UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (Eng) MATERIALS SCIENCE AND ENGINEERING

First Semester Examination 2013/14

MTEN 201: Fundamentals of Materials Science and Engineering

TIME ALLOWED: 3hrs

Answer All Questions in Section A&B

SECTION A: 30 MARKS

1. Show that the atomic packing factor for Hexagonal closed–packed (HCP) is **0.74**
2. Prove that the lattice parameter of cubic edge length of a Body Centered Cubic (BCC) is given as $\boldsymbol{a} = \frac{4R}{\sqrt{3}}$ and its atomic packing factor is **0.68**
3. Compare the activation energies of interstitial and vacancy diffusion as well as the activation energies of high and low melting point materials.
4. Draw the following crystallographic directions and planes:
   i. $[1\ 0\ 1]$
   ii. $[1\ \bar{1}\ 1]$
   iii. $(1\ \bar{1}\ 0)$
   iv. $(2\ \bar{1}\ 0)$
   v. $(\bar{1}\ 0\bar{1})$
5. Write the electronic configuration for the following atoms
   a. $_{18}\mathrm{Ar}$
   b. $_{26}\mathrm{Fe}$
   c. $_{24}\mathrm{Cr}$
   d. $_{29}\mathrm{Cu}$
   e. $_{21}\mathrm{Sc}$

Examiner: Dr. JK Efavi

6. Differentiate between the following terms
    a) Polymorphism and Allotropy
    b) Crystalline and amorphous solids
    c) Substitutional and interstitial solid solutions
7. Write the mathematical expressions for the Fick's first and second law and describe the conditions under which they are applicable
8. What is an isomophous system?
9. Differentiate between point defects and line defects
10. Name the main primary bonds in materials and explain why it is desirable to understand the attractions that hold atoms together?

SECTION B (40 MARKS)

1. (a) A common question asked by most people is, why do we need to study Phase Diagrams? Give a detailed explanation as a Materials Science Engineering Student to the importance of Phase Diagrams?

   (b) Using a sketch diagram, explain the difference between a binary isomorphous and Eutectic phase diagrams

   (c) Solders are metal alloys that are used to bond or join two or more components (usually other metal alloys). Majority of solders are Pb-Sn alloys and these materials reliable, inexpensive and have low melting points. The most common lead–tin solder has a composition of 63 wt% Sn–37 wt% Pb as seen in a lead–tin phase diagram in Figure 1.

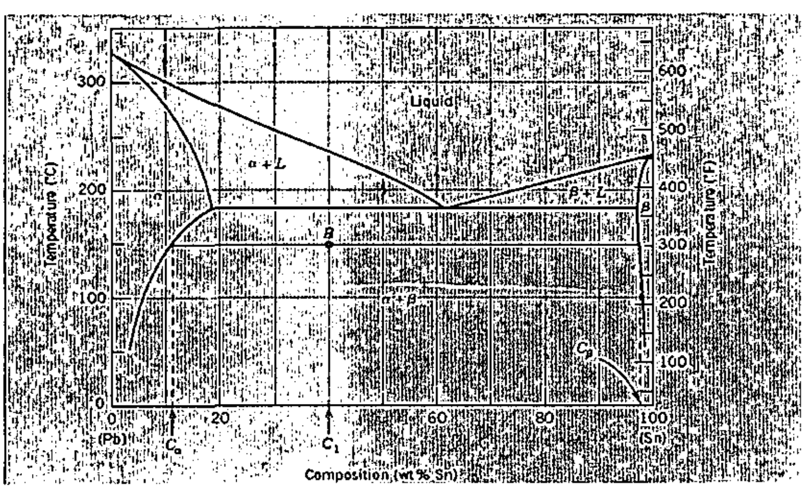


Figure 1: Lead-Tin Phase Diagram

For a 40 wt% Sn–60 wt% Pb alloy at 150°C,
(a) What phase(s) is (are) present?
(b) What is (are) the composition(s) of the phase(s)?

