Lecture 14

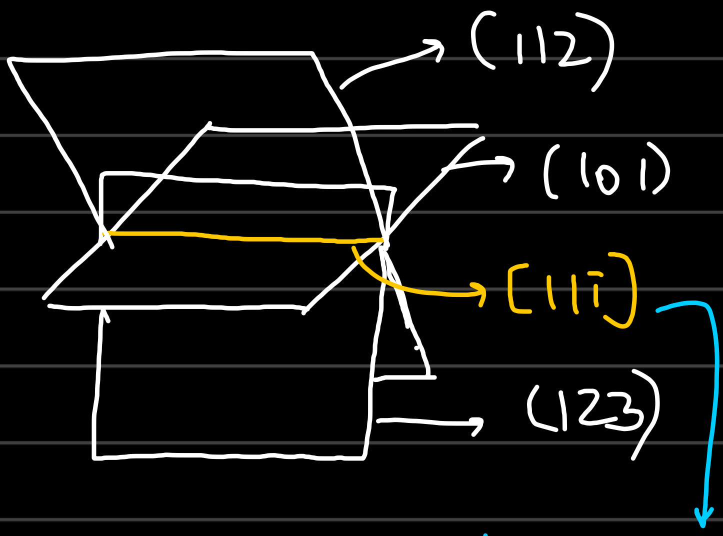
Dislocation in hcp:

burgers vector

$$\frac{a_0}{3}[11\bar{2}0] \longrightarrow \frac{a_0}{3}[10\bar{1}0] + \frac{a_0}{3}[01\bar{1}0]$$

↳ Slip occurs on basal plane (0001) in the [11$\bar{2}$0] direction.

Dislocation in bcc:

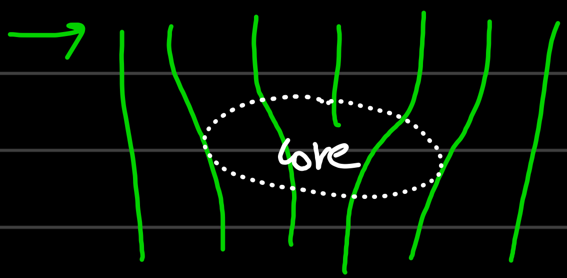


→ Slip bands in bcc:

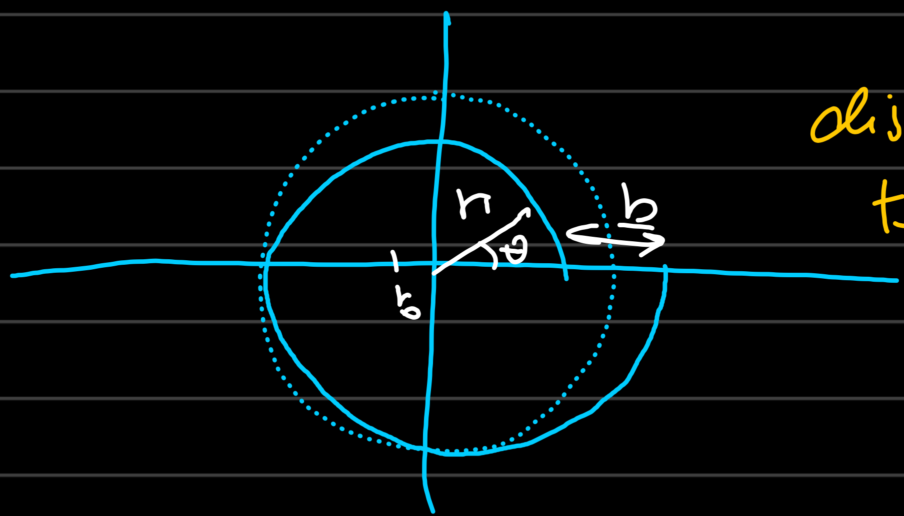
↳ Wavy glide {Wavy slip, Pencil slip}.

* Glide slip in bcc called pencil glide.

Strain field about dislocations:-



→ Stress field about dislocation is elastic.



dislocation ⊥r to plane (along axis)

→ can be considered as a plane strain condition

★ $\sigma_r = \sigma_\theta = -\dfrac{\tau_0 b \sin\theta}{r}$

$$\tau_{r\theta} = \tau_{\theta r} = \frac{\tau_0 b\cos\theta}{r}$$

$$\tau_0 = \frac{G}{2\pi(1-\nu)}$$

☆ Due to to $\tau \to \infty$ as $r \to 0$, a small cylinder of $r = r_0$ will be excluded from analysis.

