INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Subject Name: MATERIALS ENGINEERING (Sub. No. MT30001)

MID Autumn Semester, 2015   Time: 2 Hrs.   Full Marks: 30
3rd Year B. Tech. Students of ME, MF, QE and QM   No. of Students: 168
Dept.: Metallurgical and Materials Engineering

Instructions: Answer ALL the questions. Total number of questions: 5. Total number of pages: 2.
     Where necessary, use schematic diagrams to illustrate your answer.

1.
     Q1 Total: 8
     (a) What characterization technique would you use to characterize the crystal structure of a crystalline solid?   1
     (b) What would be the value of the lattice parameter of a BCC crystal for which the first order diffraction line of (200) plane occurs at an diffraction angle of 2θ, such that $\sin(\theta) = 0.45$? Assume that the wavelength of the X-Ray beam used is $\lambda = 0.18$ nm. Show your work (show the formulae you are using to solve this problem).   2
     (c) If in a XRD profile for a cubic crystal, there is a strong peak for (110) plane, then is that crystal a FCC crystal or a BCC crystal?   1
     (d) What is the Miller Bravais index for the direction which is normal to both the a_2 [$\bar{1}2\bar{1}0$] and the c [0001] axes of a hexagonal crystal?   1
     (e) What is the linear density of [110] direction in a FCC crystal of lattice parameter a?   1
     (f) Write down the slip systems for a FCC crystal?   2

2.
     Q2 Total: 6
     (a) What is the line direction (in terms of Miller index) of a screw dislocation with Burger's vector $\frac{1}{2}[1\bar{1}0]$?   1
     (b) At 327°C, the fraction of aluminium lattice sites vacant is 4.15×10^{-7}. Calculate the fraction at 627°C. Assume that the activation energy for vacancy formation (energy of formation of a single vacancy), Ev = 0.76 eV and the Boltzmann constant $k_B = 86.2 \times 10^{-6}$ eV/K.   3
     (c) Among Ti (HCP) and Ni (FCC), which one is more prone to deform by twinning? Why?   2

3.
     Q3 Total: 9
     (a) With respect to phase transformation in materials science, What are the names of the invariant reactions, in which
         i. One single solid phase forms from two solid phases while cooling?   1
         ii. Two solid phases form from one single solid phase while cooling?   1
     (b) Which binary phase diagram shows complete solid solubility (~100%) of the elements in the solid phase? Draw schematically such phase diagram between two elements, say, A and B, where pure A has higher melting point than pure B. Indicate the specific phases in the single phase regions and the two phase region in this phase diagram.   1+3
     (c) Draw schematically the microstructure that would be obtained at room temperature when a 1%C plain carbon steel alloy (hyper eutectoid composition) is slowly cooled from single phase austenite region. Indicate and explain the micro-constituents (phases) of this microstructure.   3

4.   <u>Q4 Total: 4</u>
   (a) Write down the main strengthening mechanisms involved in the "Deformation" step
       and in the "Recrystallization step".   2
   (b) What is the driving force for grain growth?   1
   (c) In a precipitation hardened alloy if dislocations bypass the precipitates by formation of
       Orwan loops, then how will strength vary with inter-precipitate distance in this alloy?
                                                                                 1

5.   <u>Q5 Total: 3</u>
   (a) Draw in the same figure, the change in Gibbs fee energy vs. radius of the solid cluster
       of atoms (radius of the spherical solid embryo/ nucleus) for both homogeneous and
       heterogeneous nucleation during solidification of a metal at the same under-cooling
       condition.   2
   (b) If interfacial energy is doubled then what will be the change in the critical radius for
       nucleation during solidification?   1

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