Indian Institute of Technology Kharagpur
Department of Metallurgical and Materials Engineering

Autumn Semester Examination (2015-16) — Full marks: 100
Subject Name: Materials Engineering (MT30001) — Time: 3 hours
No. of Students: 168

Instructions: Questions No 1 and 2 are compulsory. Answer any FIVE from the rest. Answer should be brief and to the point.

(1) Write whether the following statement is true (T) or false (F). You need to justify your answer by proper explanation and/suitable diagram. **(8×2.5 = 20)**

(a) Shot peening can improve the fatigue life of structural component.

(b) An alloy containing finer grain size should be chosen for high temperature application.

(c) BCC metals predominantly exhibit ductile-to-brittle transition temperature (DBTT) whereas FCC metals not.

(d) The thermal conductivity of a plain carbon steel is greater than for a stainless steel.

(e) Electrical conductivity of the noncrystalline metal is greater than its crystalline counterpart.

(f) Interstitial diffusion is less rapid than vacancy diffusion.

(g) Coefficient of thermal expansion for polymers is much higher than metals or ceramics.

(h) Hardenability of alloy still is generally lower than plain carbon steel.

(2) Compare and contrast the followings: **(5×3 = 15)**

(a) Gray and white cast iron

(b) Hardness and hardenability

(c) TTT diagram and CCT diagram

(d) Recovery and recrystallization

(e) Low cycle and high cycle fatigue

(3) (a) What is pincushion indentation and barrelled indentation related to Vicker hardness measurement? How these affect the accuracy of Vicker hardness measurement? **(2+2)**

(b) Determine the approximate Brinell hardness of a 99.75 wt% Fe - 0.25 wt% C alloy. HB of ferrite and pearlite is 80 and 280, respectively. **(3)**

(c) How will you measure the hardenability of a given material? **(2)**

(d) Draw a typical TTT diagram of eutectoid steel and schematically superimpose on it the cooling rate of annealing and quenching treatment to show the transformation product of austenite. **(2)**

(c) Describe briefly the microstructural changes that happen during various stages of tempering treatment. (2)

(4) (a) State the Fick's first and second law of diffusion. (3)

(b) An FCC iron-carbon alloy initially containing 0.20 wt% C is carburized at an elevated temperature and in an atmosphere that gives a surface carbon concentration constant at 1.0 wt%. If after 49.5 h the concentration of carbon is 0.35 wt% at a position 4.0 mm below the surface, determine the temperature at which the treatment was carried out. Given, for diffusion of C in FCC Fe: $D_o = 2.3 \times 10^{-5}$ m^2/s and Q_d = 148,000 J/mol. (5)

Z	erf(Z)
0.90	0.7970
Z	0.8125
0.95	0.8209

(c) What is Griffith theory of fracture for brittle material? (2)

(d) A relatively large plate of a glass is subjected to a tensile stress of 40 MPa. If the specific surface energy and modulus of elasticity for this glass are 0.3 J/m^2 and 69 GPa, respectively, determine the maximum length of surface flaw that is possible without fracture. (3)

(5) (a) $2Cu + 2H_2SO_4 + O_2 = 2CuSO_4 + 2H_2O$

Calculate the free energy change associated with the above reaction and comment on the spontaneity of the above reaction. Given the standard potential (vs. SHE) for $Cu^{+2} + 2e = Cu^0$ is +0.342V and that for $O_2 + 4H^+ + 4e = 2H_2O$ is +1.229V. (2)

(b) Briefly explain why ferritic and austenitic stainless steels are not heat treatable. (2)

(c) What is sensitization and how it happens in a typical 18:8 austenitic stainless steel? How this can be controlled in a typical 18:8 austenitic stainless steel? (3+2)

(d) Write down the names of eight forms of corrosion. Also write down the corrosion rate expression in mils per year (mpy) and define the various parameters (with units) associated with this expression. (2+2)

(6) (a) What is strain hardening? Compute the strain-hardening exponent (n) for an alloy in which a true stress of 415 MPa produces true strain of 0.10. Assume a value of 1035 MPa for strength coefficient (K). (1+2)

(b) Why metal like lead and tin cannot be strain hardened in room temperature? (1)

(c) What is critical resolved shear stress (CRSS) for plastic deformation of single crystal? The tensile stress that need to be applied along the [1-10] axis of a silver crystal to cause slip on the (1-1-1)[0-11] system is 14.7 MPa. Calculate the CRSS for this silver crystal. (1+3)

(d) Draw a typical creep-strain vs. time plot and label on it the various important stages of creep. Also, mention the deformation mechanism associated with each stage. (3)

(e) State the parameters that control the thermal shock resistance of a material. (2)

(7) (a) For intrinsic gallium arsenide, the room-temperature electrical conductivity is 10^{-6} (Ω-m)$^{-1}$, the electron and hole mobilities are, respectively, 0.85 and 0.04 m^2/V-s. Compute the intrinsic carrier concentration at room temperature. (2)

(b) Explain, with suitable diagram, how conductivity of extrinsic semiconductor changes with temperature. **(2)**

(c) With suitable illustration, explain *p*-type extrinsic semiconduction. **(2)**

(d) How *p-n* rectifying junction converts alternating current to direct current? **(3)**

(e) The room-temperature electrical conductivity of intrinsic silicon is 4×10^{-4} $(\Omega\text{-m})^{-1}$. An extrinsic *n*-type silicon material is desired having a room temperature conductivity of 150 $(\Omega\text{-m})^{-1}$. Specify a donor impurity type that may be used as well as calculate its concentration in atom percent to yield these electrical characteristic. Assume that the electron and hole mobilities are the same as for the intrinsic material, and that at room temperature the donor impurities are exhausted. Given, electron mobility for intrinsic silicon is 0.14 m^2/V-s, density of silicon is 2.33 g/cm^3 and atomic weight of silicon is 28.09 g/mol. **(4)**

(8) (a) Schematically show the atomic magnetic dipole configuration of typical diamagnetic, paramagnetic and ferromagnetic material with and without an external magnetic field. **(3)**

(b) Show schematically the magnetization curves for soft and hard magnetic materials. **(2)**

(c) What is Type I and Type II superconductor? **(3)**

(d) What is the minimum wavelength absorbed by silicon? Given, band gap energy (E_g) for silicon is 1.1 eV and Planck's constant is 6.63×10^{-34} J.s. **(2)**

(e) Briefly explain the working principle of step-index optical fiber and graded-index optical fiber. **(3)**

(9) (a) Compare the crystalline state in metals and polymers. Schematically represents the molecular structures of different types of polymer. **(1+2.5)**

(b) Draw stress-strain plots for typical brittle, plastic and highly elastic polymers. **(2)**

(c) Would you expect a crystalline ceramic material to strain harden at room temperature? Why or why not? **(1)**

(d) Briefly state the properties and application of glass-ceramics. Draw a continuous cooling transformation diagram for a lunar glass showing the cooling rate that need to be adopted to obtain glass-ceramic at room temperature. **(3+1.5)**

(e) Boron fibers, E_f = 380 GPa, are made into a unidirectional composite with an aluminum matrix, E_m = 60 GPa. What is the modulus parallel to the fibers for 10 and 60 vol%. **(2)**