☆ The strain energy involved in formation of an edge dislocations.
↳ estimated work done to diplace the cut OA along slip plane.

$$U = \frac{1}{2}\int_{r_0}^{r_1} \tau_{r\theta}\, b\, dr = \frac{1}{2}\int_{r_0}^{r_1} \tau_0 b\cos\theta \frac{dr}{r}$$

$$\boxed{U = \frac{Gb^2}{4\pi(1-\nu)} \ln\left(\frac{r_1}{r_0}\right)}$$

Total strain energy = Elastic SE + Energy of the core

→ In screw dislocations: no normal stresses

↳ only shear stresses involved.

$$\tau_{\theta z} = \frac{Gb}{2\pi r} \qquad U = \frac{1}{2}\int_{r_0}^{r_1} \tau_{\theta z}\, b\, dr = \frac{Gb^2}{4\pi}\ln\left(\frac{r_1}{r_0}\right)$$

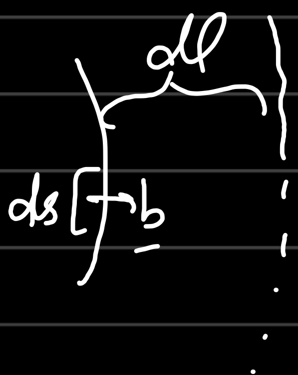
* For typical annealed crystals:

$r_1 = 100\,nm$, $b = 0.2\,nm$

$\ln\left(\frac{r_1}{b}\right) \approx 2\pi$

* Dislocation energy per unit length $\Rightarrow U = \frac{Gb^2}{2}$

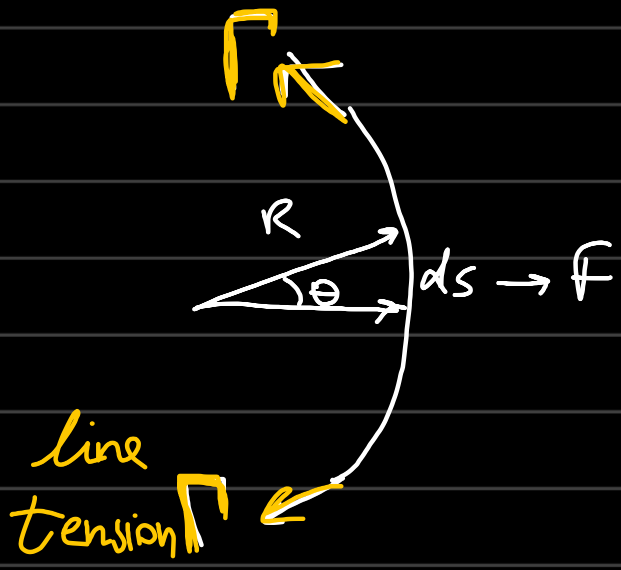
* Forces on a dislocation:



force per unit length

$$F = \frac{dW}{dl\,ds} = \tau b$$

↳ This force is normal to the dislocation line at every point and directed towards unslipped plane.



$$F = \tau b$$

$$R\,d\theta = ds$$

$$\Gamma\, d\theta = \tau b\, ds$$

$$\tau = \frac{Gb}{2R}$$

$$\Gamma = \frac{\tau}{bR}$$

Force per unit length $\Rightarrow \dfrac{Gb^2}{2R}$

* The radial force F_r between two parallel screw dislocations:

$$F_r = \tau_{\theta z} b = \frac{Gb^2}{2\pi r}$$

distance b/w dislocations.

→ For edge dislocations:

$F_r =$ $\qquad$ $F_\theta =$

Dislocation Generation:

- Study finds that the macroscopic step created on surface of crystal is not the sum of all burgers vector of inherent dislocations

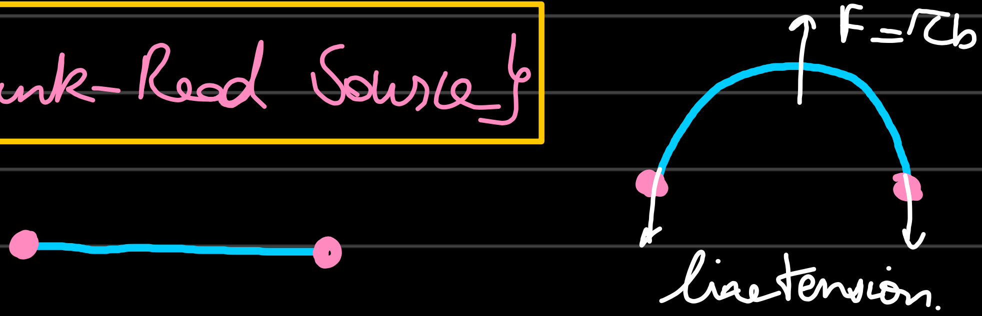
→ This suggests that there are sources in crystal which get activated due to plastic deformation and generate additional dislocations.

