1. a) The formability of hexagonal-close-packed (HCP) crystal differs metal by metal. For examples, at room temperature, formability is good for titanium alloys, but it is restricted for magnesium alloys. **Table 1** lists the crystallography data of some HCP metals. Which metal(s) in **Table 1** might have better ductility, compared with magnesium? Please specify the reason. (3%)

   b) Suggest an approach to enhance the formability of magnesium. Explain the corresponding mechanism for your suggestion. (2%)

   c) Index the shaded planes and their normal vectors in **Figure 1**, by using the Miller indices. (5%)

Table 1 The crystallography data of some HCP metals at 300 K

Metal	a (Å)	c (Å)
A	2.95	4.67
B	2.66	4.95
C	3.23	5.15
D	2.51	4.07

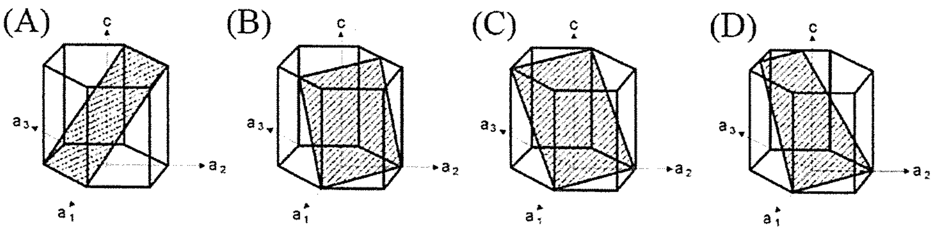

Figure 1 Crystallography planes in HCP crystals.

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2. a) Using the data in **Table 2**, calculate the diffusion coefficients of carbon in body-centered cubic iron (BCC, named ferrite) and face-centered cubic iron (FCC, named austenite), respectively, at 800 °C. Explain the difference between these two values. (3%)

b) As shown in **Figure 2**, a dilute Fe-C alloy with a carbon content of C_0 at. % was cooled from 950 °C to 800 °C for an isothermal transformation. Which concentration profile in **Figure 2** could represent the concentration profile of carbon across the austenite/ferrite (α/γ) interface during a diffusion-controlled γ→α + γ transformation? Please specify the reason. (2%)

c) Deduce the planar growth rate: $v = \frac{\partial x*}{\partial t} = \frac{D_C^{\gamma}(C_0 - C_2)^2}{2x*(C_1 - C_2)(C_1 - C_0)}$, where t is the transformation time. Assume the all diffusional gradients in **Figure 2** are linear. (5%)

Table 2 Diffusion data for carbon in austenite and ferrite

Phase	D_0 (m^2/s)	Q kJ/mol
Austenite (γ) – FCC crystal	1.5 x 10^{-5}	142.1
Ferrite (α) – BCC crystal	2.2 x 10^{-4}	122.5

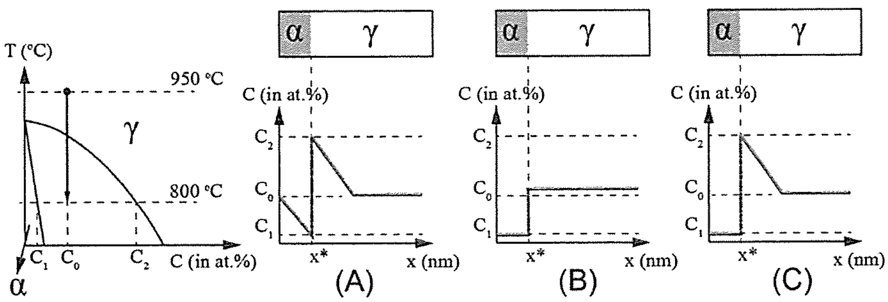

Figure 2 Phase diagram and three possible concentration profiles at the ferrite/austenite interface during diffusion-controlled growth.

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3. a) "Fine-grained materials are more resistant to deformation at low temperature; Coarse-grained materials are more resistant to deformation at high temperature." Please briefly elucidate the essentials of this statement. (5%)

b) **Figure 3** shows the Mg-Pb phase diagram. The 80Mg-20Pb (in wt. %) alloy was cooled from 750 °C to 100 °C, and directly aged at 100 °C for 1 h. Please discuss the effects of non-equilibrium cooling on the aged microstructure. Moreover, please draw the expected final microstructure. (5%)

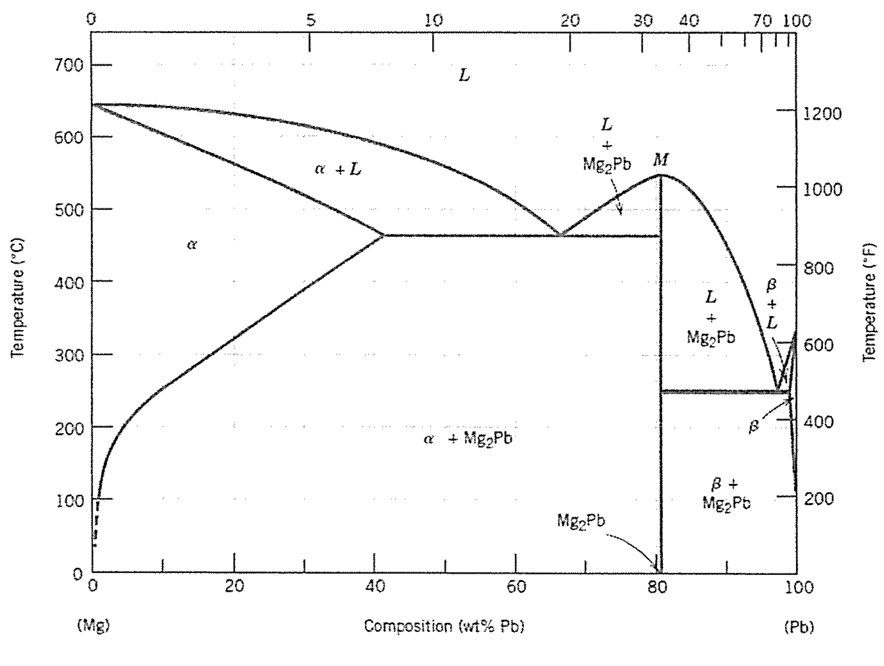

Figure 3 The Mg-Pb Phase Diagram.

