BMM1523/BHA1113
ENGINEERING MATERIALS

STRENGTHENING MECHANISM OF METALLIC MATERIALS

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Chapter Description

- **Aims**

  Student are expected to have basic understanding of strengthening mechanism for metallic materials

- **Expected Outcomes**

  Ability to explain the following strengthening mechanisms ;

  1) Grain boundary reduction
  2) Solid Solution Formation
  3) Precipitation Strengthening
  4) Cold Work

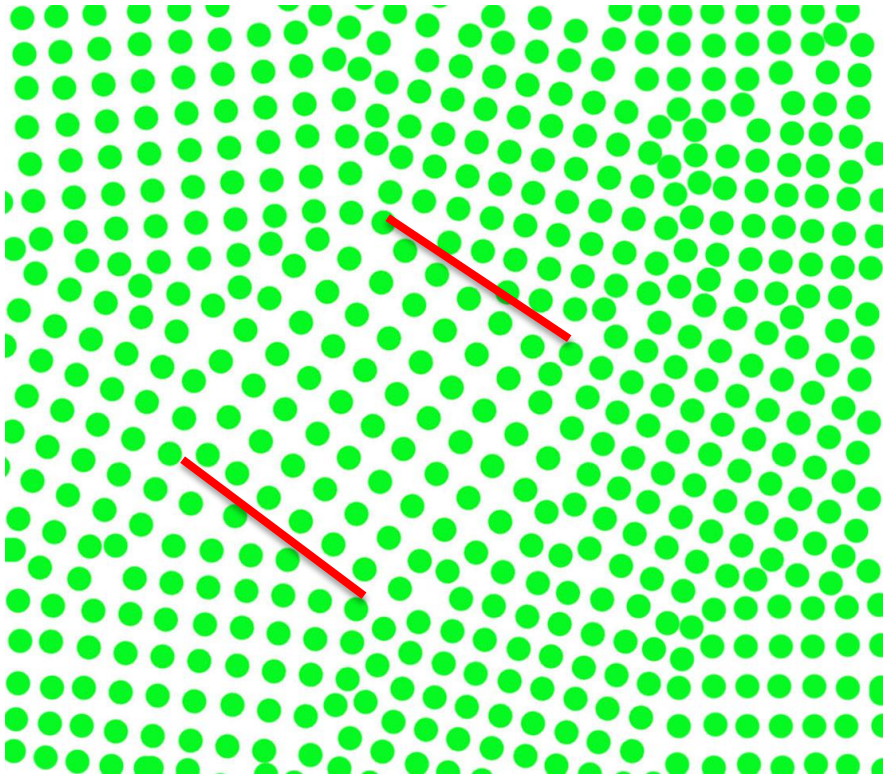
- **References**

  1. William D. Callister and David G. Rethwisch. Materials science and enginnering: An Introduction, 9th Ed. Wiley, 2014.

STRENGTHENING MECHANISMS

- Grain Size Reduction
- Solid Solution Formation
- Precipitation Strengthening
- Cold Work

(1) GRAIN SIZE REDUCTION



- Grain boundary acts as barriers to slips
- ↑ Grain boundary = ↓ Grain size
- This increase the total stress required for slip to occur
- Thus increasing the strength of respective material