↳ This generation of new dislocation allows to maintain geometric coherence of crystals.

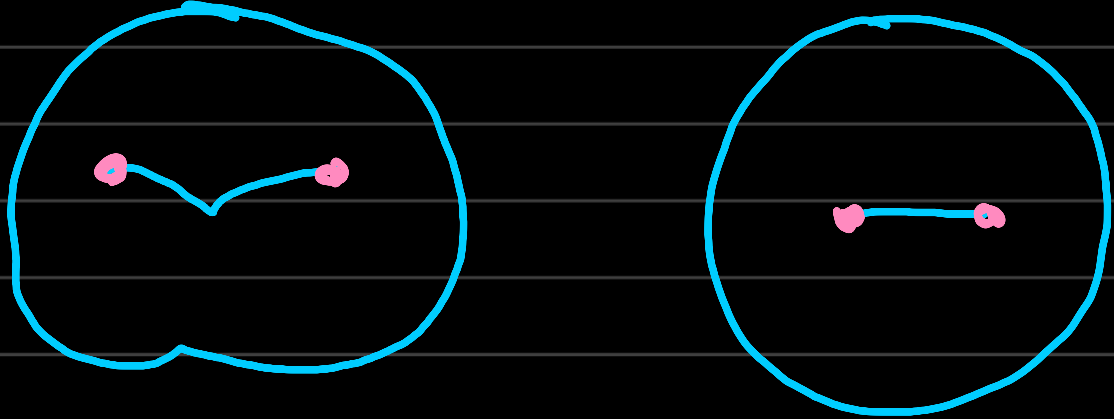
Dislocation Sources:

i) shear stress exerts $F = \tau b$ on dislocation line which is pinned on both ends.

$\boxed{\{\text{Frank-Read Source}\}}$

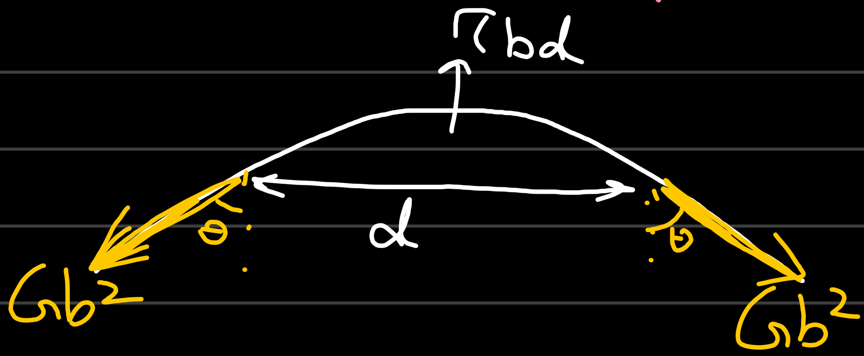


→ shear stress maximum when segment becomes semicircle.



→ series of concentric dislocation loops are formed.

Minimum stress to operate F-R source.



* $\tau b d = \underbrace{2Gb^2}_{\text{when } \theta = 90^\circ}$ $\Rightarrow$ $\boxed{\tau = \frac{2Gb}{d}}$

* $\rho = \frac{1}{d^2}$ {dislocation density vs dist b/w dislocations}

$\boxed{\tau = 2Gb\sqrt{\rho}}$ → Statistical quantity

{d cannot be estimated

ρ can be estimated}

→ Hall-petch relation:-

$$\tau_c = \frac{\pi(\tau-\tau_i)^2 D}{4Gb}$$

$$\tau = \tau_i + \left(\frac{\tau_c 4Gb}{\pi D}\right)^{1/2} = \tau_i + kD^{-1/2}$$

$$\sigma_0 = \sigma_i + kD^{-1/2}$$

σ_0 → yield strength

σ_i → friction stress: overall resistance of the crystal lattice to dislocation movement.

k → locking parameter:

Inverse Hall-petch relation:

→ post theoretical limit,

* Hall-petch relation is valid under the assumption that there are atleast $\langle N \rangle \geq 50$ 50 dislocations at the pileup near grain boundary

Recovery and Recrystallization:-

Cold work → low T → recovery
Cold work → high T → recrystallization.

↳ dynamic recovery & dynamic recrystallization.