concentration
- More drop volume
- Rotation speed

\* Rotation time depends on solvent volatility as well.

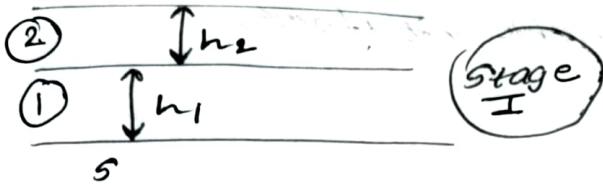
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Instability in a thin polymer bilayer.

- Both films are thin.

~~solvent should be such that it doesn't dissolve in it.~~

$\begin{array}{c} \textcircled{2} & & \phi_2 \\ \hline \textcircled{1} & & \phi_1 \\ \hline s & & \end{array}$

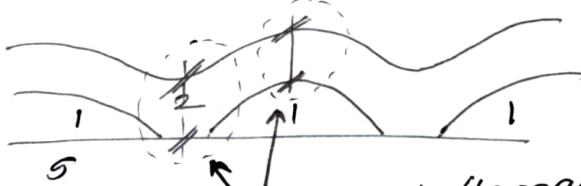
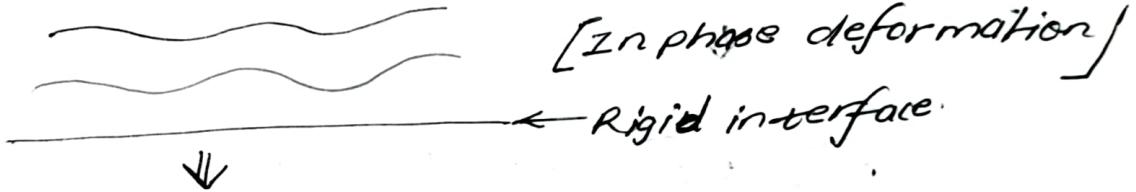


$$\phi_1 \neq 0 \quad \phi_2 \neq 0$$

$h_1 \neq h_2$  will be different  
Here, we are considering  
both layers are unstable

→ Bilayers will become unstable sequentially. The layer in which  $\phi$  is high will become unstable first.

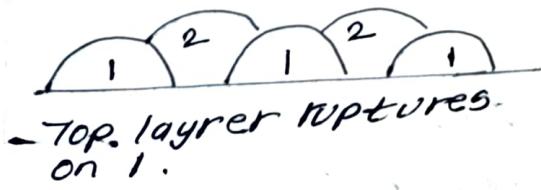
Suppose,  $\phi_1 > \phi_2$



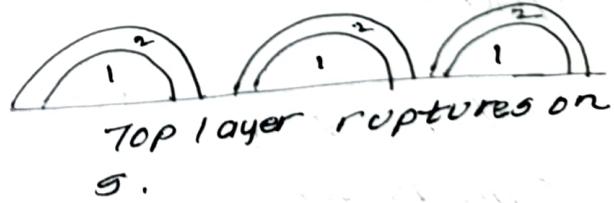
Different Hamaker constants  
 $\therefore$  Different conjoining pressure strengths

We get '2' more cases based on the interaction b/w '2' and 'S'.

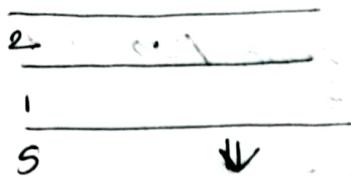
A2



A1

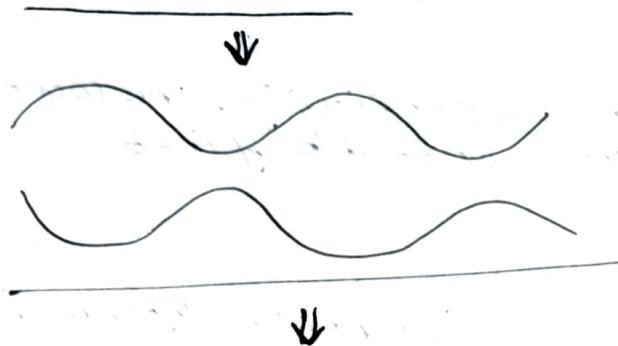


Top layer becomes unstable first

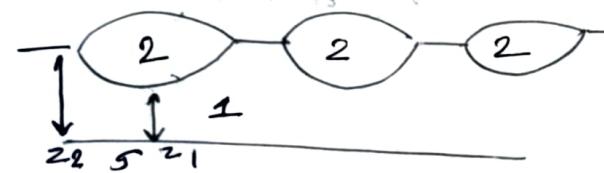


higher attraction over here

↔ 2 deformable interfaces.



[out of phase deformation]



Ko1  
• Droplets rest on 'S'  
• Young's configuration

(S)  
• Droplets of 2 rest on '1' [liquid surface]  
• Neumann's configuration.

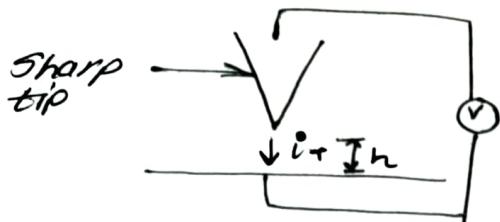
θA θB  
θA ≠ θB

ϕ₂₂ > ϕ₂₁  
Film ruptures  
between droplets  
of 2.

