

國立聯合大學 112 學年度碩士班考試招生

材料科學工程學系 入學考試試題

科目： 材料科學導論 第 1 頁共 4 頁

A. Crystal structure: (26%)

Properties of materials are closely related to their structure. In a face-centered-cubic lattice, the eight atoms are located on the corners of the cube and one at the center of each cube face. As a result, a face-centered-cubic unit cell contains (1) atoms. The coordination number is (2). The packing efficiency of the face centered cubic cell is (3) %. The most closed-packed plane is (4). The most closed-packed direction is (5). The Burgers vector is usually the distance between atoms in a close-packed direction. Therefore, the Burgers vector of an FCC crystal is (6). There are (7) slip systems in FCC crystals. When the tensile stress is applied along the [111] direction of an FCC sample, (8) slip systems will be activated first. The crystal structure can be determined by (9).

1. (2%) (a) 1 (b) 2 (c) 4 (d) 6 (e) 8
2. (2%) (a) 3 (b) 4 (c) 6 (d) 8 (e) 12
3. (2%) (a) 38 (b) 52 (c) 68 (d) 74 (e) 78
4. (2%) (a) {100} (b) {110} (c) {111} (d) {0001} (e) {321}
5. (2%) (a) $\langle 100 \rangle$ (b) $\langle 110 \rangle$ (c) $\langle 111 \rangle$ (d) $\langle \bar{1}\bar{1}20 \rangle$ (e) $\langle 321 \rangle$
6. (4%) (a) $\langle 100 \rangle$ (b) $1/2 \langle 101 \rangle$ (c) $1/2 \langle 111 \rangle$ (d) $1/6 \langle 1\bar{2}1 \rangle$ (e) $\langle 111 \rangle$
7. (4%) (a) 3 (b) 6 (c) 12 (d) 24 (e) 48
8. (4%) (a) 1 (b) 2 (c) 4 (d) 6 (e) 8
9. (4%) (a) optical microscopy (b) X-ray diffraction (c) X-ray photoelectron spectroscopy (d) X-ray fluorescence (e) energy dispersive spectroscopy

B. Mechanical properties: (34%)

When a sufficient load is applied to a metal or other structural material, it will cause the material to change shape. This change in shape is called deformation. Elastic deformation is the deformation that disappears upon removal of the external forces. Plastic deformation is a permanent deformation or change in shape of a solid body. "(10)" is not the characteristics of the elastic deformation. During elastic deformation, the strain of the material is proportional to the applied stress, known as (11). In the stress-strain curve, the point that separate the elastic and plastic deformation is the (12). Assume that σ is stress and ϵ is strain. When the stress field is elastic, the total strain energy is equal to (13). The (14) crystal structure usually exhibits lowest critical resolved shear stress. The tensile stress required to cause yielding the single-crystalline aluminum is 2.4 MPa if the tensile axis is [100]. Consequently, the critical resolved shear stress for yielding in aluminum is (15). The polycrystalline HCP metals are found to be more brittle than FCC and BCC metals, because (16). The two primary methods of deformation in metals are slip and twinning. Slip occurs first on that slip system having the highest (17) along its slip direction. In twinning, only a small movement of atoms occurs and it is a co-operative process it can occur much more (18) than slip, making it much more common in (19) stress rate situations. Annealing twins are typically found in metals with the (20).

10. (2%) (a) Elastic deformation is reversible (b) Elastic deformation causes the chemical bonds to undergo stretching and bonding (d) Elastic deformation causes a limited number of chemical bonds to undergo breakage (e) Atoms do not slip pass on each other
11. (2%) (a) Hooke's Law (b) Beer's Law (c) Kirchhoff's Laws (d) Snell's Law (e) First law of thermodynamics
12. (2%) (a) proportional limit (b) elastic limit (c) yield point (d) ultimate tensile strength (e) fracture point
13. (4%) (a) σ/ϵ (b) $\frac{1}{2}\sigma/\epsilon$ (c) $\sigma\epsilon$ (d) $\frac{1}{2}\sigma\epsilon$ (e) $2\sigma\epsilon$
14. (4%) (a) FCC (b) HCP (c/a < 1.632) (c) BCC (d) zinc blend (e) diamond