2. For the lead-tin system in figure 1, at 150°C take the densities of Pb and Sn to be 11.23 and 7.24 g/cm^3 respectively. Calculate the relative amount of each phase in terms of
   (a) Mass fraction
   (b) Volume fraction

3. (a) A plate of iron is exposed to a carburizing (carbon-rich) atmosphere on one side and a decarburizing (carbon-deficient) atmosphere on the other side at 700°C. If a condition of steady state is achieved, calculate the diffusion flux of carbon through the plate if the concentrations of carbon at positions of 5 and 10 mm beneath the carburizing surface are 1.2 and 0.8 kg/m^3, respectively. Assume a diffusion coefficient of $3x10^{-11}m^2/s$ at this temperature.
   (b)A sheet of steel 2.5mm thick has nitrogen on both sides at 900°C and is permitted to achieve a steady state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $1.2x10^{-10}m^2/s$, and the diffusion flux is found to be $1.0x10^{-7}$ $kg/m^2.s$. Also it is known that the concentration of nitrogen in steel at the high-pressure surface is 2 kg/m^3. How far into the sheet from this high pressure side will the concentration be $0.5kg/m^3$? Assume a linear concentration profile

4. (a) Many materials, when in service, are subjected to forces or loads; examples include an aluminum alloy from which an airplane wing is constructed and the steel in an automobile axle. In such situations it is necessary to know the characteristics of the material and to design the member from which it is made such that any resulting deformation will not be excessive and fracture will not occur. There are a number of significant regions and points on a stress-strain curve that helps one to understand and predict the way every engineering material will behave when under load. Reproduce figure 2; and label the various points/regions together with the physical behavior of the material at each point.

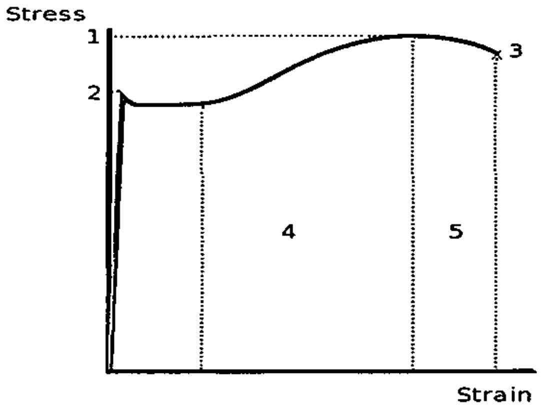
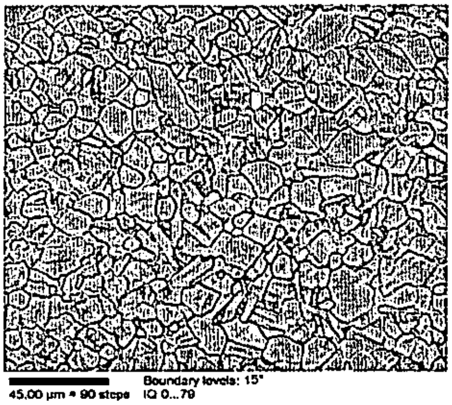
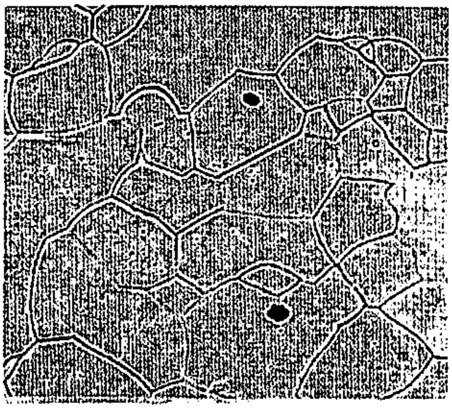


Figure 2, Stress-Strain diagram of an engineering material under tensile loading

4 (b) As a metallurgists or Materials Scientist, you need to know the importance of grain size, and be sure you understand how grain size will affect mechanical properties especially when designing process recipes. Figure 3 is a micrograph showing the grains of a material processed with different process variables. Compare fig. 3a and 3b and explain the effect of the different process recipe on the mechanical properties (list at least 3 mechanical properties to justify your answer)



(a)



(b)

Figure 3, Stress-Strain diagram of an engineering material under tensile loading