ϕ₂₁ > ϕ₂₂  
Film ruptures below  
droplets of 2.

- Atomic force microscope (AFM).
- Scanning Tunneling microscope (STM) } Scanning Probe microscope [SPM]

• STM

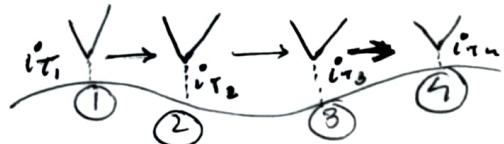


quantum tunnelling

$$i = f(\text{separation})$$

$i_T = f(h)$  ... Relation is known

Tip is progressively moved



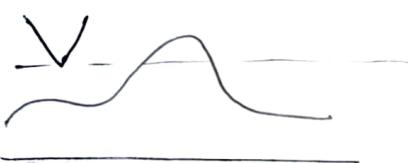
• STM operates at high vacuum.

• Modes of STM:

1. Constant height mode STM.

Limitations

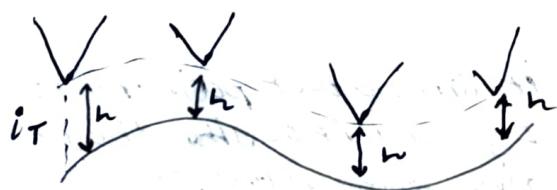
①



②



2. Constant current mode STM [feedback control loop is employed]



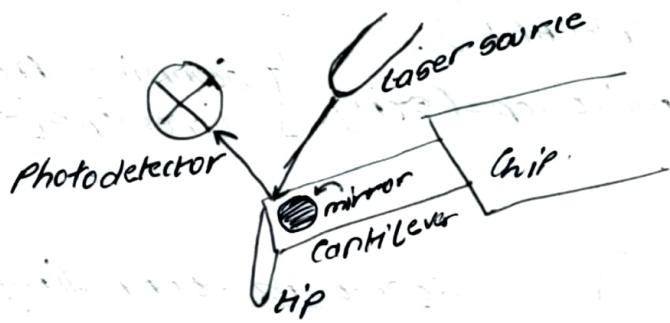
$$\epsilon = i_{T(SP)} - i_T$$

↓  
setpoint

Limitations: The surface needs to be conducting.

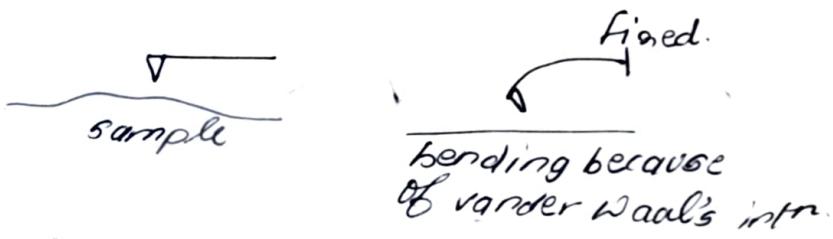
∴ AFM is used. → van der Waal's interaction used as an analogue to current.

AFM

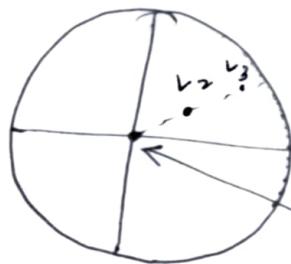


Major components:

1. Tip & cantilever
2. Quadrant photo detector diode
3. Laser source
4. Feedback control
5. Piezoelectric tip mount/scanner



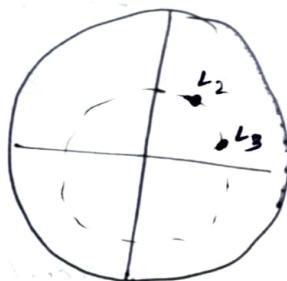
Quadrant  
Photodiode-



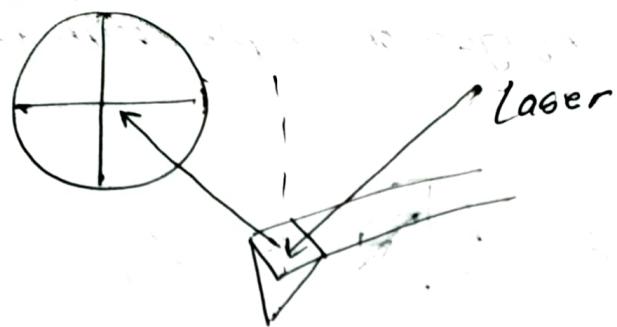
if light falls over here.  
 $= \text{am } V.$

$A160,$

$$V_{L_3} > V_{L_2}$$



it can detect positions  $L_2$  &  $L_3$  even though they will give same voltage.

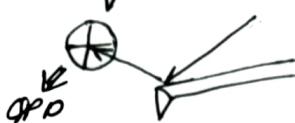


→ Alignment of cantilever is important.

