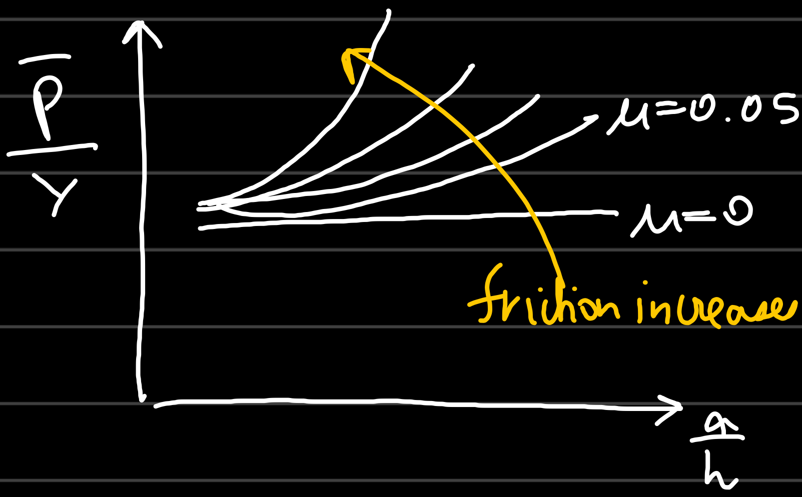
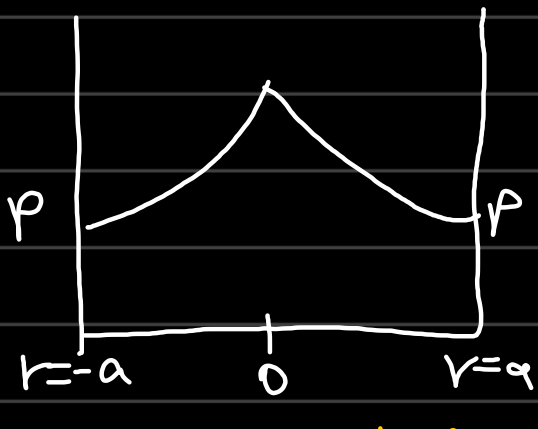
Lecture 32

Mechanics of Metal Working

Role of Friction:





Friction hill.

Above analysis for sliding friction.

Sticking Friction:

↳ in hot deformation condition.

$$m = \frac{\tau_i}{k}$$

τ_i → interface shear strength.

k → yield shear strength of bulk.

$m \in (0,1)$

↳ often seen in hot-working where lubrication may be difficult

↳ No relative motion is possible.

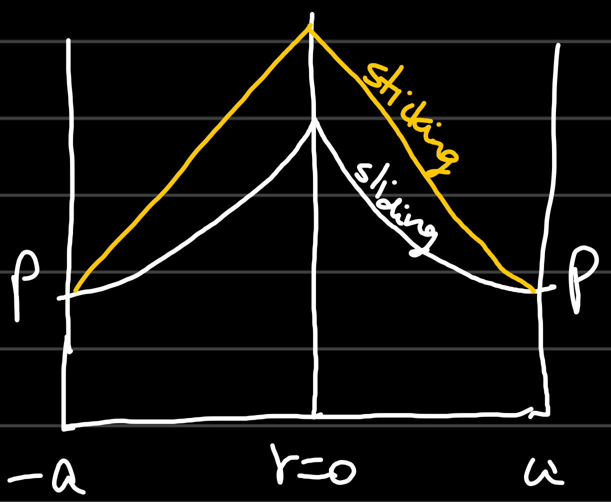
$m = 0 \Rightarrow \tau_i = 0 \Rightarrow$ perfect sliding

$m = 1 \Rightarrow \tau_i = k \Rightarrow$ interface shear = bulk shear.
"perfect sticking scenario".

$$P(r) = Y \exp\left(\frac{2\mu}{h}(a-r)\right)$$

↳ Coulombic friction model

$$P(r) = \overset{Y}{\overset{||}{\sigma_0}} \left[1 + \frac{2}{\sqrt{3}} \frac{(a-r)}{h}\right] \Rightarrow \text{sticking friction model.}$$



m = interface friction factor.

