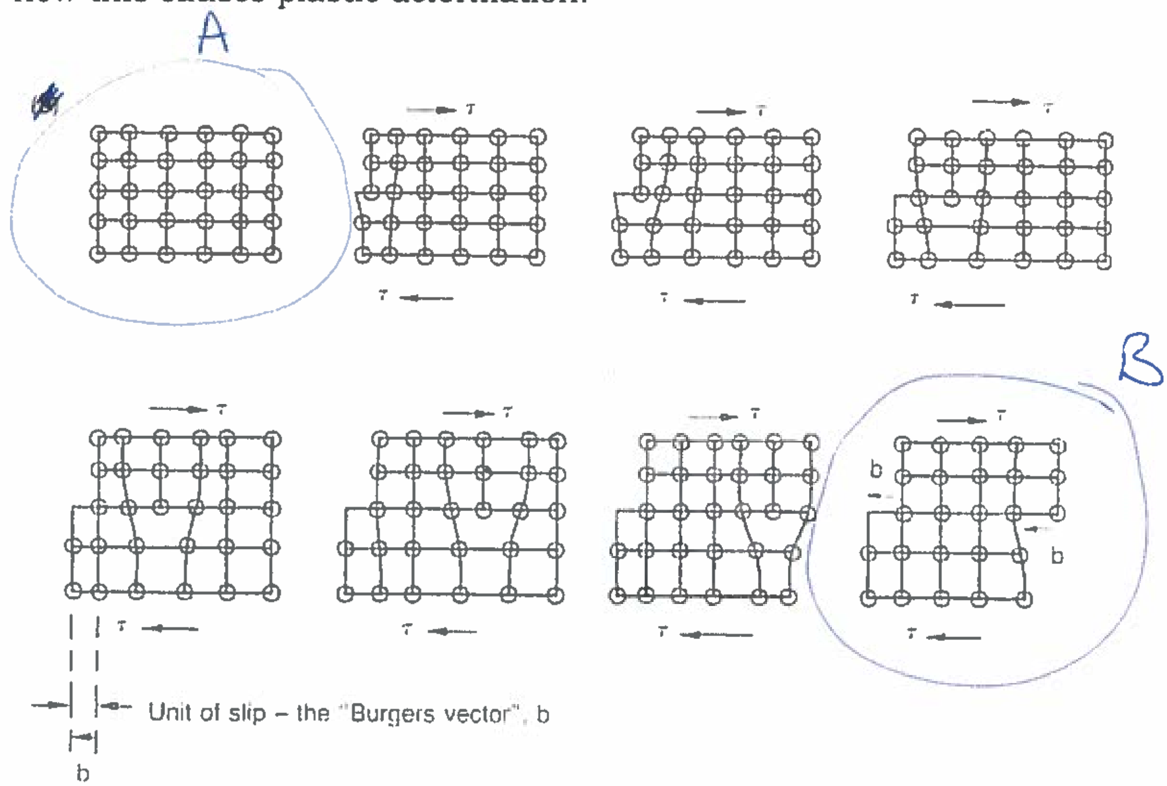
SA1. It has been shown in class that crystal defects known as dislocations are important to understand plastic deformation. Draw a diagram or series of diagrams to show how an edge dislocation moves through a crystal and how this causes plastic deformation.



4

Comparison of A and B shows how the crystal has been permanently deformed

1

SA2. Calcium has a FCC crystal structure. Calculate the density of calcium (in units of gcm^{-3}) given the atomic diameter of a calcium atom is 0.39517 nm and the molecular weight of ~~nickel~~ Calcium is 40.078 g/mol.

Density Calculation

Density = ρ = (mass of atoms in unit cell)/(volume of unit cell)

1

$$\rho = \frac{nA / N_A}{V_c}$$

n = number of atoms per unit cell

A = Atomic weight g/mol

V_c = unit cell volume = a^3

N_A = Avogadro's Number (6.023×10^{23} atoms/mol)

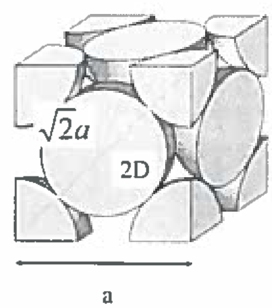
FCC 1

Unit Cell Length

a = lattice parameter

R = atomic radius

1 $a = \sqrt{2}D$



Calcium is FCC, therefore 4 atoms per unit cell

$D = 0.39517\ nm = 3.9517 \times 10^{-8}\ cm$

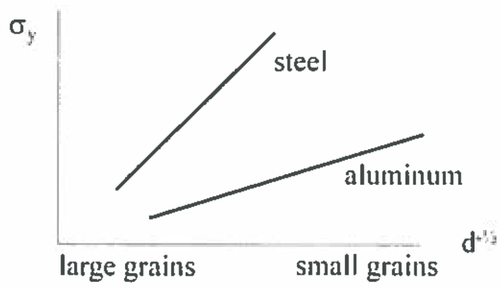
2 $$\rho = \frac{4 \times 40.078\ g/mol\ /\ 6.02 \times 10^{23}\ atoms/mol}{(\sqrt{2} \times 3.9517 \times 10^{-8}\ cm)^3}$$

$\rho = 1.53\ g\ cm^{-3}$

SA 3. The yield stress of two steels with grain sizes of 3 and 30 μm was measured to be ~~300~~ 650 and ~~650~~ 300 MPa, respectively. Determine the yield stress of a steel with a grain size of 10 μm.