1. 1st set of screws



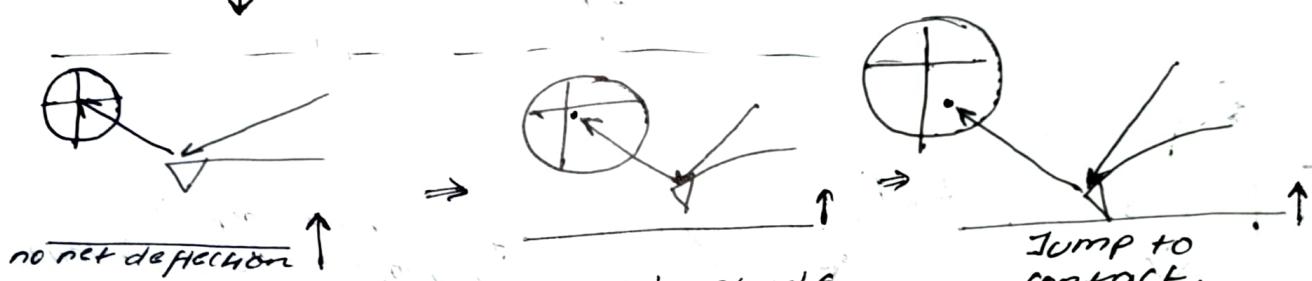
2. 2nd set of screws



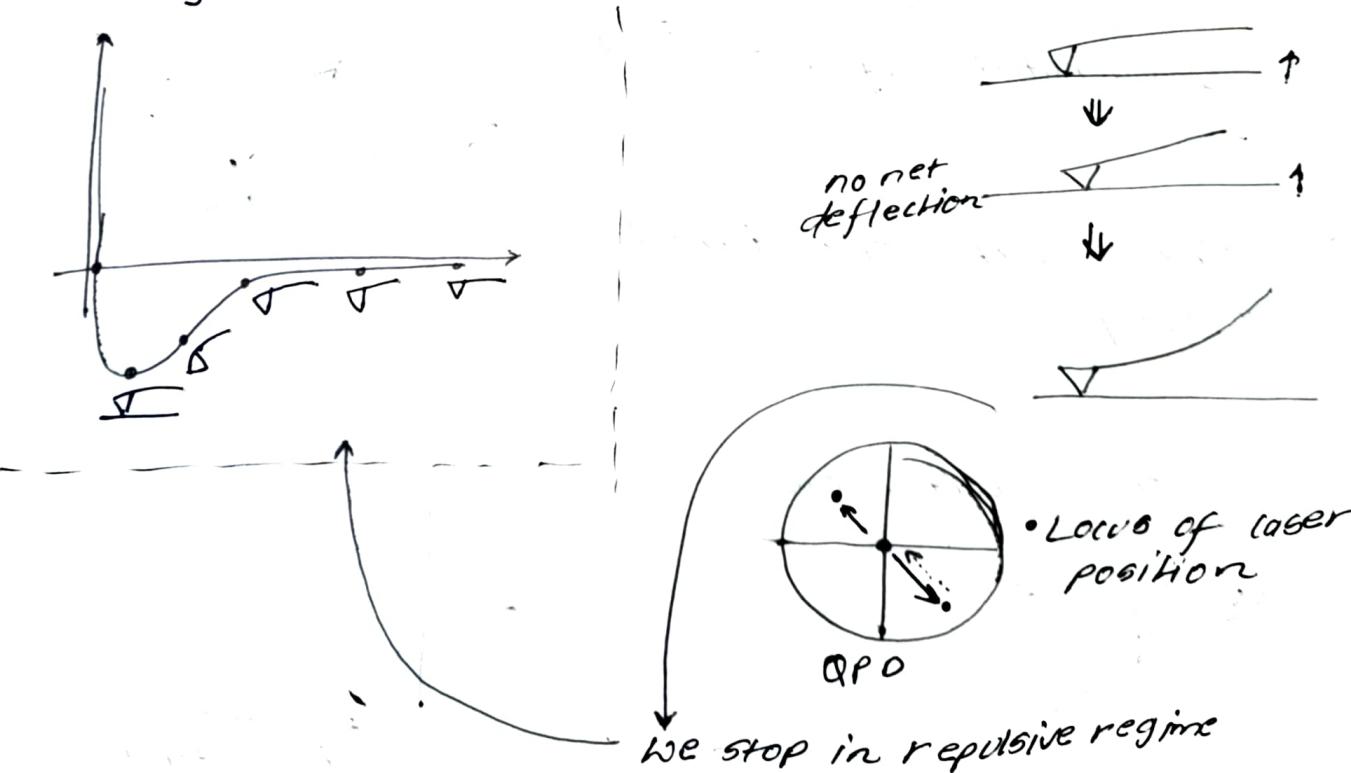
→ Bringing sample close to tip using stepper motor. [Approach process]

When the tip is "close"

↓  
Inter-surface vdW forces start / get active.



- As sample approaches tip, tip starts bending because of vdw forces.

