RS

W'05 : 1 AN : AN 202/AD 302 (1402)

MATERIALS SCIENCE AND ENGINEERING

Time : Three hours

Maximum marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing data or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Calculate the volume of an FCC unit cell in terms of the atomic radius, R. Show that the atomic packing factor of FCC unit cell is more than that of BCC. 10

(*b*) Differentiate between Frenkel pairs and Shottkey defects. 5

(*c*) Explain why interstitial atoms such as C in Fe, can diffuse more rapidly, compared to vacancies. 5

(*Turn Over*)

2. (a) A tensile sample of polycrystalline copper has been loaded in tension to an arbitrary stress, σ exceeding the yield stress, σ_0 and then unloaded.

(i) With a schematic true stress-true strain curve representing the loading and unloading behaviour, show how elastic and plastic strains can be determined.

(ii) If the sample was a single crystal of copper, and subjected to compression right after unloading in tension, will the yield stress be equal to, more or less than σ_0. Explain. 10

(b) Assuming that the true stress-true strain curve follows the relation : $\sigma = \sigma_0 + K\varepsilon_p^n$, where σ is the true stress, σ_0 is the flow stress at plastic strain = 0, ε_p = true plastic strain, and n is the strain hardening exponent. Show that the rate of strain hardening, $d\sigma/d\varepsilon_p$ is a function of n, σ, σ_0 and ε_p. Estimate the value of $d\sigma/d\varepsilon_p$, where $n = 0{\cdot}3$, $\sigma = 300$ MPa, $\sigma_0 = 200$ MPa and $\varepsilon_p = 0{\cdot}05$. 5

(c) Draw schematic stress strain curves for ideally elastic, ideally plastic and viscoelastic solid. Explain how is the behaviour of viscoelastic solid different from those of other two. 5

3. (a) Explain why is twinning associated with homogeneous shear, though atoms are displaced by equal distance in slip? 5

(b) What are the three regimes of a typical creep curve, showing creep strain against time? Distinguish between the deformation mechanisms involved in the three stages of creep. 10

(c) What is the fundamental difference between stress-relaxation test and a creep test? 5

4. (a) Explain on the basis of dislocation theory, why ceramics and intermetallic compounds are brittle, while metals are ductile? 5

(b) Consider a single crystal of silver (fcc). The angle between normals to the planes $(h_1\,k_1\,l_1)$ and $(h_2\,k_2\,l_2)$ is

$$\cos^{-1}\{(h_1 h_2 + k_1 k_2 + l_1 l_2)/[(h_1^2 + k_1^2 + l_1^2)(h_2^2 + k_2^2 + l_2^2)]^{0.5}$$

If a tensile stress of 10·0 MPa is applied along the [010] direction. Determine the resolved shear stress along the (111) plane and [110] direction. 5

(c) Mild steel samples A, B and C have been fractured by impact at liquid nitrogen temperature and in tension with a strain rate of $10^{-5}\,s^{-1}$ at 700 °C in air. Explain with reasons the differences in fracture surface morphology. 5

(d) What are the differences in grain structure and dislocation substructure do you expect after working different parts of same strip of copper through similar reduction at room temperature and 0·6 of its absolute melting point. 5

Group B

5. (*a*) What are the eutectoid and eutectic reactions in the Fe-C binary phase diagram? 4

(*b*) If you carry out impact test on 0·4% C steel, subjected to heat treatments: (*i*) quenching in brine after soaking above the A3, and (*ii*) tempering at 500 °C for 1 h. Will the results vary? Explain. 4

(*c*) 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 mm and 10 mm beneath the carburizing surface are 1·2 and 0·8 kg/m^3. Assume a diffusion coefficient of $3 \times 10^{-11}\ m^2/s$ at this temperature. How will you attempt the same problem, if non-steady state conditions exist. 6

(*d*) Differentiate between age hardening and dispersion hardening, emphasizing on how dislocations interact with the second phase and suitability for application of the materials strengthened by those methods at high temperatures. 6

6. (*a*) What are the two mechanisms responsible for thermal conductivity in materials? Why are amorphous ceramics or polymers less thermally conductive, compared to those, which are crystalline? 6

(*b*) Explain two different sources of thermal stresses in materials, which could be of any dimensions and used in different structural components. How is the thermal shock resistance dependent on thermal conductivity, coefficient of thermal expansion, elastic modulus, and anisotropy along crystallographic directions? 8

(*c*) How will you select and design materials to be used in (*i*) turbine blades of jet engines, operating at 1300 °C, (*ii*) propeller of a ship travelling in the Arctic ocean. Emphasize on requirements of microstructure, physical and mechanical properties. 6

7. (*a*) What do you mean by glass transition temperature? How do the plots showing variation of specific volume with temperature for amorphous glass ceramic and a crystalline solid differ? 5

(*b*) Why are ionic ceramics used as dielectric in capacitors, and what does dielectric constant depend on? What is special in ferro-electric ceramics, and is it necessary for iron to be present? 6

(*c*) Distinguish between structure and properties of thermosetting and thermoplastic resins. 6

(*d*) Is substitutional solid solution of ceramics possible? What is the additional condition, which is not a requirement for metals? 3

8. (*a*) Distinguish between paramagnetism and ferromagnetism, explaining the mechanisms involving electron spins. 5

(*b*) Draw the magnetic hysteresis loop for hard and soft magnets, and explain the differences in behaviour in response to alternating field with emphasis on the magnetization parameters. 5

(*c*) Distinguish between addition and condensation polymerization, and state which of those are applied for processing polyethylene and polycarbonates. 5

(*d*) Using the character of electron distribution in different energy bands, explain the cause behind a material acting as conductor, and other acting as insulator. 5

Group C

9. Answer the following questions in *one* or *two* sentences : 2 × 10

(*i*) How many independent slip systems are required for plastic deformation in polycrystalline materials ?

(*ii*) Why is the actual fracture strength of materials normally 10^{-1} - 10^{-3} times that of the theoretical cohesive strength ?

(*iii*) Which microstructural parameter of a material can be tailored to increase simultaneously the yield strength as well as the fracture toughness ?

(*iv*) Under the application of an external stress, what is the direction of movement of edge and screw dislocation in a solid with respect to the Burgers vector ?

(*v*) There are two alloys, one with a very high stacking fault energy compared to the other, which one is expected to demonstrate a higher rate of strain hardening ?

(*vi*) Why does addition polymerization need a monomer with carbon-carbon double bond to begin with ?

(*vii*) What are the two mechanisms of elastic deformation of elastomers such as rubber, which are absent in metals ?

(*viii*) What is the cause of dielectric energy loss, when direction of an external electric field is alternated ?

(*ix*) What is the principal difference in the elastic and physical properties of particle and fibre reinforced composites, which is important from the point of view of application ?

(*x*) What modification was made in the expression of Griffith theory for universal application to all materials ?