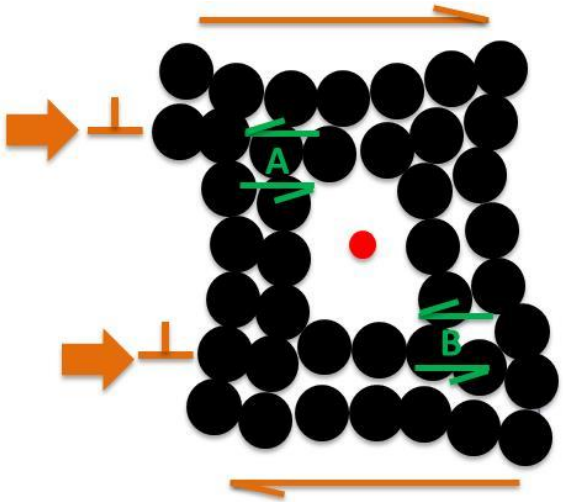
Grain boundary

Hall-Petch Equation $\sigma_{yield} = \sigma_0 + k_y d^{-1/2}$

https://commons.wikimedia.org/wiki/File:Crystallite.jpg

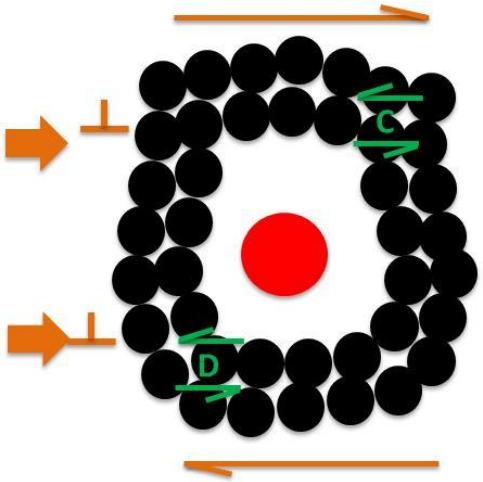
(2) SOLID SOLUTION FORMATION

- Impurity atom induce lattice distortion
- This leads to generation of lattice strains
- These strains act as barrier to dislocation motion
- ↑ Lattice strains= ↑ strength



- Impurity induce local stress at A and B that oppose dislocation motion

(a) Smaller substitutional impurity atom

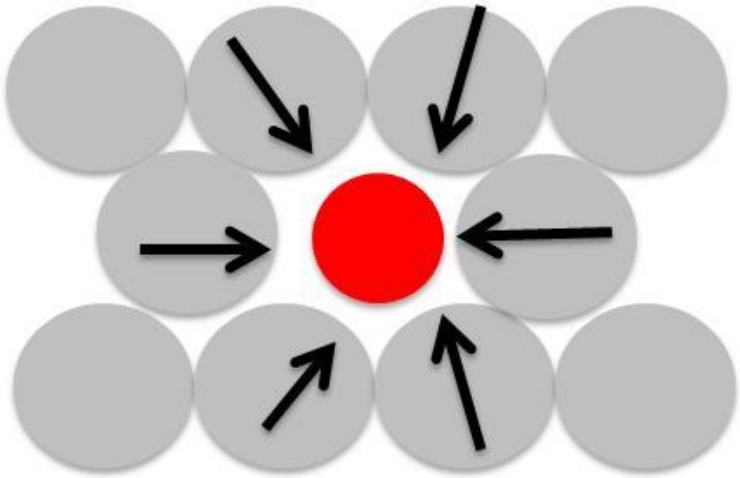


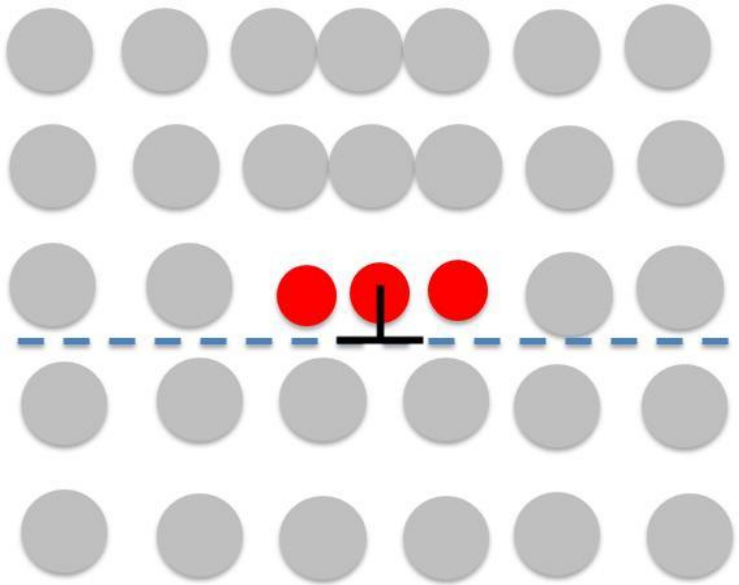
- Impurity induce local stress at C and D that oppose dislocation motion