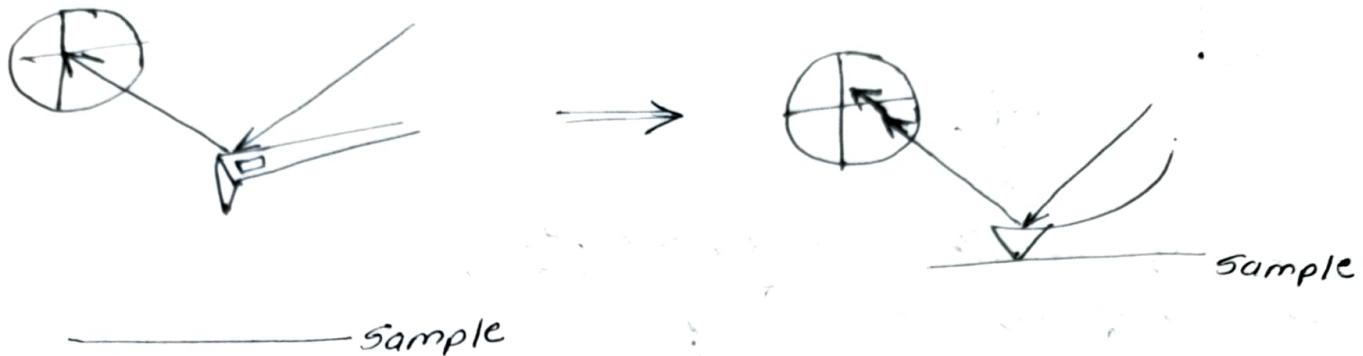


- Locus of laser position

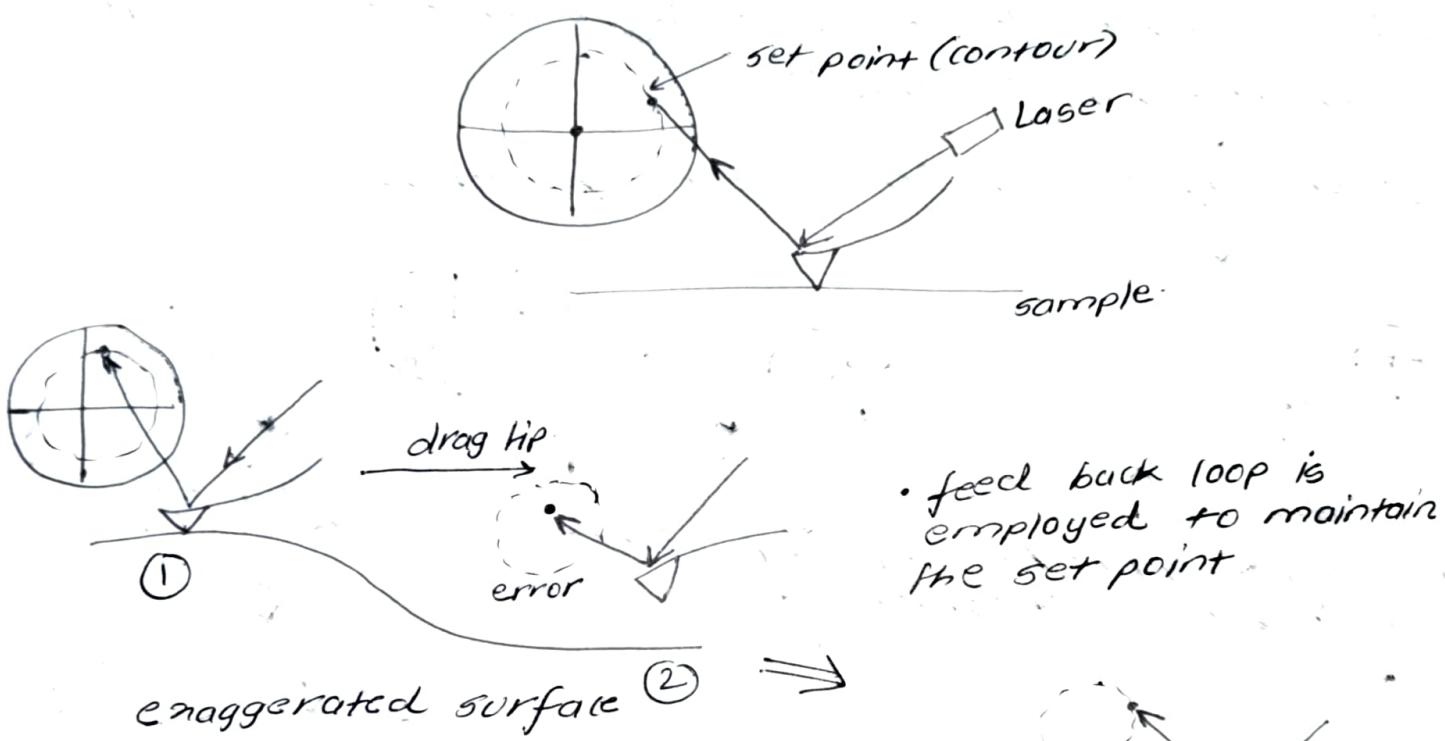
↓  
We stop in repulsive regime

for stopping we choose a set point

→ How the sample gets engaged or coupled with the tip



→ Set point

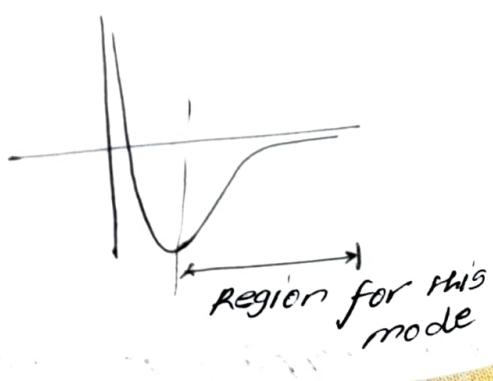


→ Above is the contact mode imaging

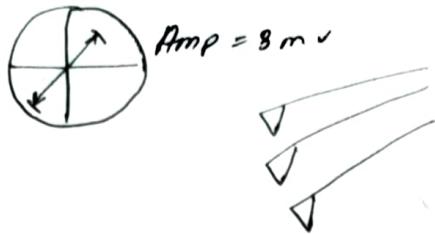
→ non-contact mode:



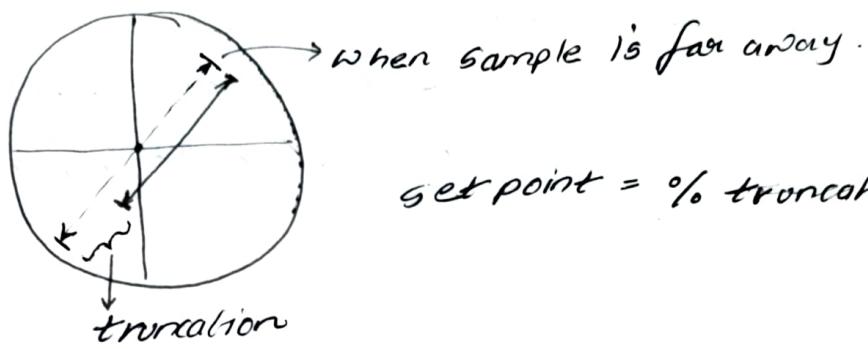
Disadvantage - low resolution



→ Tapping mode / Intermittent contact mode  $\Rightarrow$  Suited for soft samples



→ Consequences of tip hitting the sample [on QPD]?



set point = % truncation

→ Patterns  $\rightarrow$  chemical pattern

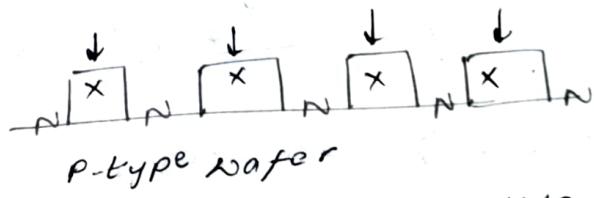
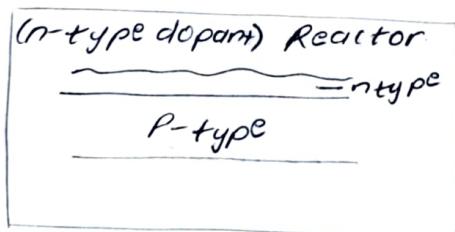
topographical pattern

Physico-chemical patterns

→ Metals are hydrophilic (bcz of high  $\kappa_s$ ).

→ meta-materials (-ve RI)

→ Photolithography -



concept to make multiple junctions

## 6IC steps

1. grow oxide layer.



2. coat photo resist.

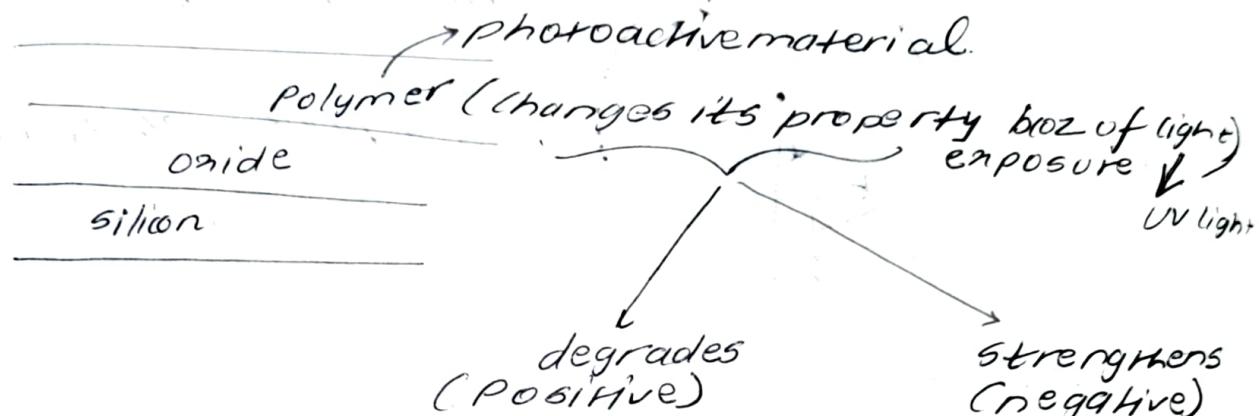
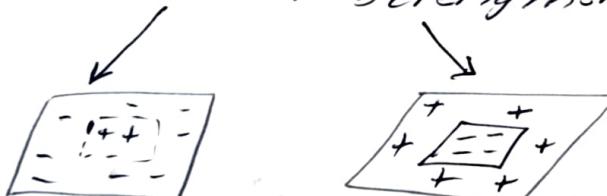


