1. As shown in **Figure 1(a)**, a Fe-C alloy with a carbon content of C_0 at. % was isothermally held at T_1 °C. Then, a decarburization was applied at the ferrite end, and therefore, ferrite (α) could start to grow into austenite (γ), which is a very long volume as shown in **Figure 1(b)**. The decarburization maintained the carbon concentration to be C_s at. % at the surface of ferrite. In **Figure 1(b)**, both concentration gradients are linear.

   (a) When the steady state is reached, deduce the ferrite growth rate ($v = \frac{\partial x}{\partial t}$) in terms of a, b, C_o, C_s, C_α, C_γ, D_α, and D_γ. D_α, and D_γ are diffusivities of ferrite (α) and austenite (γ) at T_1. (6%)

   (b) Deduce "a/b" value in terms of C_o, C_s, C_α, C_γ, D_α, and D_γ, when the interface is stationary. (4%)

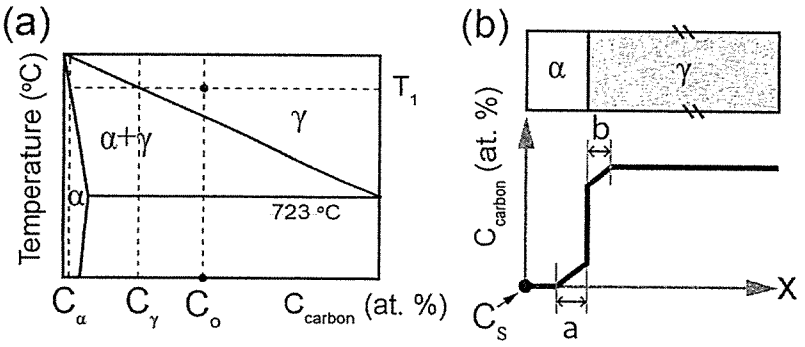

Figure 1(a) The Fe-C phase diagram and (b) the concentration profile across α /γ interface during phase transformation at T_1.

2. What are the characteristics of martensitic transformation? (5%)

3. What are principles (or requirements) in selecting creep-resistant alloys? (5%)

4. You executed tensile tests on single aluminum crystals, which is the face-centered cubic crystal (FCC). The experimental configuration of tensile test is shown in **Figure 2(a)**, and the tensile direction is [5 5 2] for all samples.

   (a) Assume the crystal deforms by dislocation slip only, what is/are the initial slip system(s)? (4%)

   (b) Following (a), what would be the crystal direction along the tensile axis after deformation? And why? (3%)

   (c) The experimental design included two samples sizes: 50 nm and 5 mm in diameters. The experimental configurations for both samples were same. Two stress-

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strain curves were then obtained as shown in **Figure 2(b)**. Please identify the sample size for each curve and provide the reasons. (3%)

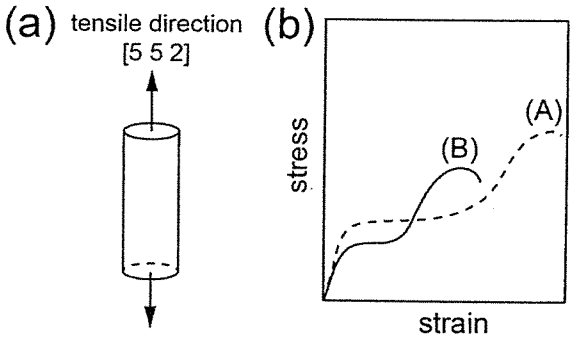

Figure 2 (a) The configuration of tensile experiment and (b) the stress-strain curves of two samples with different size.

5. **Figure 3** shows a non-planar dislocation loop whose Burgers vector is *b*. The slip planes can be *XY* plane and *ZX* plane. At this moment, all of the dislocation segments are parallel or perpendicular to the coordinate axes as shown in **Figure 3**. The segment labeled AH is a positive edge dislocation.
(a) Determine the character of the segments CD and FG. (2%)
(b) Draw the shape of the dislocation loop at next moment. Please use dash line [- - -] to show the original shape and solid line [—] to show the new shape. (4%)
(c) How many dislocation loops could exist at the final moment? (2%)
(d) Following (c), how many dislocation loops are immobile by slip? (2%)

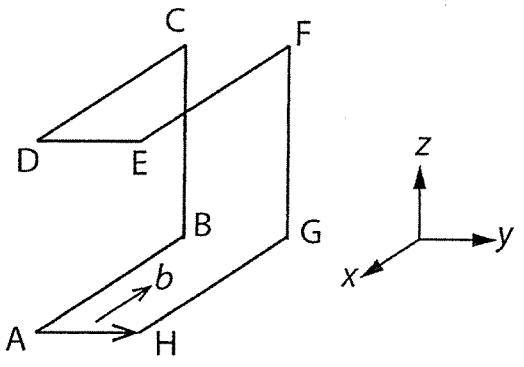

Figure 3 The schematic diagram showing a non-planar dislocation loop.

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6. For a FCC lattice, how many (i) tetrahedral sites and (ii) octahedral sites are within the lattice? (6 marks)

7. What is the coordination number of Ca in perovskite $CaTiO_3$? Explain your answer. (6 marks)

8. From the MgO-Al_2O_3 phase diagram, define the congruent melting point of spinel $MgAl_2O_4$. Explain why this point is important to the processing of $MgAl_2O_4$. (8 marks)

9. Sketch trans and cis structures for polybutadiene. (5%) Which one could be employed in tire for automobiles? Why? (5%)

10. For the above pair of polymers, plot and label schematic logarithm of the relaxation modulus versus temperature form -180 °C to 500 °C on the same graph. Also, label the glass transition temperature in the plot. (10%)

11. (10%) Please describe the material issues for the development of electronic devices in nanoscale.

12. (10%) What are photonic crystals? Please describe the optical properties, structures, materials, dimensions, and applications of the photonic crystals working in visible regime.

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