(b) Larger substitutional impurity atom

(2) SOLID SOLUTION FORMATION

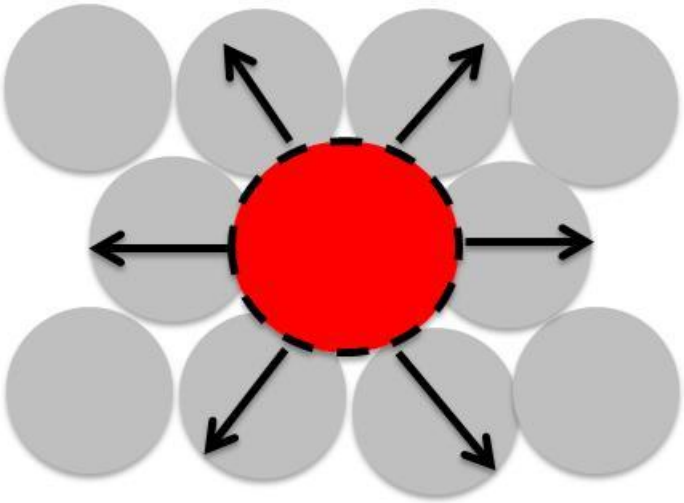
- ***Smaller impurity atoms*** tend to focus at dislocations regions
- This result in partial cancellation of strains (in this case ***compressive strains***)
- More stress is needed to cause dislocation movement ➡ increase strength

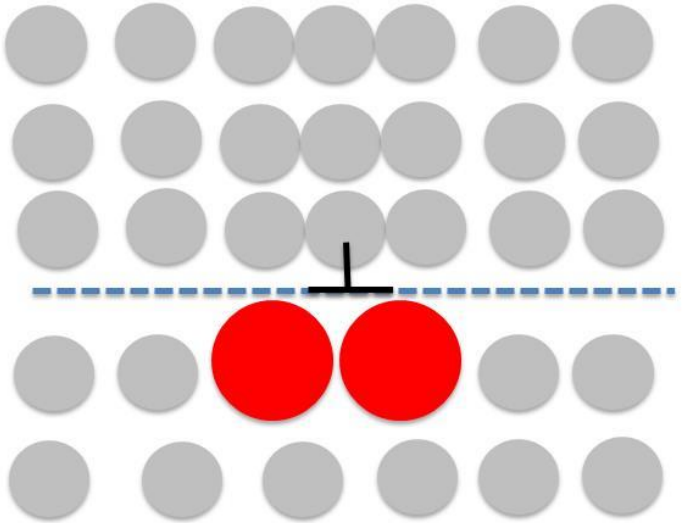




(2) SOLID SOLUTION FORMATION

- ***Larger impurity atoms*** tend to focus at dislocations regions
- This result in partial cancellation of strains (in this case ***tensile strains***)
- More stress is needed to cause dislocation movement ➡ increase strength