Grain Size Strengthening

$$\sigma_y = \sigma_0 + k_y d^{-1/2}$$



- Grain boundaries act as barrier to dislocations
- As grain size decreases, number of barriers to dislocations increases
- Therefore strength increases

Two equations with two unknowns:

$$650 = \sigma_0 + k_y (3\mu m)^{-1/2} \quad (1)$$

$$300 = \sigma_0 + k_y (30\mu m)^{-1/2} \quad (2)$$

(1) − (2)

$$350 = k_y\left[(3\mu m)^{-1/2} - (30\mu m)^{-1/2}\right]$$

$$k_y = 886.6 \text{ MPa } \mu m^{-1/2}$$

Substitute into (1)

$$\sigma_0 = 138.1 \text{ MPa}$$

for 10 μm

$$\sigma = 138.1 \text{ MPa} + 886.6 \text{ MPa } \mu m^{-1/2} \times (10\mu m)^{-1/2}$$

$$= 418.5 \text{ MPa}$$

6 total

LA1. Given the Cu-Ag phase diagram on page 13.

a) Consider at 85wt%~~Sn~~ Ag -15wt%~~Pb~~ Cu alloy which is held at 800 °C
Determine:

i. What phase(s) are present at equilibrium
ii. The composition of the phase(s)
iii. The weight fraction of the phase(s)

2 i) β + Liquid

ii) β - 93wt% Ag - 7wt% Cu

2 Liquid - 77.5wt% Ag - 22.5wt% Cu

iii) $$W_\beta = \frac{85-77.5}{93-77.5} = 0.48 \quad \approx 50\%$$

4 $$W_{Liquid} = \frac{93-85}{93-77.5} = 0.52 \quad \approx 50\%$$

Note: could also measure line lengths on tie line. Gives same result.

b) Sketch the expected microstructures for a 85wt%~~Sn~~ Ag-15wt%~~Pb~~ Cu alloy at the following temperatures:

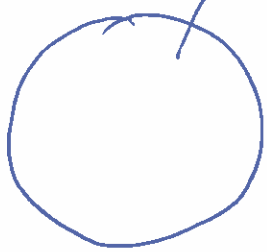
i. 900 °C

ii. 780 °C

iii. 778 °C

i) 900°C

2



100% liquid
85 wt% Ag- 15wt% Cu

ii) 780°C

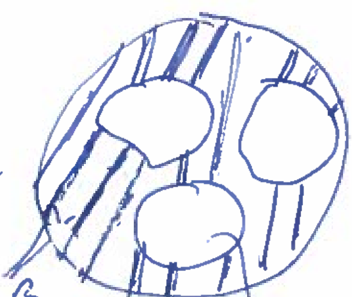
2

β
91.2 wt% Ag - 8.8wt% Cu

liquid 71.9wt% Ag - 28.1 wt% Cu

iii) 778°C

2



$\alpha + \beta$
Eutectic
Structure

β

c) What fraction of the β phase do you expect at 780 °C?

2

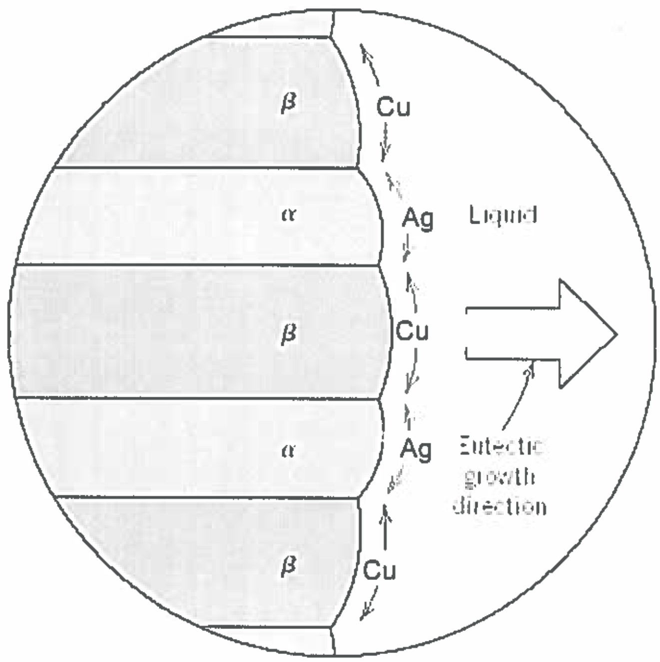
$$W_\beta = \frac{85-71.9}{91.2-71.9} = 0.68$$

d) What fraction of the β phase you expect at 778 °C?

2

$$W_\beta = \frac{85-8}{91.2-8} = 0.925$$

e) Explain how liquid of the eutectic composition (71.9wt% ~~Sn~~ Ag) transforms to solid when it is cooled from below 779 °C.



2

1

The system must find the most efficient mechanism to transform from a homogeneous liquid phase to two solid phase, one predominately Ag and the other Cu. This is done by a cooperative growth mechanism as shown above where a lamellar (sandwich) structure is formed. This is the most efficient way to divide the Ag and Cu atoms into their respective solid phases.

You may remove this page from the test.