NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4104 – MATERIALS SCIENCE I

BSc HONOURS PART IV: DECEMBER 2005 *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF QUESTION **ONE** IN SECTION **A** AND ANY **THREE** QUESTIONS FROM SECTION **B**. SECTION **A** CARRIES 40 MARKS AND SECTION **B** CARRIES 60 MARKS.

SECTION A

1. (a) Tin atoms are introduced into FCC copper lattice producing an alloy with a lattice parameter of 0.37589 nm and a density of 8.772g/cm^3.

   (i) Calculate the atom % tin in the alloy and [3]

   (ii) the weight % tin in the alloy. [3]

   (b) Determine the volume packing factor for FCC nickel. [4]

   (c) Using the radius ratios, determine whether UO_2, BeO , NiO have the Caesium chloride, Sodium Chloride, or the Zinc Blende structure. [2]
   Based on your answer, determine

   (i) the lattice parameter, [2]

   (ii) the density and [3]

   (iii) the packing factor for NiO. [2]

   (d) An FCC single crystal of a metal is orientated so that the [001] direction is parallel to an applied stress of 35MN/m^2. Calculate the resolved shear stress acting on the (111) slip plane in the [110] slip directions. [4]

   (e) Distinguish between hardness and toughness. [3]

   (f) A 0.6% plain carbon steel has a fatigue limit of 320MPa when the mean stress is zero and a tensile strength of 740MPa. Use the Goodman relationship to predict the fatigue limit at a mean stress of 200MPa. [4]

(g) (i) Write brief notes on carburization. [5]

(ii) A 0.205 carbon steel is to be surface hardened by difussing more carbon into its surface. Determine the length of time needed to obtain a concentration of 0.35 carbon at a distance of 1.5mm from the surface if the carbon concentration remains at 0.95% at the surface. The diffusion coefficient at the temperature of the process is 1.74×10^{-11} m^2s^{-1}. [5]

SECTION B

2. (a) (i) Determine the repeat distance, linear density and linear packing fraction for BCC lithium in the [100] , [110] and the [111] directions. The lattice parameter for lithium is 0.35089 nm. [9]

(ii) Which direction is close packed? [1]

(b) With the aid of diagrams and the Peierls-Nabarro equation, explain why slip easily takes place on the planes and in the close packed directions. [6]

(c) Determine the ratio of the shear stresses for slip in BCC tantalum for the two slip systems given below:
(110) / [111] and (111) / [110].

Assume k = 2 in your calculations. [4]

3. (a) Discuss in brief the statement " all metals are inherently defective". [5]

(b) (i) What is a dislocation ? [2]

(ii) Describe how the strength of a material is affected by dislocations, grain size or grain boundaries and impurity atoms. [9]

(c) Distinguish a screw from an edge dislocation [4]

4. (a) Write brief notes on the following topics:

(i) glass transition temperature, (ii) endurance ratio,

(iii) true strain and (iv) flexural modulus. [12]

(b) A test bar 12.83 mm in diameter with a gauge length of 50mm is loaded elastically with 156 kN and stretched by 0.356mm. Its diameter is 12.80mm under load.

(i) Calculate the bulk modulus and [5]

(ii) the shear modulus of the test bar. [3]

5. (a) Show that the Brinell Hardness Number (BHN) is given by

$$BHN = \frac{2F}{\prod D\left[D - \left(D^2 - d^2\right)^{0.5}\right]}$$

where F - is the applied force,

D - is the diameter of the indenter and

d - is the diameter of the indentation [5]

(b) Draw a fully labeled creep curve for a metal and explain what happens at each stage. [6]

(c) What are the advantages and disadvantages of the radiographic, ultrasonic, and magnetic particle non - destructive testing methods? Describe the physical principles involved in any one of the three methods. [9]

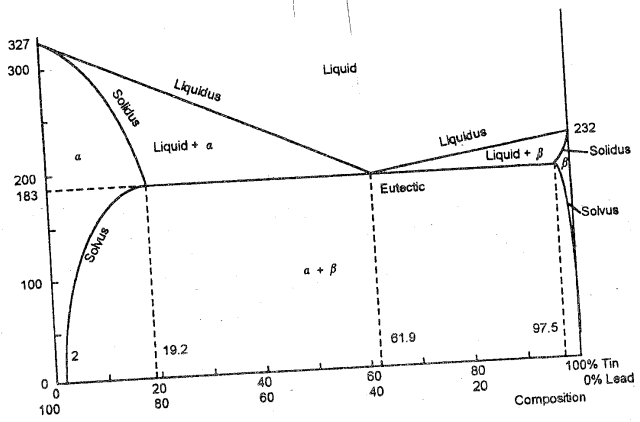
6. (a) Using the tin – lead phase diagram in Fig 1 below

(i) determine the solubility of tin in lead at 100°C, [3]

(ii) determine the amount of the primary α relative to the amount of eutectic for a 30% tin-70% lead alloy when it has been cooled to 00°C and 100°C. [5]

(iii) draw a cooling curve for the eutectic composition and 30% tin alloy. [3]

(iii) determine the composition of a lead –tin alloy having a structure with 23% primary α and 77% eutectic.. [3]



Phase diagram for lead–tin alloys

Figure 1

(b) Explain the use of the Pilling – Bedworth ratio in determining the nature of an oxide layer. [6]

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