

國立臺灣科技大學
九十三學年度碩士班考試試題

系所組別：高分子工程系丁組

科目：材料科學

總分100分

1. Calculate the density of a polyethylene crystal. Explain why all commercial samples have a lower density, about 0.97 g/cm^3 . (6%)

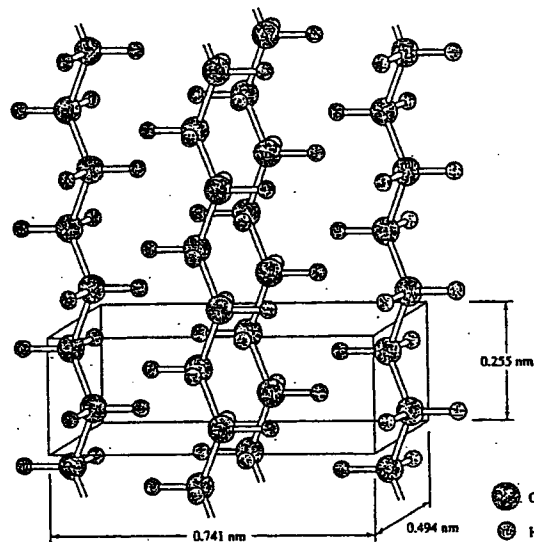


Figure. Crystalline polyethylene is composed of polyethylene chains arranged in an orthorhombic unit cell. (Adapted from C. W. Bunn, Chemical Crystallography, 1945, by permission of Oxford University Press.)

2. Figure shows a hypothetical binary eutectic phase diagram on which we indicate an alloy of composition 0.27 B. Calculate the following quantities: (6%)
- A. The fraction of primary solid that forms under equilibrium cooling at the eutectic temperature.
- B. The amount of α phase that will form from the liquid just below the eutectic isotherm.

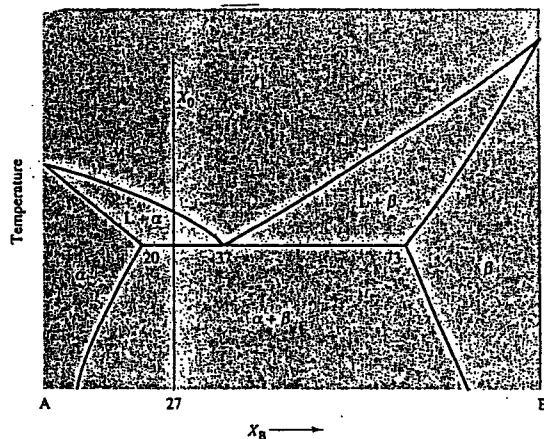


Figure A hypothetical binary eutectic phase diagram indicating an alloy of composition 0.27B.

3. (6%)

- A. Explain the simultaneous influence that undercooling has on the barrier to nucleation and the atomic rearrangements necessary to initiate the transformation. Show how these competing effects lead to classical C-curve behavior in the nucleation of diffusional transformations.
- B. Explain how the value of interfacial energy between the parent phase and the transforming phase affects the critical radius and the barrier to nucleation.

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4. Consider a plot of $\ln \sigma$ versus $(1/T)$ for a sample of silicon doped with 10^{18} Al atoms/cm³. [This doping concentration corresponds to about 20 Al per 10^6 Si atoms, so the common nomenclature is 20 parts per million (ppm).] σ = conductivity (6%)

A. Estimate the slope of the curve in the extrinsic regime.

B. Estimate the conductivity of this material in the saturation (horizontal) region of the curve.

Table Impurity energy levels (E_a or E_d) in Si and Ge.

Host	Dopant	Energy Level
Silicon	Sb	$E_c - E_d = 0.039$ eV
	P	$E_c - E_d = 0.044$ eV
	As	$E_c - E_d = 0.049$ eV
	Bi	$E_c - E_d = 0.069$ eV
	B	$E_a - E_v = 0.045$ eV
	Al	$E_a - E_v = 0.057$ eV
	Ga	$E_a - E_v = 0.065$ eV
	In	$E_a - E_v = 0.160$ eV
	Tl	$E_a - E_v = 0.260$ eV

Table Band gaps and charge carrier mobilities for a variety of semiconductors.

Material	Band Gap (eV)	μ_n (cm ² /V-s)	μ_p (cm ² /V-s)
C	5.4	1800	1400
Si	1.107	1900	500
Ge	0.67	3800	1820

5. (6%)

A. Polyethylene has a polarization of 5.75×10^{-8} C/m² in a field of 5,000 V/m. Calculate the dielectric constant of this polymer.

B. A simple parallel plate capacitor that can store a charge of 10^{-4} C at 3 kV is required for a particular application. The thickness of the dielectric is 0.02 cm. Calculate the area of the plate if the dielectric is PE.

VALUES OF SELECTED PHYSICAL CONSTANTS

Constant	Symbol	Value
Absolute zero of temperature		-273.2°C
Avogadro's number	N_A	6.023×10^{23} /mol
Boltzmann's constant	k	1.381×10^{-23} J/K
		8.63×10^{-5} eV/K
Bohr magneton	μ_B	9.274×10^{-24} A/m ²
Electronic charge	q	1.602×10^{-19} C
Electron mass	m_e	9.110×10^{-31} kg
Faraday's constant	F	9.649×10^4 C/mol
Gas constant	R	1.987 cal/mol-K
		8.314 J/mol-K
Gravitational acceleration	g	9.806 m/s ²
Permeability of vacuum	μ_0	$4\pi \times 10^{-7}$ Wb/A-m
Permittivity of vacuum	ϵ_0	8.854×10^{-12} F/m
Planck's constant	h	6.626×10^{-34} J-s
Velocity of light in vacuum	c	2.998×10^8 m/s

It can be solved using

$$\kappa = 1 + (P/\epsilon_0 E)$$

$$C = Q/V$$

$$A = Cd/\epsilon = Cd/\kappa\epsilon_0$$



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6. For intrinsic gallium arsenide, the room-temperature electrical conductivity is $10^{-6} (\Omega\text{-m})^{-1}$; the electron and hole mobilities are respectively, 0.85 and $0.04 \text{ m}^2/\text{V}\cdot\text{s}$. Compute the intrinsic carrier concentration n_i at room temperature. (10%)
7. For a plastic material, the stress at which plastic deformation begins is 345 MPa (50,000 psi), and the modulus of elasticity is 103 GPa ($15.0 \times 10^6 \text{ psi}$)
 - (a) What is the maximum load that may be applied to a specimen with a cross-sectional area of 130 mm^2 (0.2 in^2) without plastic deformation? (5%)
 - (b) If original specimen length is 76 mm (3.0 in), what is the maximum length to which it may be stretched without causing plastic deformation? (5%)
8. Briefly explain what determines the characteristic color of a metal and a transparent nonmetal? (10%)
9. There are two pieces of transparent polyethylene (PE) with densities of 0.92 g/cm^3 and 0.96 g/cm^3 , respectively. Which one would become translucent earlier, after being baked at 60°C for few days? Why? (10%)
10. How do the relative dielectric constants for polytetrafluoroethylene (PTFE) and polyvinyl chloride (PVC) change with frequency from 10^2 Hz to 10^{10} Hz ? Why? (10%)
11. How does the refractive index of polymethyl methacrylate (PMMA) change with temperature from 20°C to 140°C ? Why? (The glass transition temperature of PMMA equals to 105°C .) (10%)
12. Why can liquid crystal be used to produce colors under white light? (10%)

