Material Science
EXAM I

Nov. 14, 2013

I. Explain the following terms: (20%)

1. hydrogen bond
2. a-Si
3. undercooling
4. primary bonds
5. close-packed plane
6. dopants
7. HCP
8. single crystal
9. substitution solid solution
10. vacancy

II. Short answer: (48%)

1. Pure aluminum is a ductile metal with low tensile strength and hardness. Its oxide Al_2O_3 (alumina) is extremely strong, hard, and brittle. Can you explain this difference from the viewpoint of atomic bonding?
2. What is a transmission electron microscope (TEM)?
3. After ionization, why is the sodium ion smaller than the sodium atom? After ionization, why is the chloride ion larger than the chlorine atom?
4. Who is John Bardeen ?

5. What are the three most common metal crystal structures?
6. Methanol, CH_3OH, has a much higher boiling point than methyl mercaptan, CH_3SH. Why?
7. Name as many carbon allotropes as you can, and discuss their crystal structure (at least two allotropes).
8. What are the four primary traditional experimental equipments used in the study of material science?
9. Why is it that ceramic materials are brittle ?
10. List the number of atoms bonded to a C atom that exhibits sp^3, sp^2, and sp hybridization. For each, give the geometrical arrangement of the atoms in the molecule.
11. In HCP unit cells, why is the four-index system (Miller-Bravais coordinate system) used instead of the three-index one to describe a direction or plane ?
12. Explain how ultra-rapid（超快速）cooling of some metal alloys produces metallic glass.
13. What are the coordination numbers for simple cubic structure, body-centered cubic structure, and face-centered cubic structure?
14. Is the relative degree of atomic solid solubility of chromium in iron high or low? Why is that?

Element	Atom radius (nm)	Crystal structure	Electro-negativity	Valence
Iron	0.124	BCC	1.7	+2, +3
Chromium	0.125	BCC	1.6	+2,+3,+6

15. In HCP, the three-index expression for a direction is [100], what is its four-index expression?
16. Why is X-ray used to study crystal structure?

III. Draw the following crystallographic planes in a cubic unit cell: (111), (b) (200). (4%)

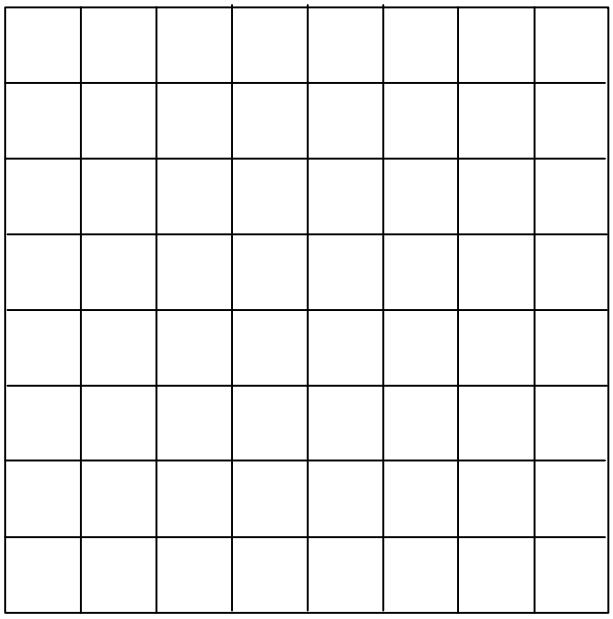
IV. 複選題: (6%)

1. Which of the following types of bonding is (are) directional? (A) metallic bonding (B) ionic bonding (C) covalent bonding (D) hydrogen bonding (E) van der Waals.
2. Which one of the following defects is NOT a point defect? (A) Vacancy (B) Frenkel defect (C) Schottky defect (D) Grain boundary (E) dislocation (F) surfaces (G) interstitial atom.

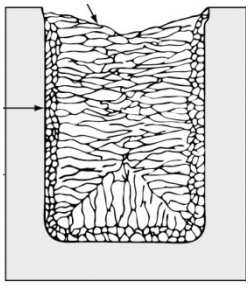
V. For an FCC unit cell, (*a*) how many atoms

are there inside the unit cell, (*b*) what is the coordination number for the atoms, (*c*) what is the relationship between the length of the side *a* of the FCC unit cell and the radius of its atoms, and (*d*) what is the atomic packing factor? (8%)

VI. Determine, by counting, the ASTM grain-size number of the virtual microstructure shown in the following figure. This micrograph is at 100x with the area of one square inch. Assume that each small square is a grain. (5%)



VII. Write down what you can read from the following schematic drawing of microstructure. (6%)



VIII. A certain application requires a material that is lightweight, an electrical insulator, and has some flexibility. (*a*) Which class of materials would you search for this selection? (*b*) Explain your answer from a bonding point of view. (6%)

IX. Calculate the linear atomic density in atoms per millimeter for the following directions in FCC iridium, which has a lattice constant of 0.38389 nm: (*a*) [100], (*b*) [110], (*c*) [111]. (6%)

X. Determine the Miller-Bravais direction indices of the directions indicated in Fig. P3.62. (8%)

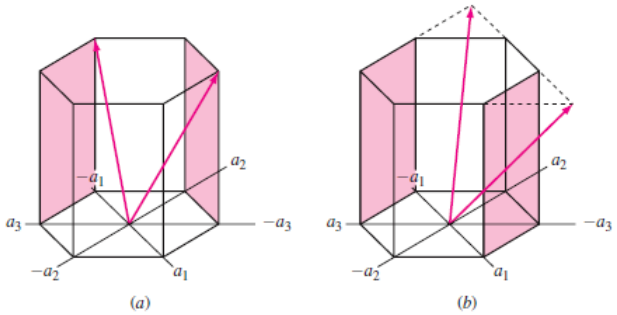


Figure P3.62

XI. An x-ray diffractometer recorder chart for an element that has either the BCC or the FCC crystal structure showed diffraction peaks at the following 2θangles: 40.663°, 47.314°, 69.144°, and 83.448 . (Wavelength λof the incoming radiation was 0.15405 nm.)

(a) Determine the crystal structure of the element. (3%)

(b) Determine the lattice constant of the element. (3%)

(c) Identify the element. (2%)

$$\sin^2\theta = \lambda^2\left(h^2+k^2+\ell^2\right)/(4a^2)$$

FCC: (111), (200), ...;
BCC: (110), (200), ...

	element	a (nm)
1	copper	0.36147
2	gold	0.40788
3	nikel	0.35263
4	iridium	0.38389
5	lead	0.49502
6	tungsten	0.31648