↳ depends on τ & k

does not depend on P.

coulombic friction (μ) depends on normal stress (p).

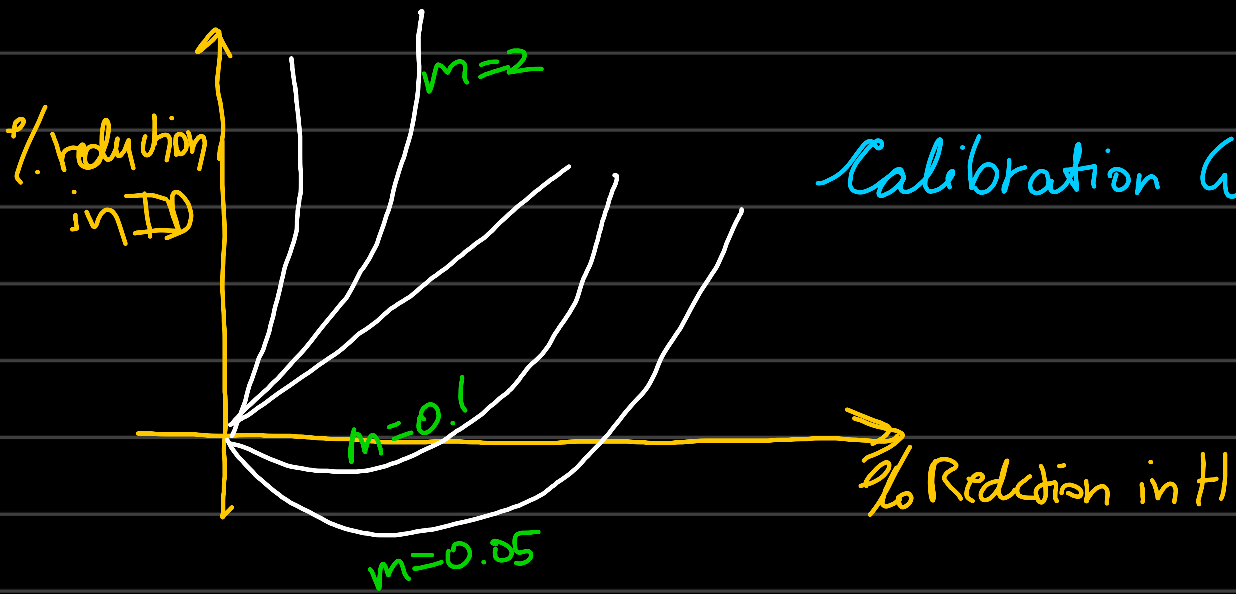
Ring Compression Test:-

↳ m value can be determined.

OD : ID : thickness

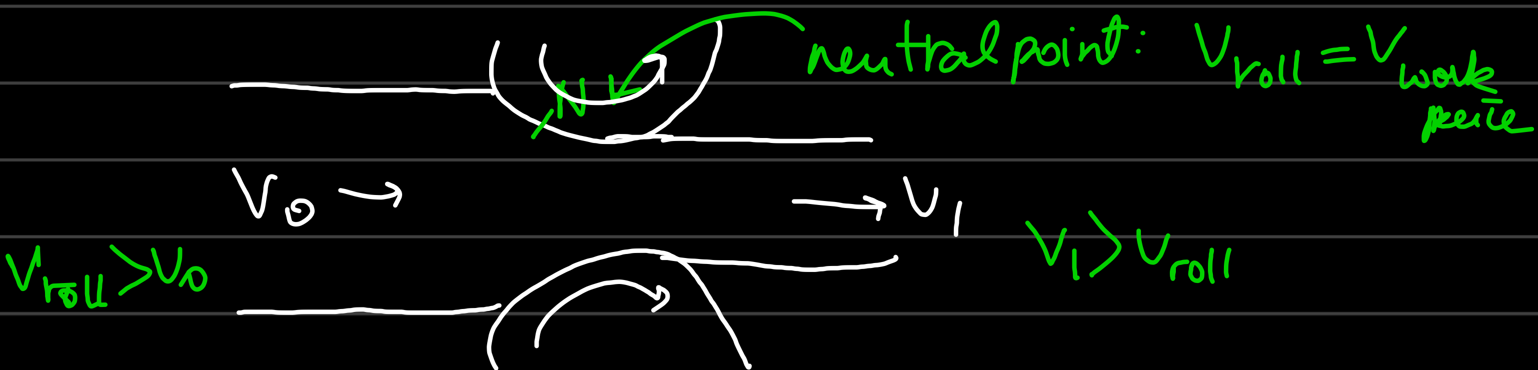
= 3 : 2 : 1

Post compression; record %reduction in ID
%reduction in H



Calibration Curve.