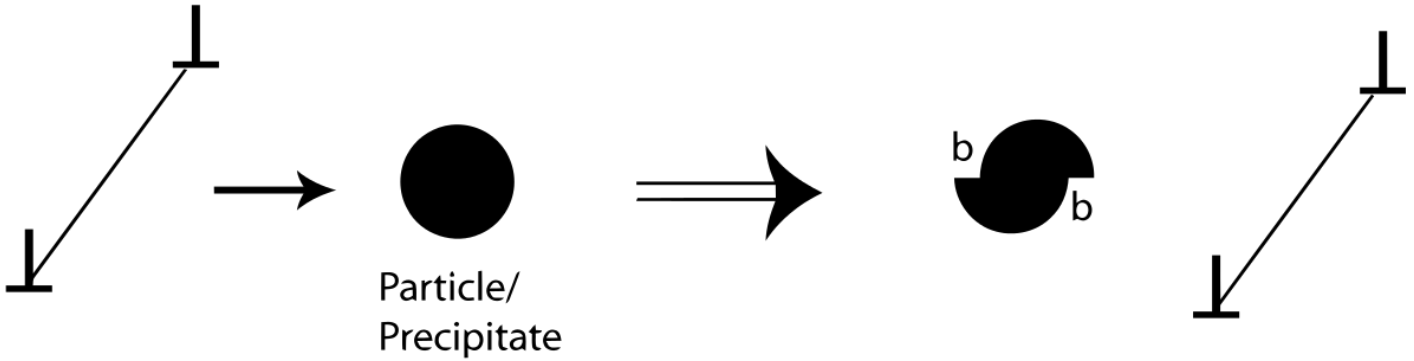


Relation between alloy strength and concentration of alloying element

$$\sigma_y \sim C^{1/2}$$

(3)PRECIPITATION STRENGTHENING

- Precipitates act as barrier to dislocation movement
- Greater stress is needed to move dislocation towards precipitate
- Strength of material increases



Larger shear stress is needed to move dislocation through precipitate and shear it.

(3)PRECIPITATION STRENGTHENING

Aluminum-copper alloy

Plate-like copper precipitates

- Aluminium copper alloy (4 at% Cu)
  .
- Copper precipitation exist within the aluminium matrix.

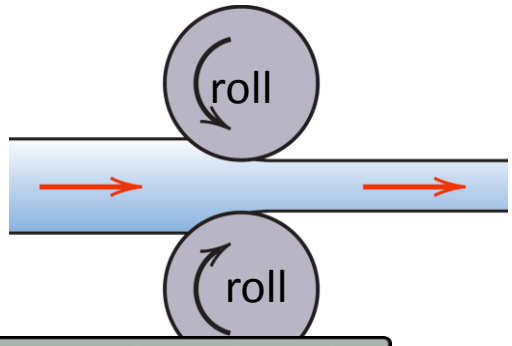
(4) COLD WORK

- Cold Work involves deforming workpiece at room temperature
- Usually results in decreasing the cross sectional area of workpiece
- Cold Work induce dislocations pile up ➡ dislocation entanglement ➡ dislocation movement barrier ➡ higher strength

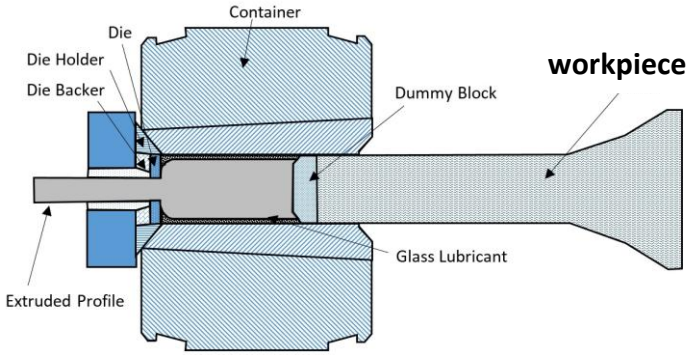
Percentage of Cold Work

$$\%CW = \frac{A_o - A_d}{A_o} \times 100$$

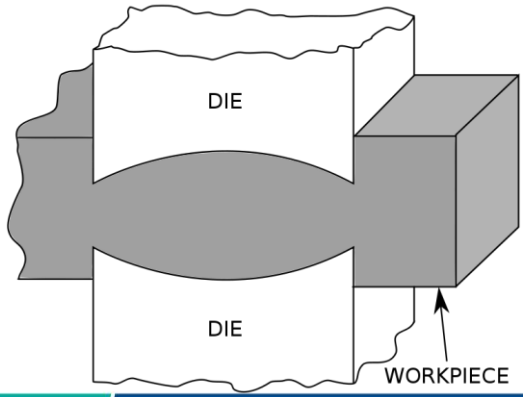
Cold Rolling



Extrusion



Forging



SUMMARY

- The main concept of strengthening metallic material is to hinder dislocation movement

- The main mechanism of metallic materials ;

1) Grain Size Reduction
2) Solid Solution Formation
3) Precipitation Strengthening
4) Cold Working

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Research Interest:

- ❑High Temperature Physical Chemistry
- ❑Thin Films Technology
- ❑Metals and Alloys.

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