15. (4%) (a) 5.9 MPa (b) 3.4 MPa (c) 2.4 MPa (d) 1.0 MPa (e) 0.6 MPa
 16. (4%) (a) it has closed packing (b) it has large critical resolved shear stress (c) it has few slip systems (d) it has directional bonding (e) it has strong bonding.
 17. (4%) (a) tensile stress (b) compressive stress (c) shear stress (d) normal stress (e) torsional stress
 18. (2%) (a) slowly (b) quickly
 19. (2%) (a) high (b) low
 20. (4%) (a) FCC (b) BCC (c) HCP (d) diamond (e) SC structure

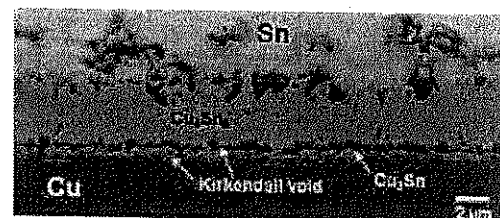
C. Solid solution (20%)

(21) defines the structure of the phase diagram. Materials that have incompatible crystal structures cannot form homogeneous solid solutions. This criterion is based on (22). They are forced to phase separate into an A-rich solid phase and a B-rich phase, to preserve their stable crystalline forms. The chemical bond energy of this type suggests (23). The activities show (24) deviations. The absolute value of the mixing entropy (i.e., $|\Delta S_M|$) is (25) that of an ideal solution. (26) is representative of this kind of solution.

21. (4%) (a) Internal energy (b) Defect energy (c) Vacancy concentration (d) Lattice energy (e) Gibbs free energy
 22. (4%) (a) level rule (b) Fick's first law (c) First law of thermodynamics (d) Hume-Rothery rule (e) Hall-Petch equation
 23. (4%) (a) $\epsilon_{AB} < \frac{1}{2}(\epsilon_{AA} + \epsilon_{BB})$ (b) $\epsilon_{AB} = \frac{1}{2}(\epsilon_{AA} + \epsilon_{BB})$ (c) $\epsilon_{AB} > \frac{1}{2}(\epsilon_{AA} + \epsilon_{BB})$ (d) $\epsilon_{AB} < (\epsilon_{AA} + \epsilon_{BB})$ (e) $\epsilon_{AB} > (\epsilon_{AA} + \epsilon_{BB})$
 24. (2%) (a) positive (b) negative
 25. (2%) (a) lower than (b) equal to (c) higher than
 26. (4%) (a) isomorphous system (b) superlattice (c) miscibility system (d) eutectic system (e) congruent system

D. Diffusion (18%)

Soldering to Cu interconnect pads with Sn-containing alloys usually leads to the formation of a layered $\text{Cu}_6\text{Sn}_5/\text{Cu}_3\text{Sn}$ structure on the pad/solder interface, as shown in the right figure. Frequently, microscopic voids within Cu_6Sn_5 have been observed to develop during extended thermal aging. The Kirkendall voiding is caused by different (27) of Sn and Cu. Kirkendall effect proves that substitutional diffusion is dominated

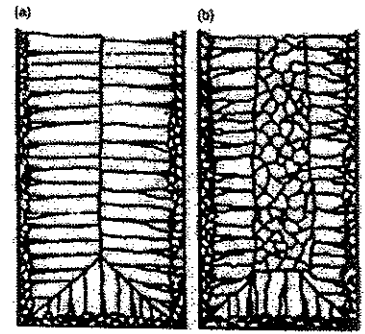


by the (28). Sn has (29) melting point than Cu. Therefore, Sn in Cu_6Sn_5 phase diffuses (30) Cu in Cu_3Sn phase. Compressive stress is developed just (31) the $\text{Cu}_6\text{Sn}_5/\text{Cu}_3\text{Sn}$ interface. In the figure, single-phase regions appear with finite thickness. The two-phase region appears with zero thickness. This is because the (32) remains constant in between the two-phase region.

