材料科學導論基礎、金屬，所佔比例 40%

1. **True or False (reason your answer if you think the statement is false) (12%):**

(a) For a solid material, the greater depth of the potential well, the higher Young's modulus, bond strength, and the thermal expansion coefficient will be. (2%)

(b) Annealing twins are formed due to growth accidents during the recrystallization of damaged crystals; they are recognized based on their lenticular shape. (2%)

(c) The impact toughness will be effectively increased after tempering a quenched steel with a martensitic microstructure. (2%)

(d) The hardenability of low-carbon steel is typically raised by adding alloying elements such as chromium, manganese and increasing the austenitic grain size. (2%)

(e) We can only prevent austenitic stainless steel from sensitization by reducing the carbon content. (2%)

(f) Both $C(x,t) = \alpha_1 + \alpha_2 \operatorname{erf}\left(\frac{\alpha_3 x}{\sqrt{Dt}}\right)$ and $C(x,t) = \frac{\alpha_4}{\sqrt{Dt}} \exp\left(-\frac{\alpha_5 x^2}{Dt}\right)$ can be solutions of Fick's 2nd law if $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ and the diffusion coefficient D are all constants (i.e., not a function of x, t). (2%)

2. **Impurities in Solids (6%):**

Solids containing impurity elements can have more interesting properties than pure metals and metalloids. Today you are asked to add 1.5×10^{20} Y atoms per cubic centimeter of an X-Y solid solution. Knowing the mass density of pure X 3.48 g·cm^{-3}, pure Y 5.4 g·cm^{-3}, and the atomic weight of Y 67.45 g·mol^{-1}, determine the weight percentage of Y in this X-Y solid solution. (6%)

3. **The structure of crystalline solids and slip systems (14%):**

(a) A handful of powder was accidentally mixed with two different types of crystals. We only know that one crystal structure is BCC, and the other is FCC. When monochromatic X-ray radiation having a wavelength of 1.54Å is used, there are peaks at 2θ=40°, 44°, 47°, 64°, 68°, 81°, 82°, 86°, 97°, 104°, 114° in the diffraction pattern for this powder. Determine the lattice parameter(s) for the BCC and FCC, respectively. (6%)

(b) It is well known that the slip directions for BCC structure are $\langle 111 \rangle$; the slip planes can be $\{110\}$, $\{211\}$, and $\{321\}$. Prove that a (321) plane can contain one of four $\langle 111 \rangle$ slip directions by a schematic illustration. (2%)

(c) A single crystal of metal with the BCC crystal structure is oriented such that tensile stress is applied in the [100] direction, and the magnitude of this stress is 5.1 MPa. If the critical resolved shear stress of this single crystal is 2.4 MPa, which slip systems will be activated? [Hint: in this case, "only" twelve $\{110\}\langle \bar{1}11 \rangle$ and twelve $\{211\}\langle \bar{1}11 \rangle$ slip systems should be considered] (6%)

4. **The kinetics of phase transformations (8%):**

(a) It is generally agreed that the overall phase transformation rate is equal to some product of the nucleation rate, $\dot{N}$, and the growth rate, $\dot{G}$. Draw a schematic plot showing curves for $\dot{N}$, $\dot{G}$, and overall phase transformation rate versus temperature. "Temperature" should be the vertical axis of your plot, and you should explain why the curves you draw look like these. (3%)

(b) For solid-state transformations, the Avrami equation $y = 1 - \exp(-kt^n)$ is useful to analyze the kinetic behavior. The following table shows the resuls of two recrystallization experiments of an alloy:

Data	Time, t [s]	The fraction of transformation, y [-]
#1	100	0.3
#2	300	0.7

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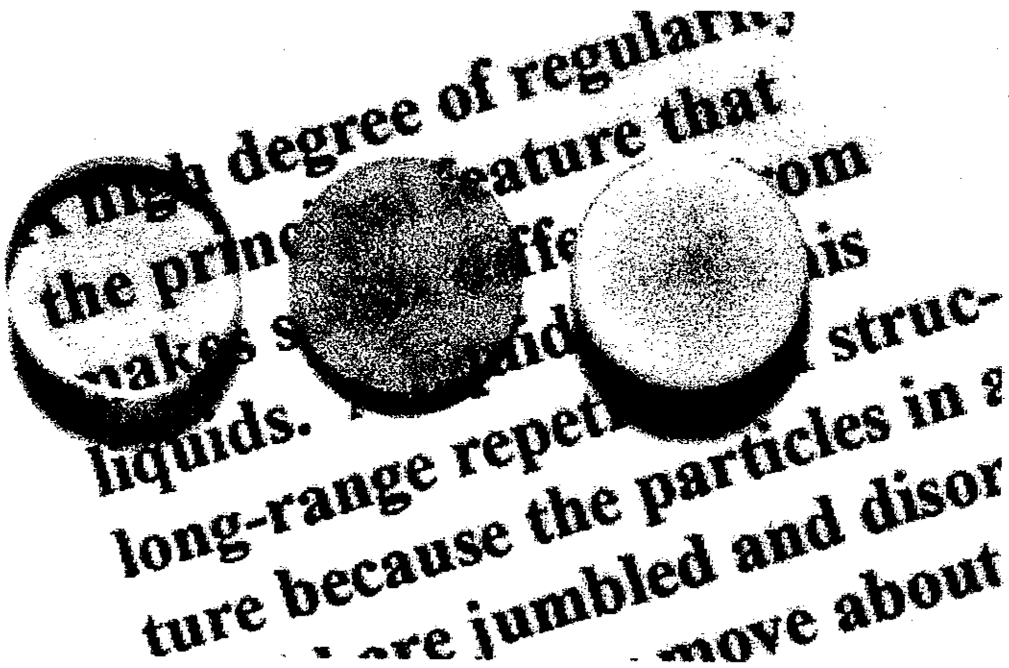
Assuming that the recrystallization kinetics of this alloy perfectly follows the Avrami equation, derive n. (2%)

(c) Following to the previous question, predict the time required to reach 0.9 fraction of transformation. (3%)

5. Three aluminum oxide cylindrical discs are shown in the following photo. The dimensions of these 3 specimens are the same, the Al2O3 content in these specimens is higher than 99%. The left specimen is a single crystal, the middle specimen and the right specimen are polycrystalline ceramics. Please give two possible reasons why the light transmittance of the left specimens is the highest. (10%)



6. The thermal conductivity of the left specimen shown in the above photo is slightly higher than that of the middle specimen. Why is this so? (5%)
7. The flexural strength of the middle specimen shown in the above photo is slightly higher than that of the right one. Why is this so? (5%)
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(a) Sketch chemical structures of PP, PVC, PMMA, Nylon 6 and Nylon 6,6 (5 %)
(b) Why PMMA is difficult to form crystalline? (2 %)
(c) Between PP and PVC, which one has higher melting point? Why? (4 %)
(d) Why Nylon 6,6 has higher melting point than Nylon 6? (3 %)

9. Although the glass transition temperatures (Tg) of PE and nature rubber are much lower than room temperature, why their products generally present good mechanical properties at room temperature? (6 %)

10. (10%) What is the wavelength range of electromagnetic waves in extreme ultraviolet (EUV) regime? Why EUV technologies are important for semiconductor devices? What are the dielectric properties of materials changed from microwave, infrared (IR), visible, EUV, and X-ray spectral regimes?

11. (10%) What are the most effective ways of heat dissipation for electronic devices, solar cells, buildings, and the Earth, respectively? What are the most effective ways of heat dissipation for polymer, ceramics, semiconductor, and metallic materials, respectively? Please describe the reasons for your answers.

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