Rolling: friction aids working



→ friction helps to pull material inside roll.

Thin Film Deposition:

→ from atoms/ions/molecules →

Thin film deposition:

1) Physical Vapor Deposition (PVD)
   ↳ vaporize material of interest and deposit on substrate.

2) Chemical Vapor Deposition (CVD)
   ↳ chemical reaction involved which derives the material of interest.

Physical Vapor Deposition (PVD):

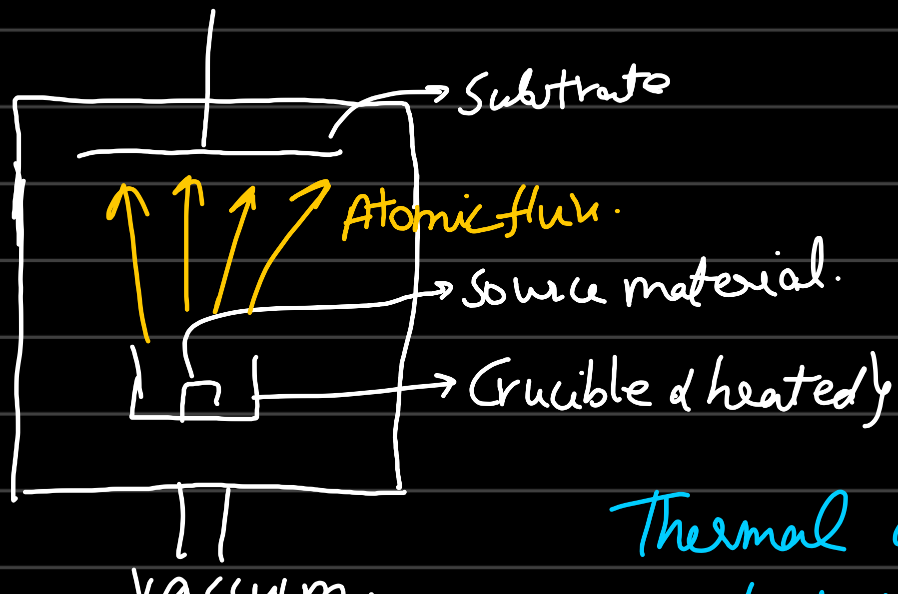
Sputtering

→ bombard target material with ions which knockout atoms

Evaporation.

→ thermal energy involved
→ e-beam vaporization
→ localized heating

which deposit on substrate → pulsed laser deposition.



Thermal deposition technique.

→ Limitations: thickness uniformity.
Difficult to evaporate materials with low vapor pressures.

Φ_e {flux of atoms targeted on substrate}

$$\Phi_e = \frac{\alpha_e N_A (P_e - P_h)}{(2\pi MRT)^{1/2}} \quad \left\{\frac{\text{moles}}{\text{cm}^2\text{-s}}\right\}$$

α_e → constant $\in (0,1)$

M → mwt of source material.

P_e = vapour pressure of source material.

P_h = hydrostatic pressure ↳ will go against P_e vapor pressure.

$$\phi_e = 5.84 \times 10^{-12} \times \left(\frac{M}{T}\right)^{1/2} \times P_e\{\text{torr}\} \ \frac{gm}{cm^2\text{-}s}$$

Critical value of Vapor pressure: $P_e = 10^{-3}$ torr

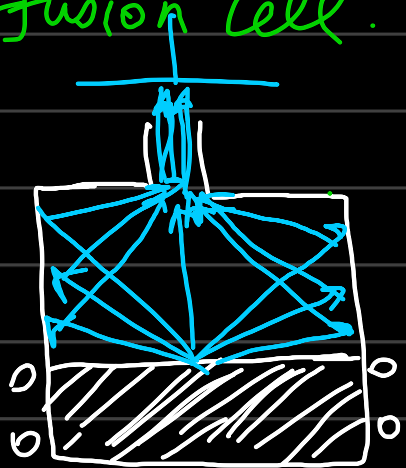
Can alloy be deposited as thin film using PVD?

eg: Brass {Cu-Zn} ≈ 70-30 composition.