27. (4%) (a) atomic sizes (b) diffusion rates (c) bonding types (d) electronegativities (e) densities
 28. (4%) (a) direct exchange mechanism (b) ring mechanism (c) vacancy mechanism (d) kick out mechanism (e) Frank-Turnbull mechanism
 29. (2%) (a) lower (b) higher (c) equal
 30. (2%) (a) slower than (b) equal to (c) faster than
 31. (2%) (a) below (b) at (c) above
 32. (4%) (a) diffusion coefficient (b) strain energy (c) concentration gradient (d) free energy (e) partial-molar free energy

E. Solidification (26%)

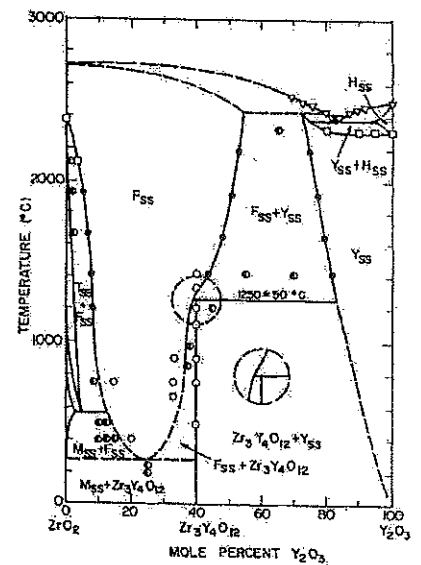
On solidification, there can be up to three distinct zones in the microstructure. In contact with the mold wall, the (33) is formed, in which the grains are fine, equiaxed and have a largely random crystallographic orientation. As solidification continues towards the center of the casting, the grains become elongated, giving the (34). The dendritic growth will occur in the freezing, when the temperature gradient in front of the advancing interface is (35). For (36), the columnar zone continues to the center of the casting without formation of the equiaxed zone (Figure (a)). Growth tends to occur along fast growth directions which are generally (37) for cubic metals. Generally, the ingot structure appears rarely (38). Gravitational effects are often a factor in producing (39). Slow growing bubbles are trapped by the solid and form (40).



33. (2%) (a) equiaxed zone (b) chill zone (c) columnar zone (d) GP zone (e) fusion zone
 34. (2%) (a) equiaxed zone (b) chill zone (c) columnar zone (d) GP zone (e) fusion zone
 35. (2%) (a) positive (b) zero (c) negative
 36. (4%) (a) pure metals (b) impure metals (c) alloys (d) nucleant particles in the melt (e) stirring in the melt
 37. (4%) (a) <100> (b) <110> (c) <111> (d) <211> (e) <321>
 38. (4%) (a) cellular (b) dendritic (c) equiaxed (d) columnar (e) peritectic
 39. (4%) (a) micro segregation (b) macro segregation (c) inverse segregation (d) coring (e) dendrite
 40. (4%) (a) vacancy (b) dendritic porosity (c) large cavity form at the top (d) blowholes (e) wormholes.

F. Ceramics: (28%)

Yttria-stabilized zirconia (YSZ) is a ceramic in which the cubic crystal structure of zirconium dioxide is made stable at room temperature by an addition of yttrium oxide. Stabilization of the cubic polymorph of zirconia over wider range of temperatures is accomplished by substitution of some of the Zr^{4+} ions. Y^{3+} ions replace Zr^{4+} on the cationic sublattice. It can be expressed as (41). A vacancy on the O site is expressed as (42). The total equation is (43). From the phase diagram shown in the right figure, there is a (44) point at 83 ± 1 mol% Y_2O_3 and a (45) point at 76 ± 1 mol% Y_2O_3 . F_{ss} is a fluorite-type solid solution. Fluorite structure in general terms is a common motif for compounds with the formula (46) wherein the X ions tend to occupy the (47) tetrahedral interstitial sites. On the other hand, the M ions occupy the regular sites of a (48) structure. It crystallizes in the (49) space group.