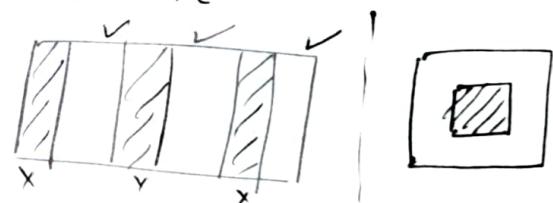
Photo lithography is done in 'yellow room' [minimal uv light]

3. Exposure to UV *next*

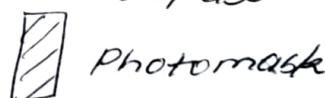
• Photo resist will either degrade or strengthen



3. Photo mask

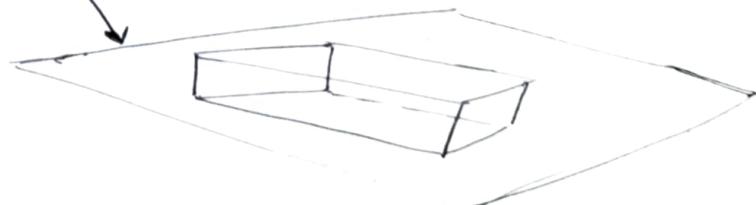
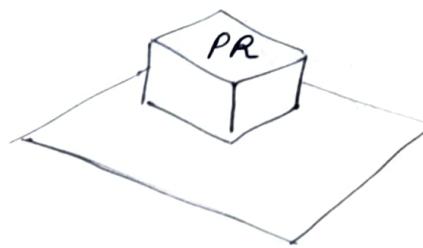


X → UV light won't be allowed to pass



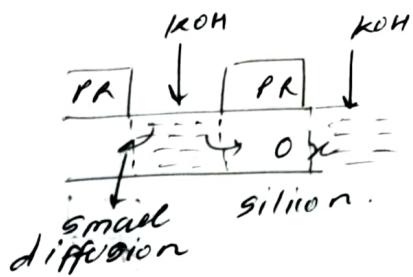
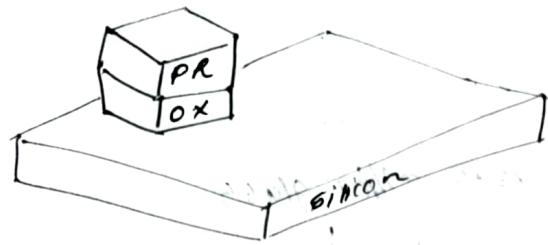
Photomask

5. development stage [using solvent to dissolve weak part]



\*\* Development time is crucial so that it dissolves only weak part of PR & not a strong part.

6. Etching  $\rightarrow$  immersed in KOH (to dissolve oxide)



7. Complete removal of PR using developer (longer duration than before)

8. n-type doping

9. Removal of oxide layer (remaining) using KOH

$\rightarrow$  Photoresist processing

\* 1. dehydratn & Priming

- after cleaning liq. is present on wafer.
- $\therefore$  heating is done to remove liq. ( $400^\circ\text{C}$  to  $800^\circ\text{C}$ )
- After dehydratn, priming is done to increase adhesion b/w PR & oxide layer.  $\Rightarrow$  some polymer which is spin coated on oxide layer

\*\* 9. Soft baking:

After spin coating



- This solvent needs to be removed therefore soft baking is used [ $T \rightarrow 90-110^\circ\text{C}$ ]

\* Photo mask-



→ Optical Exposure: Printing modes

Contact printing  $\Rightarrow$  mask touches photoresist.

Possibility of mask damage

Proximity printing  $\Rightarrow$  ~~mask~~ mask does not touch photoresist.

$\rightarrow$  increase in hardware to do this

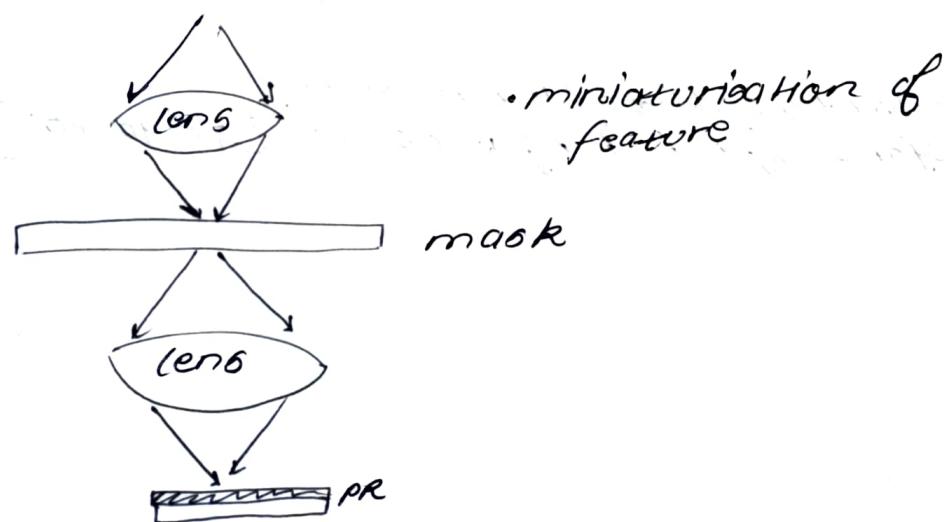
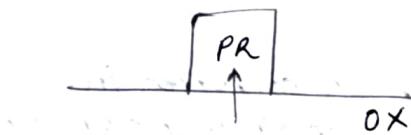
$\rightarrow$  drop in resolution