4. **Figure 4** shows a series of X-Ray diffraction spectra collected for polycrystallined metallic samples, cold rolled by increasing thickness reductions from A to E. Spectrum A is from the well-annealed sample, and Spectrum E is from the heavily rolled sample. The X-Ray source used here is CuKα radiation (wavelength = 0.15405 nm).

a) What is the crystal structure and lattice parameter of this alloy? (5%)

b) Explain the detailed mechanism for the vanishment of X peak and the enhancement of Y peak from Spectrum A to Spectrum E in **Figure 4**. (3%)

c) **Figure 5** shows the metallographic image of the cold-rolled metal. Which element might be this metal: (A) Aluminum (B) Copper (C) Magnesium (D) Iron? Also, specify the reason. (2%)

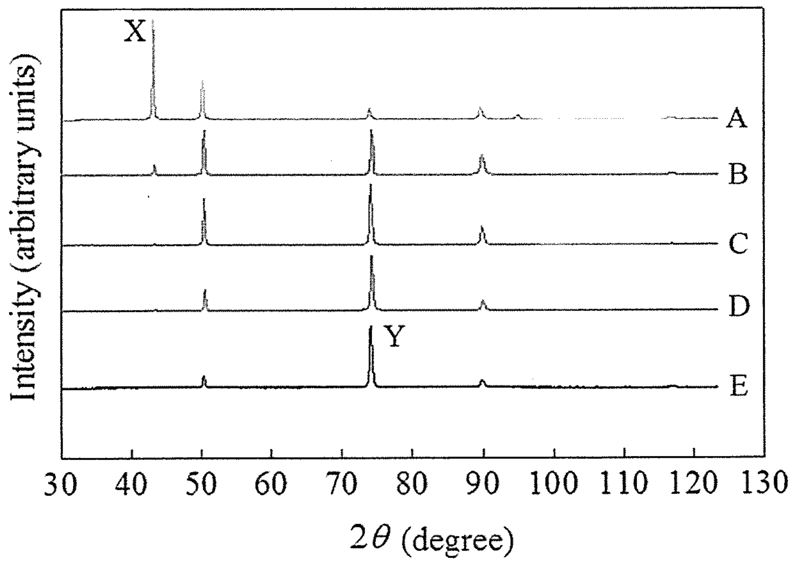

Figure 4 The X-Ray diffraction spectra of polycrystallined metallic samples, cold rolled by increasing thickness reduction ratios (η). A: as annealed; B: η=5 %; C: η=10 %; D: η=20 %; E: η=40 %.

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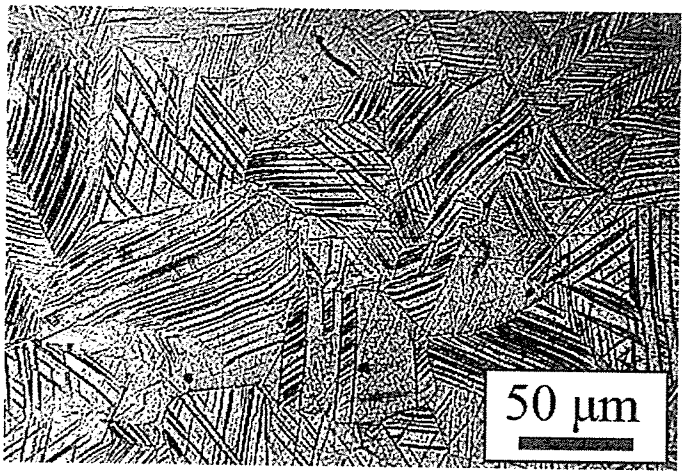

Figure 5 The metallographic image of the cold-rolled metal.

5. For a BCC lattice, how many (i) tetrahedral sites and (ii) octahedral sites are within the lattice? (4%)

6. What processing method(s) can be adopted in order to reduce the concentration of oxygen vacancies in perovskite $BaTiO_3$ bulk ceramics? Explain your answers. (6%)

7. Explain the hardening mechanism of hydraulic cement after being combined with water. (10%)

8. Sketch chemical structures for polystyrene and polycarbonate. (10%)

9. Plot the logarithm of E (modulus) versus temperature for atactic polystyrene and syndiotactic polystyrene in the same figure and explain the difference between two curves. The temperature range is from -180 °C to 200 °C. Mark the glass transition temperature in the plot. (10%)

10. (6%) (a) Explain the two sources of magnetic moments for electrons.

(b) Do all electrons have a net magnetic moment? Why or why not?

(c) Do all atoms have a net magnetic moment? Why or why not?

11. (14%) (a) What are the common materials of light sources operating in ultraviolet, visible, and infrared ray regimes? Please describe the reasons and working principles. (b) What are the suitable materials of the photo-detectors operating in ultraviolet, visible, and infrared ray regimes? Please also describe the reasons and working principles.