

- (a) Write down the *Hall-Petch equation* and explain it. (4%)

(b) Is *Hall-Petch equation* valid for extremely fine grain polycrystalline materials? Why? (3%)

(c) Is *Hall-Petch equation* valid for deformation at high temperatures? Why? (3%)
- The diffusion coefficient of carbon in austenite can be approximated by the equation

$$D_c = 0.2 \exp(-33000 \text{ cal/mole} / RT) \text{ cm}^2/\text{sec}$$

(a) Evaluate D_c for 920°C. (3%)

(b) How long does it take for the composition $\frac{C_s + C_0}{2}$ to penetrate 1 mm at this temperature? How long for 3 mm? (4%) [C_s: surface carbon content, C₀: initial carbon content, erf(0.5) ≃ 0.5]

(c) What temperature of anneal is required to double the penetration in a given time? (3%)
- The following questions are related to mechanical twinning.

(a) Demonstrate the differences (at least two respects) between slip and twinning deformations. (3%)

(b) At what conditions that mechanical twinning occurs in metals? Briefly explain the reasons. (4%)

(c) Use the pole mechanism of Cottrell and Bilby to briefly explain the twin growth in a BCC crystal. (3%)
- SAE8620 steel is a well-known high strength low alloy (HSLA) steel.

(a) What is the carbon content for this steel? (3%)

(b) This steel contains alloying elements of Nickel, Chromium and Molybdenum. What is the main effect for these alloying elements in this steel? (3%)

(c) Design the heat treatments for this steel to exhibit high strength and toughness simultaneously. Briefly explain your idea. (4%)
- Sketch chemical structures of polypropylene (PP) (4%), polycarbonate (PC) (3%), and poly(ethylene terephthalate) (PET) (3%)
- Describe the detailed structure of a spherulite in semicrystalline polymer. (10%)
- For a cubic close packing of oxygen ions, if all the tetrahedral interstitial sites are filled up with cations, what structure do you obtain? (4%)
- An advanced ceramic, sialon, has a tensile strength of 414 MPa. What is the maximum tensile stress that can be applied to a thin crack 0.25 mm deep having a tip radius of 100 Å if fracture is not to occur? (6%)
- Describe in detail the equilibrium solidification and cooling of a SiO₂-40% Al₂O₃ ceramic. The important temperatures for the SiO₂-40% Al₂O₃ ceramic are the liquidus temperature (1810 °C) and the eutectic temperature (1595 °C). (10%)
- Briefly tell what is meant by the drift velocity and mobility of a free electron. (5%)
- What is liquid crystal? How can we use liquid crystals to construct a liquid crystal display? (15%)