$\rightarrow$  No mask damage

Projection printing:



lp  $\Rightarrow$  limited by wavelength  
of light used (uv)



→ Limitation of photo lithography-

1. Expensive.

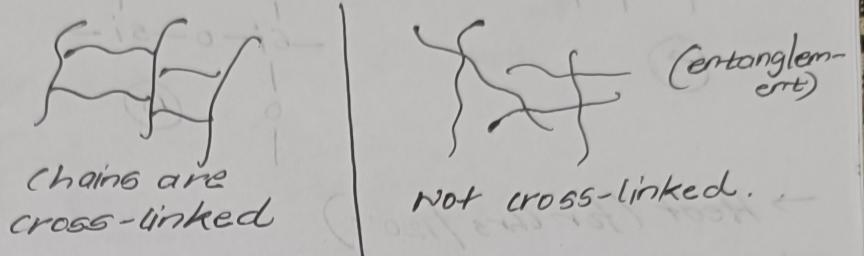
2. Resolution limited by optical diffraction.

- Limitation of photo lithography-
1. Expensive
  2. Resolution limited by optical diffraction.
  3. Limited to planar surfaces.

⇒ Soft Lithography [Group of techniques for patterning soft surfaces. ex - Polymeric surface]

Types of polymer?

Long chain → Based on the nature of chains  
(organic)



Cross-linked polymer it does not have a  $T_g$  and spontaneous instability is not observed in cross-linked polymer.

→ Classification of soft lithography techniques:

- Based on nature of pattern

- chemical patterns
- topographic patterns

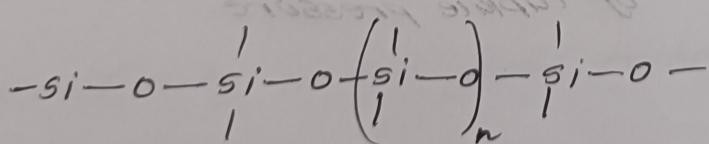
- Based on nature of mold

- Rigid
- Flexible

→ REM [Replica Molding]

The polymer used for REM is cross-linkable POMS

falls in category of elastomers



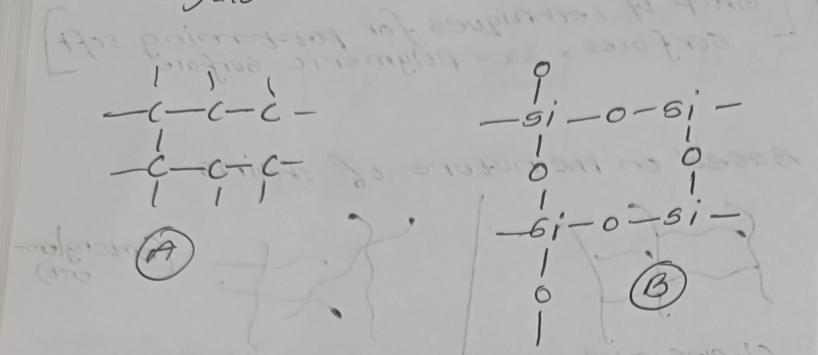
thermo curable

POMS (has 2 parts) → part A (oligomer)  
Sylgard 184 → part B (cross linker)

Part A + Part B  $\xrightarrow{\text{heating}}$  cross-links develop (solidification)

## REMI (Still material specific)

- Take a patterned surface
- Pour mixture of POMS + crosslinker on patterned surface



B is more flexible than A.

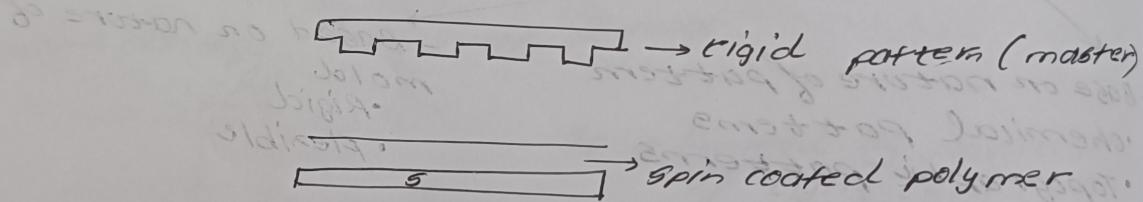
→ Heat (for 6 hrs / 120°C).

→ Peel off cross-linked elastomer.

→ We get a negative replica of the master/mold.

## Nano Imprint Lithography (NIL)

⇒ For uncrosslinked glassy polymer

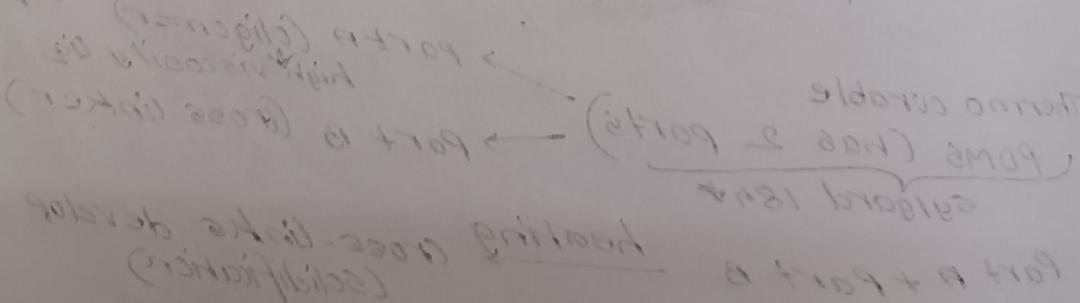


heat → press → cool → withdraw master

cooling before withdrawal to  
avoid flattening of surface due  
to capillary pressure.