41. (4%) (a) Zr_Y' (b) Zr_Y'' (c) Y_{Zr}' (d) Y_{Zr}'' (e) Y_{Zr}^{\times}
 42. (4%) (a) V_O'' (b) $V_O^{\cdot\cdot}$ (c) V_O^{\times} (d) O_V'' (e) $O_V^{\cdot\cdot}$
 43. (4%) (a) $Y_2O_3 \rightarrow 2Y_{Zr}' + 3O_O^{\times} + V_O''$ (b) $Y_2O_3 \rightarrow 2Zr_Y' + 3O_O^{\times} + O_V^{\cdot\cdot}$ (c) $Y_2O_3 \rightarrow 2Y_{Zr}'' + 3O_O^{\times} + V_O''$ (d) $Y_2O_3 \rightarrow 2Y_{Zr}' + 3O_O^{\times} + O_V^{\cdot\cdot}$ (e) $Y_2O_3 \rightarrow 2Zr_Y'' + 3O_O^{\times} + V_O''$
 44. (4%) (a) eutectic (b) eutectoid (c) peritectic (d) peritectoid (e) monotectic
 45. (4%) (a) eutectic (b) eutectoid (c) peritectic (d) peritectoid (e) monotectic
 46. (2%) (a) MX (b) MX_2 (c) M_2X (d) MX_3 (e) M_3X
 47. (2%) (a) 2 (b) 4 (c) 6 (d) 8 (e) 12
 48. (2%) (a) BCC (b) FCC (c) simple cubic (d) hexagonal (e) monoclinic
 49. (2%) (a) $P6mm$ (b) $Pnma$ (c) $P42/mmm$ (d) $F\bar{4}3m$ (e) $Fm\bar{3}m$

G. Semiconductors: (24%)

Wide band gap semiconductors enable a higher power density which is required for high power devices such as electric/hybrid vehicles and renewable energy sources devices. Band gap means the difference in energy between (50). The wider bandgap materials have higher (51) than Si. GaN and SiC are wide-band-gap semiconductors. GaN is a (52) band gap semiconductor. It means that the top of the valence band and the bottom of the conduction band occur at the same value of (53). SiC can be classified as a thermally conductive material. The high thermal conductivity stems from high (54) group velocity and (55) mean free paths. The p-type silicon carbide substrate generally refers to an (56)-doped silicon carbide substrate. The Fermi level is (57) the valence band in a p-type semiconductor.

50. (4%) (a) the core level and the valence band (b) the valence band and the Fermi level (c) the conduction band and the Fermi level (d) the valence band and the conduction band (e) the conduction band and the vacuum
51. (4%) (a) intrinsic carrier concentrations (b) extrinsic carrier concentrations (c) resistivity (d) conductivity (e) Fermi level
52. (2%) (a) direct (b) indirect
53. (4%) (a) energy (b) momentum (c) position (d) direction (e) wave function
54. (4%) (a) electron (b) photon (c) phonon (d) ion (e) neutron
55. (2%) (a) long (b) short
56. (2%) (a) Ge (b) P (c) As (d) Al (e) Sb
57. (2%) (a) close to (b) far from

H. Polymers: (24%)

Ethyl cellulose (EC) is thermoplastic and soluble in most hot polymers, solvents, and oil & wax mixtures used in heat seal formulations. Thermoplastic polymer means that (58). The hydroxyl groups, denoted as (59), of cellulose can be partially or fully reacted with various reagents to afford derivatives with useful properties like mainly cellulose esters and cellulose ethers, denoted as (60). Regarding the properties of polymers, (61) molecular weight polymers increase the viscosity of liquids in which they are dissolved. The increase in viscosity is caused by strong internal (62) between the randomly coiled and swollen macromolecules and the surrounding solvent molecules. The glass transition temperature (T_g) also (63) with molecular weight. The T_g represents a point at which dramatic changes take place in polymer properties. T_g is the temperature at which amorphous polymers undergo a transition from a (64) to a (65) state when the temperature is rising.

58. (4%) (a) it has long chains of molecules strongly cross-linked to form a 3-D network structure (b) it is stronger, but more brittle than thermosetting (c) it decomposes on heating instead of melting (d) upon heating, it softens and melts (e) it is not easily recyclable due to cross-linking
59. (4%) (a) $-\text{COOH}$ (b) $-\text{SH}$ (c) $-\text{NH}_2$ (d) $-\text{OH}$ (e) $-\text{OR}$
60. (4%) (a) $-\text{COOH}$ (b) $-\text{SH}$ (c) $-\text{NH}_2$ (d) $-\text{OH}$ (e) $-\text{OR}$
61. (2%) (a) High (b) Low
62. (4%) (a) electric force (b) gravitational force (c) friction force (d) dispersion force (e) coercive force
63. (2%) (a) increases (b) decreases
64. (2%) (a) fluid (b) viscous (c) rubbery (d) leathery (e) glassy
65. (2%) (a) fluid (b) viscous (c) rubbery (d) leathery (e) glassy