GX641

OLLSCOIL NA hÉIREANN
The National University of Ireland

University College Galway

Michaelmas Examinations, 2000/01

Third Year Mechanical & Biomedical Engineering Examination

METALS and METAL PROCESSING

Professor J.J. O'Connor
Professor J.F. McNamara
Dr. M. Bruzzi

Attempt Three Questions
Time Allowed: 2 hours

1 (a) For a Face Centre Cubic (FCC) crystal structure, sketch and identify in terms of the Miller indices, one of the most closely packed planes in the unit cell.
What is the total number of slip systems in such a crystal structure?
What is the relevance of the most closely packed planes? Explain.

(3)

(b) Discuss the large difference between the theoretical strength based on the atomic bond strength and the experimentally measured critical resolved shear stress in a single crystal.

(2)

(c) Discuss crystal imperfections under the following headings:
- Point Defects
- Line Defects
- Planar Defects

(6)

(d) Calculate the Burgers vector $\underline{\mathbf{b}}$ for (i) α-Fe
(ii) Al
where the atomic radius of α-Fe = 0.124nm and that of Al = 0.143nm.

(4)

(e) Sketch a resolved shear stress – shear strain curve for a single crystal of a metal and explain it in the context of dislocation motion.
Sketch a typical stress-strain curve for a polycrystal and explain why its shape differs from that of the single crystal.

(4)

(f) Discuss the effects and stages of annealing a polycrystalline metal component following cold working.

(6)

2 (a) Define and comment on the following terms used in alloying:

- Solid Solution
- Intermediate Compound
- Intermetallic

(3)

(b) Discuss Interstitial and Substitutional solid solutions in terms of solubility and diffusion.

(4)

(c) For the case of Carbon interstitially dissolved in BBC α-Fe, how much oversize is the Carbon atom. Atom Radius of α-Fe = 0.124nm. Atomic Radius of C = 0.077nm. Comment on the solubility of Carbon in α-Fe.

(5)

(d) Discuss, with the aid of sketches, coring of a Cu / Ni alloy.
How is the coring removed?

(8)

(e) For a steel alloy, a carburizing heat treatment of 15h duration will raise the carbon concentration to 0.35 wt% at a point 2.0mm from the surface. Estimate the time necessary to achieve the same concentration at a 6.0mm position for an identical steel and at the same carburizing temperature.

(5)

3 (a) Discuss the restrictions in using a phase equilibrium diagram for representing the state of an alloy.

(3)

(b) Explain the terms in the modified version of Gibb's Phase Rule for a metallic alloy.
Why was it modified?
Discuss its use in explaining a Eutectic point of a Binary alloy.

(3)

(c) Figure 3 shows a phase equilibirium diagram for Magnesium / Tin alloys.
Briefly discuss the Mg_2Sn phase in terms of:

- Material type and composition in wt%
- Representation on phase diagram
- Melting temperature

(4)

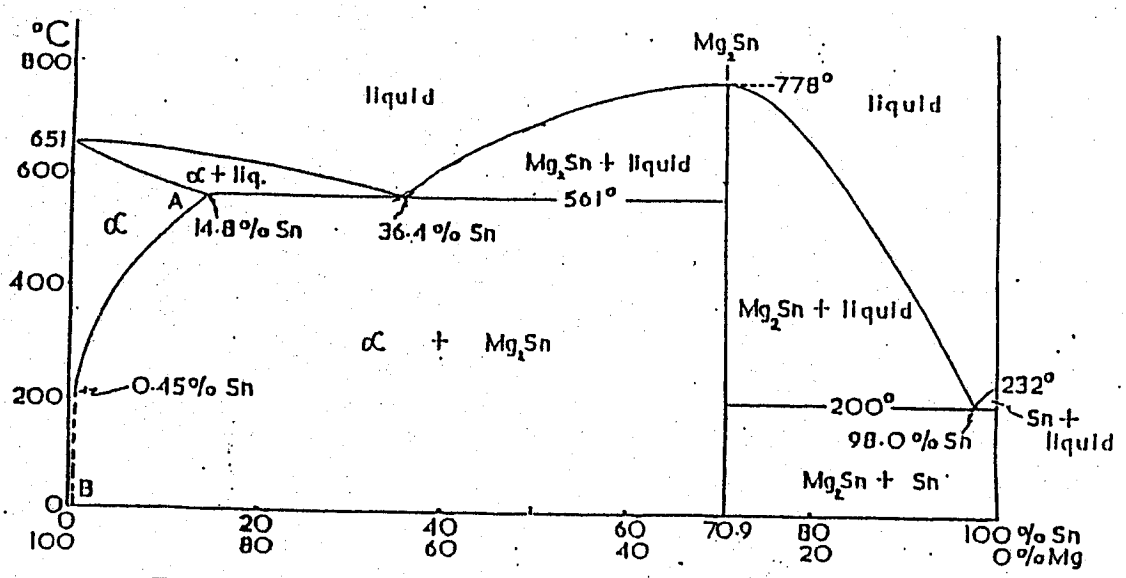

Figure 3: Phase Equilibrium Diagram for Magnesium / Tin

(d) Specify temperature - composition points at which all eutectic phase transformations occur. Discuss the formation of a Eutectic structure.

(5)

(e) Describe the slow cooling from liquid to room temperature of an alloy with 50 wt% Mg, 50wt% Sn. Sketch the equilibrium microstructures at a number of stages during the cooling process.
Estimate the compositions and relative amounts in weight percentages of the various phases at 400°C.

(10)

4(a) Discuss the microstructure of Pearlite and comment on its material properties.

(2)

(b) Discuss the following heat treatments in terms of heating, cooling and their effect on the microstructure of plain carbon steels:

- Process anneal
- Spherodizing anneal
- Normalising
- Full anneal

Sketch the temperature-composition regions of each on a phase equilibrium diagram.

(8)

(c) Draw and clearly label a Time Temperature Transformation (TTT) diagram for a 0.8wt% Carbon steel.
Draw continuous cooling curves for the transformation of Austenite to:

- Pearlite
- Martensite
- Bainite + Martensite

Comment on their microstructure and associated mechanical behaviour.

(6)

(d) Sketch on a TTT diagram the mass effect associated with the continuous cooling of components with different thicknesses.
Discuss the problems and appropriate solutions of quenching a large component to produce uniform Martensite.

(4)

(e) How may the material properties of Martensite be made less brittle? Discuss.

(2)

(f) Discuss the isothermal treatments of Martempering and Austempering.
Indicate these processes on a TTT diagram.

(3)