## Limitation:

1. Removal of stamp.



Rise from side

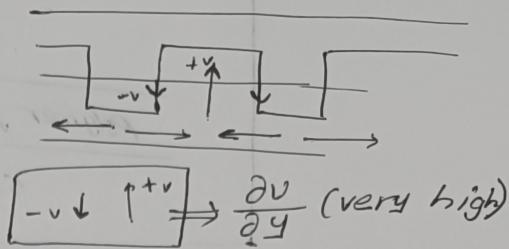
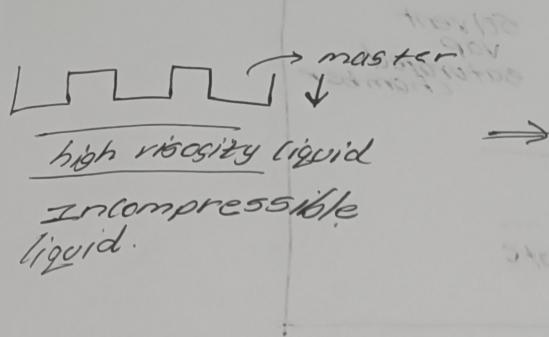
⇒ Sim

\* Solvent

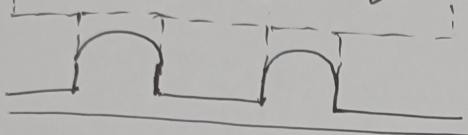
Mole

Cohes

→ Hydrodynamics and stresses in NIL



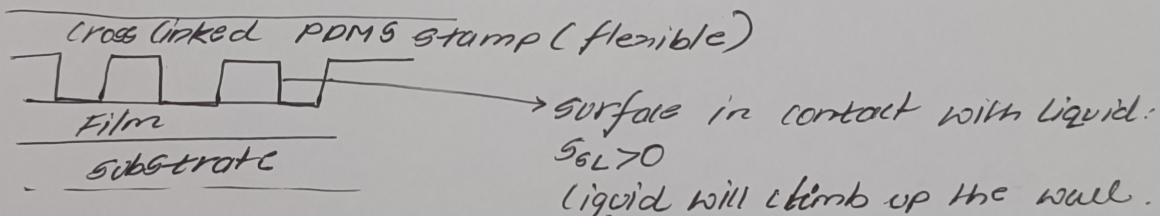
→ for abrupt cooling we get:



Rise from center → in NIL

\*\*\* soln to reduce  $\tau$  is slip enhancing coating of the stamp.

→ capillary force lithography [gentle technique as compared to NIL]

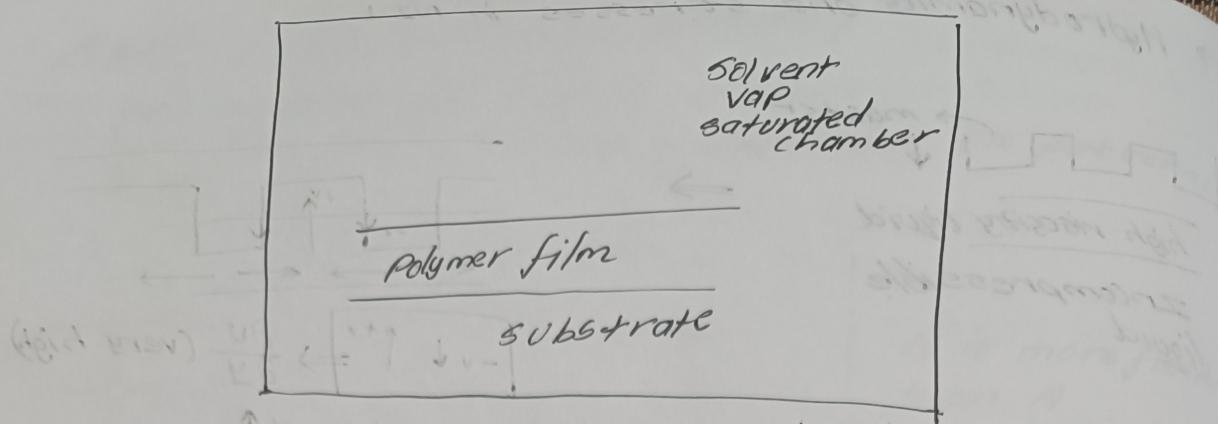


Rise from side ⇒ we get a negative replica.

The stamp can be peeled off since it is flexible.

→ similarity in the above techniques: we start with thin film in NIL, OFL, PL.

\* Solvent vapour assisted nanoimprint lithography:  
Molecular adsorption is positive for a solid dissolving in liq.  
or  
cohesive interaction in solid  $\angle$  adhesive interaction



→ Instead of using heat we use solvent vapour to make it behave like a liquid.

NETT