↳ difficult to maintain composition if brass itself a source material as $\phi_e\{Cu\} = \phi_e(Zn)$

→ possible if two different sources (Cu & Zn) used.

✱ Effusion Cell: direct flux in one particular direction.

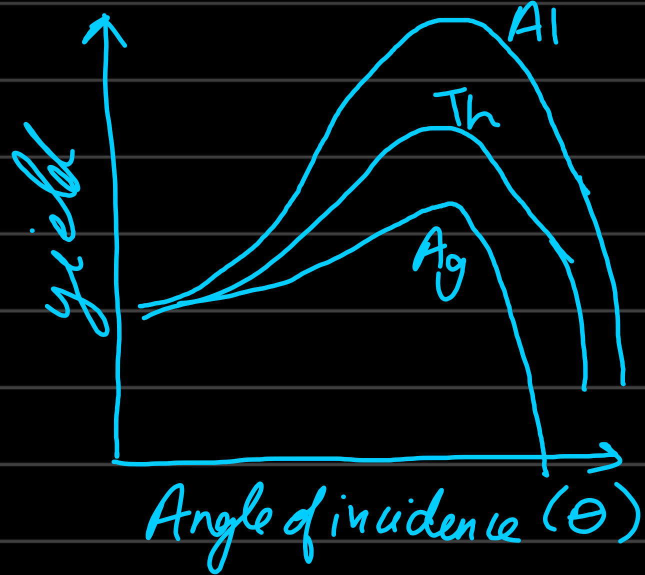


Sputtering Process:

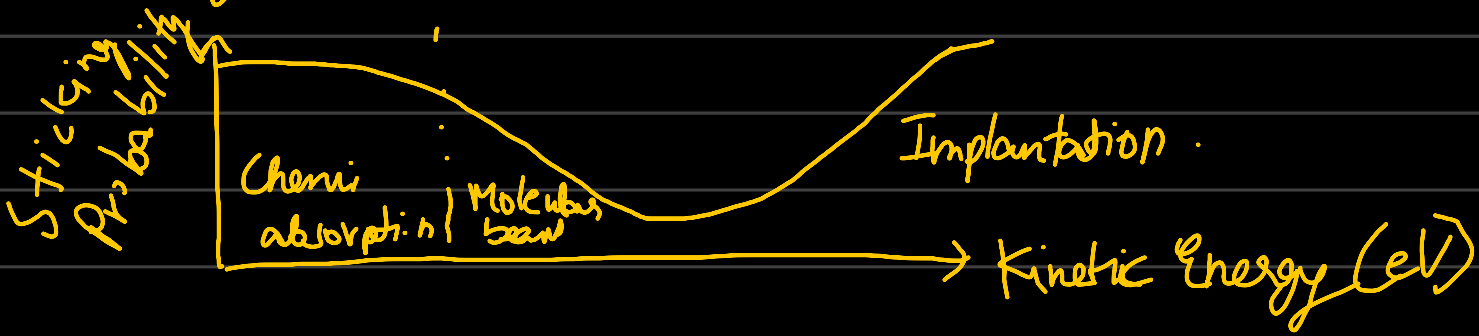
Sputtering Yield.

= Avg no. of sputtered atoms per collision.

Sputtering Yield:



Sputtering: Energies of ions:



Epitaxy / Epitaxial growth:-

Epitaxy: Crystallographic information or order of substrate is continued in thin films.

Homoepitaxy: same material

Heteroepitaxy: different material.

Molecular Beam Epitaxy (MBE):

→ $< 10^{-10}$ torr, n>10, highly directional source.

→ layer by layer control is possible. → Slow & labscale process. to