National Exams December 2018

12-Mtl-A3, Structure and Characterization of Materials

3 hours duration

**NOTES:**

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
3. Any non-communicating calculator is permitted.
4. Eight (8) questions constitute a complete exam paper.
5. Each question value is indicated in the left column.
6. Clarity and organization of the answer are important.

/10 1. For both FCC and BCC crystal structures, interstitial sites that may be occupied by impurity atoms are located at the centers of each of the unit cell edges. Compute the radius $r$ of an impurity atom that will just fit into one of these sites for each of the two crystal structures in terms of the atomic radius $R$ of the host atom.

/10 2. Plastic deformation often involves dislocations moving along close-packed directions within close-packed planes. For FCC metals, a Burgers vector along a [110] type direction lies within the close-packed (111) plane.

**a)** Which specific members of the <110> family of directions lie within the (111) plane?
**b)** Sketch the answer to part (a)

/10 3. **a)** Make a schematic graph of the room temperature tensile strength versus annealing temperature (at constant annealing time) over the temperature range at which recrystallization occurs for an alloy that has been cold worked prior to the annealing treatment.

**b)** Superimpose and label on this same plot, a curve for the same alloy that is subjected to a greater degree of cold work. Explain.

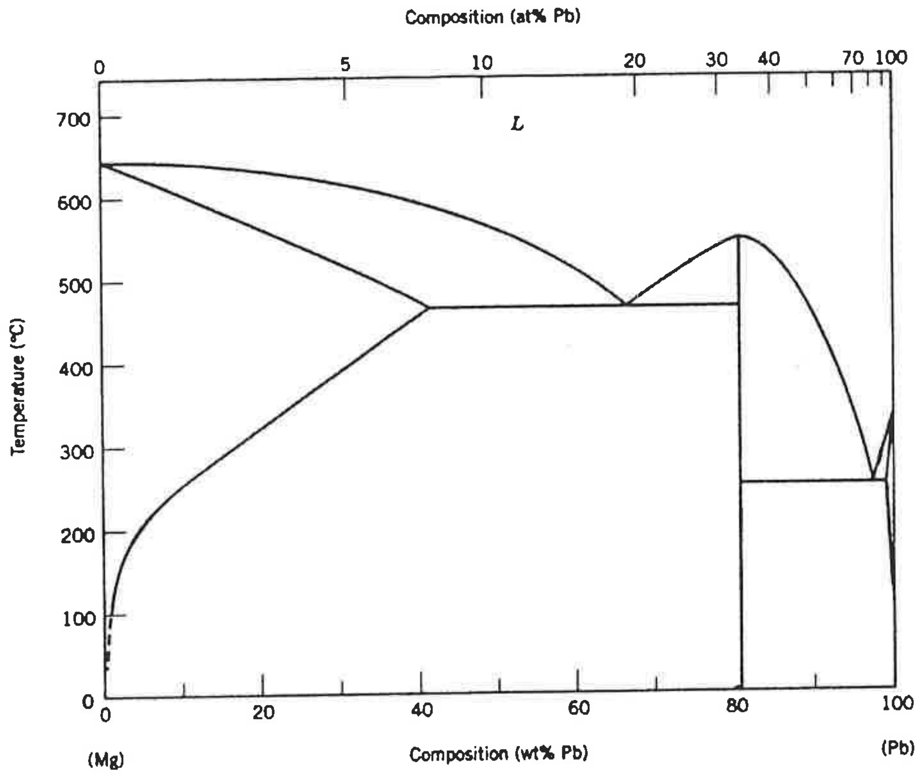
**c)** Superimpose and label on this same plot, a curve for the same alloy, only with a higher content of alloying elements, yet with the same degree of cold work as in (a). Explain.

/5 4. **a)** Would you expect the plane strain fracture toughness of a metal to decrease, increase or remain constant with rising temperature? Briefly explain your answer.

/10 **b)** Some structural component is constructed from an aluminum alloy having a plane strain fracture toughness of 40 MPa $m^{1/2}$. It has been observed that this component fails at a stress of 200 MPa for a surface crack of maximum length 4.0 mm. Would this same component fail if a titanium alloy is used (having a plane strain fracture toughness of 50 MPa $m^{1/2}$) when the stress and maximum surface crack length are 150 MPa and 10.0 mm, respectively? Why or why not?

/5 5. **a)** Label all of the phase fields in the Mg-Pb binary phase diagram given below.

/10 **b)** A magnesium-lead alloy of composition 75wt%Pb - 25 wt% Mg is slowly cooled from a temperature of 600°C. Using the Mg-Pb phase diagram, do the following:
(i) Determine the composition of the first solid phase to form.
(ii) Determine the composition of the last liquid remaining prior to complete solidification.
(iii) Make a schematic sketch of the microstructure at 400°C and label the phases that are present. Explain.
(iv) Give the mass fraction of each of the phases present in (iii).

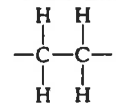
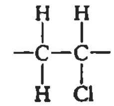
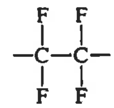
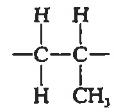
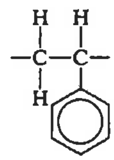
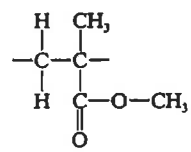
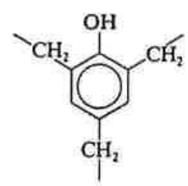
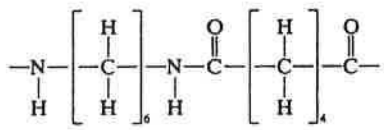


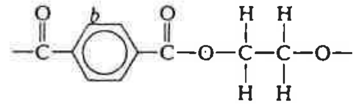
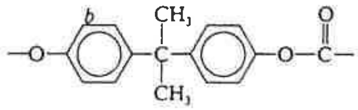

/10 6. The first three diffraction peaks of a metal powder are $2\theta = 44.4^{\circ}$, $64.6^{\circ}$ and $81.7^{\circ}$ using CuK$\alpha$ radiation. Is this a BCC or an FCC metal.

/10 7. a) Explain what is meant by a block, graft, random, and alternating copolymer.

/10 b) Is it possible to have a random poly(ethylene-propylene) copolymer having number- and weight-average degrees of polymerization of 2500 and 2000, respectively, and number- and weight-average molecular weights of 81,500 and 67,200 g/mol, respectively? Why or why not?

/10 8. In your own words, describe the mechanisms by which semicrystalline polymers plastically deform.

| *Polymer* | *Repeating (Mer) Structure* |
|---|---|
| Polyethylene (PE) |  |
| Polyvinyl chloride (PVC) |  |
| Polytetrafluoroethylene (PTFE) |  |
| Polypropylene (PP) |  |
| Polystyrene (PS) |  |
| Polymethyl methacrylate (PMMA) |  |
| Phenol-formaldehyde (Bakelite) |  |
| Polyhexamethylene adipamide (nylon 6,6) |  |

| | |
|---|---|
| Polyethylene terephthalate (PET, a polyester) |  |
| Polycarbonate |  |

[b] The  symbol in the backbone chain denotes an aromatic ring as