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BE / B Tech (Full Time) DEGREE ARREAR EXAMINATIONS APRIL / MAY 2012

MATERIALS SCIENCE & ENGINEERING BRANCH

SEVENTH SEMESTER

**ML-9022 – Physical Metallurgy of Ferrous and Aluminium Alloys**

(REGULATIONS 2008)

Time : 3 hrs. Max. Mark : 100

Instructions : 1. Read questions carefully and write *'to the point'* answers

2. Question Nos. 1 to 11 are compulsory

Answer ALL Questions

**Part – A (10 x 2 = 20 Marks)**

1. What is heterogeneous nucleation?
2. State Fick's first law of diffusion.
3. What is the temperature dependence of diffusion? Write down the corresponding equation.
4. What is up-hill diffusion?
5. Write down the precipitation sequence in an Al – 4 wt% Cu alloy aged at 190°C.
6. Define misfit strain.
7. What is an anti-phase boundary (APB)?
8. In a TTT-diagram, draw a cooling curve for which Austenite will transform to upper Bainite.
9. What is known as 'site saturation'?
10. Give two examples of cellular transformation processes.

**Part – B (5 x 16 = 80 Marks)**

11. (a) Derive Avrami equation for a cellular transformation $\alpha \rightarrow \beta$ in which the product phase is continuously nucleated throughout the transformation process. Assume necessary parameters. (8)

(b) (i) State 'random jump characteristics' of interstitial diffusion. (2)

(ii) For a dilute interstitial solid solution having concentration gradient with respect to solute B-atoms, show that the net flux of B-atoms, down the concentration gradient, obeys Fick's 1st law. Consider 'random jump characteristics' and assume relevant parameters. (6)

12. (a) Write short notes on the followings: (i) Pearlitic transformation, (ii) Bainitic transformation, (iii) Massive transformation, (iv) Spinodal decomposition. (4x4)

OR

(b) (i) Explain briefly the various stages of annealing process. (6)

(ii) Define recrystallization temperature. (2)

(iii) Name the factors that affect recrystallization temperature and explain the dependence on those process parameters. (2+6)

13. (a) With respect to martensitic transformations, explain the followings:

(i) driving force for the transformation, (ii) microstructures of martensite, (iii) nucleation kinetics & role of dislocation in martensite nucleation, (iv) Bain distortion model. (4x4)

OR

(b) With respect to order-disorder transformations, explain the followings:

(i) thermodynamics of order-disorder transformation, (ii) short range and long range ordering, (iii) 1st and 2nd order transformations, (iv) ordering of 'shape memory' metal: Nitinol. (4x4)

14. (a) (i) Discuss in detail the growth of a pure solid on atomically rough and smooth surfaces.

(ii) For the growth of a newly formed solute B-rich β-precipitate (composition, $C_\beta$) from parent α-phase (bulk composition $C_0$ and equilibrium composition at the interface is $C_e$), show that the precipitate thickening obeys a parabolic growth law with time t, i.e., thickness of the slab, $x \propto \sqrt{(Dt)}$, D being the diffusivity of species B. Assume other relevant parameters. (8+8)

OR

(b) (i) What is Gibbs-Thomson effect?

(ii) Derive the expression of the free energy increase ($\Delta G$) based on Gibbs-Thomson effect.

(iii) Discuss in detail about the 'particle coarsening' focusing on its governing equation, thermodynamics and the factors affecting particle coarsening. (2+6+8)

15. (a) (i) Write down the general solution of Fick's second law for non-steady state diffusion. (2)

(ii) Draw a concentration vs. distance profile for the decarburization process of steel. (4)

(iii) At 950°C, a 1.2 %C-steel is getting decarburized for a duration of 3 hours in an atmosphere equivalent to 0% carbon at the surface of the steel. Determine the minimum depth at which carbon concentration of 0.8% can be obtained. Use: $D_c$ in Fe(γ) at 950°C = $1.4 \times 10^{-11}$ m$^2$/s; and error function chart as given below. (6)

(iv) State the process of experimental determination of the diffusion coefficient, D, using a diffusion couple based on the Fick's second law. (4)

OR

(b) (i) Write down the general solution of Fick's second law for non-steady state diffusion. (2)

(ii) Draw a concentration vs. distance profile for the carburization of steel. (4)

(iii) At 950°C, a low-carbon-steel with 0.2 %C is carburized for 4 hours in an atmosphere equivalent to 1.2% carbon at the surface of the steel. Calculate the depth at which carbon concentration of 0.6% can be obtained. Use: $D_c$ in Fe(γ) at 950°C = $1.4 \times 10^{-11}$ $m^2/s$; and error function chart as given below. (6)

(iv) Discuss how the corrosion resistance of duralumin is achieved based on the Fick's second law. (4)

Tabulation of Error Function Values

| $z$ | $erf(z)$ | $z$ | $erf(z)$ | $z$ | $erf(z)$ |
|---|---|---|---|---|---|
| 0 | 0 | 0.55 | 0.5633 | 1.3 | 0.9340 |
| 0.025 | 0.0282 | 0.60 | 0.6039 | 1.4 | 0.9523 |
| 0.05 | 0.0564 | 0.65 | 0.6420 | 1.5 | 0.9661 |
| 0.10 | 0.1125 | 0.70 | 0.6778 | 1.6 | 0.9763 |
| 0.15 | 0.1680 | 0.75 | 0.7112 | 1.7 | 0.9838 |
| 0.20 | 0.2227 | 0.80 | 0.7421 | 1.8 | 0.9891 |
| 0.25 | 0.2763 | 0.85 | 0.7707 | 1.9 | 0.9928 |
| 0.30 | 0.3286 | 0.90 | 0.7970 | 2.0 | 0.9953 |
| 0.35 | 0.3794 | 0.95 | 0.8209 | 2.2 | 0.9981 |
| 0.40 | 0.4284 | 1.0 | 0.8427 | 2.4 | 0.9993 |
| 0.45 | 0.4755 | 1.1 | 0.8802 | 2.6 | 0.9998 |
| 0.50 | 0.5205 | 1.2 | 0.9103 | 2.8 | 0.9999 |