國立聯合大學 113 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

A. Atomic structure: (10%)

An atom consists of a nucleus (protons and neutrons) orbited by electrons. The atomic number is the number of _(1)_ in the nucleus, and the atomic mass presents the mass of _(2)_ in an atom. Electrons occupy discrete energy levels within the atom. Only _(3)_ electrons may occupy the same energy level.

Carbon is an abundant element on Earth and is crucial for life and many technological applications. Pure carbon exists in several types with the same composition and different arrangements of its atoms, which are known as _(4)_. Herein, Diamond is one of the highest melting-point materials known with a melting temperature of 3550°C. This is due to the strong _(5)_ bonding between atoms.

1.(2%) (a) protons (b) neutrons (c) electrons (d) nucleus
2.(2%) (a) protons (b) neutrons (c) electrons (d) nucleus
3.(2%) (a) 1 (b) 2 (c) 3 (d) 4
4.(2%) (a) isotopes (b) ionic (c) amorphous (d) allotropes
5.(2%) (a) metallic (b) ionic (c) covalent (d) van der Waals

B. Crystal structure: (32%)

Scientists have developed a set of instruments in order to characterize the structure of materials at various length scales. The length scales for materials include atomic structure, short- and long-range atomic arrangements, nanostructure, microstructure, and macrostructure. Herein, the nanostructure is the structure of a material at a length scale of _(6)_.

The properties of materials are closely related to their structure. The crystal structure can be determined by _(7)_. In a body-centered-cubic lattice, the unit cell contains _(8)_ lattice points with the coordinates : (0, 0, 0) and _(9)_. In contrast, in a face-centered-cubic lattice, the unit cell contains _(10)_ lattice points. The packing efficiency of the face-centered cubic cell is _(11)_ %. The most closed-packed plane is _(12)_. The most closed-packed direction is _(13)_.

6.(4%) (a) 1 to 10 nm (b) 1 to 100 nm (c) 1 to 10 μm (d) 1 to 100 μm
7.(4%) (a) optical microscopy (b) X-ray diffraction (c) X-ray photoelectron spectroscopy (d) X-ray fluorescence
8.(4%) (a) 1 (b) 2 (c) 3 (d) 4
9.(4%) (a) (1, 1, 0) (b) (1, 0, 0) (c) (1/2, 1/2, 1/2) (d) (1, 1, 1)
10.(4%) (a) 1 (b) 2 (c) 3 (d) 4
11.(4%) (a) 38 (b) 52 (c) 68 (d) 74
12.(4%) (a) {100} (b) {110} (c) {111} (d) {0001}
13.(4%)(a) <100> (b) <110> (c) <111> (d) <321>

C. Imperfections & Defects: (44%)

The arrangement of the atoms or ions in materials contains imperfections or defects. These defects often have a profound effect on the properties of materials. For example, in semiconductor materials, phosphorus and boron are added to silicon crystals to improve the _(14)_ properties of pure silicon. By intentionally introducing substitutional atoms, we cause _(15)_ strengthening. According to the Hume-Rothery rules, a _(16)_% similarity in size is required for elements to form a solid solution.

In addition, _(17)_ are line imperfections in an otherwise perfect crystal. The Burgers vector is _(18)_ to the screw dislocation, and _(19)_ to the edge dislocation. We can control the dislocation densities by heating a metallic material to a relatively high temperature (below the melting temperature) and holding it there for a long period of time. This heat treatment is known as _(20)_.

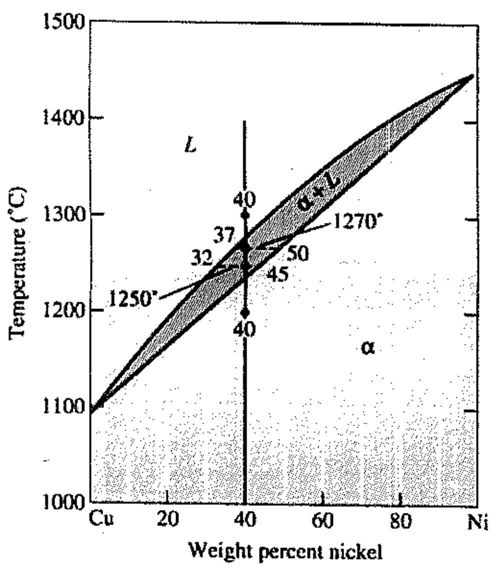
Surface defects are the boundaries, or planes, that separate a material into regions. For example, a _(21)_, the surface that separates the individual grains, is a narrow zone in which the atoms are not properly spaced. The Hall-Petch equation represents the grain size to the yield strength. By _(22)_ the grain size, the yield stress of steel at room temperature would increase.

Stacking faults, which occur in FCC metals, represent the _(23)_ stacking sequence instead of the FCC stacking sequence. A _(24)_ is a plane across which there is a special mirror image misorientation of the crystal structure The stacking faults and twin boundaries may interfere with the slip process of metals and increase their strength.

14.(4%)(a) thermal (b) electrical (c) mechanical (d) structural
15.(4%)(a) solid-solution (b) dislocation (c) working (d) cold-working
16.(4%)(a) 10 (b) 15 (c) 20 (d) 50
17.(4%)(a) pores (b) impurities (c) dislocations (d) grain boundaries
18.(4%)(a) parallel (b) perpendicular
19.(4%)(a) parallel (b) perpendicular
20.(4%)(a) casting (b) forging (c) quenching (d) annealing
21.(4%)(a) interface (b) stacking fault (c) twin boundary (d) grain boundary
22.(4%)(a) increasing (b) reducing
23.(4%)(a) SC (b) BCC (c) HCP (d) BCT
24.(4%)(a) interface (b) stacking fault (c) twin boundary (d) grain boundary

D. Phase & Phase Diagram: (24%)

A copper-nickel system is called _(25)_ because the two components are completely miscible in both liquid and solid phases. Thus, its phase diagram shows _(26)_ solid phase. According to the Cu-Ni phase diagram shown below, determine the composition of the liquid phase in a Cu-40% Ni alloy at (27)1300 °C, (28) 1270 °C, (29)1250 °C, and (30)1200 °C.



25.(4%)(a) amorphous (b) eutectic (c) eutectoid (d) isomorphous
26.(4%)(a) 0 (b) 1 (c) 2 (d) 3
27.(4%) (a) No liquid phase (b) 20% Ni (c) 40% Ni (d) 60% Ni
28.(4%) (a) 20% Ni (b) 37% Ni (c) 47% Ni (d)50% Ni
29.(4%) (a) 32% Ni (b) 37% Ni (c) 45% Ni (d)50% Ni
30.(4%) (a) No liquid phase (b) 20% Ni (c) 40% Ni (d) 60% Ni

E. Metals: (20%)

Solidification is one of the most important manufacturing processes of metals. Millions of kilograms of steel, aluminum alloys, etc. are produced via casting each month. In solidification, _(31)_ is the formation of the first nanocrystallites from molten material. _(32)_ nucleation occurs when undercooling (cooling below melting temp.) of the pure metal is large enough to allow the formation of stable nuclei.

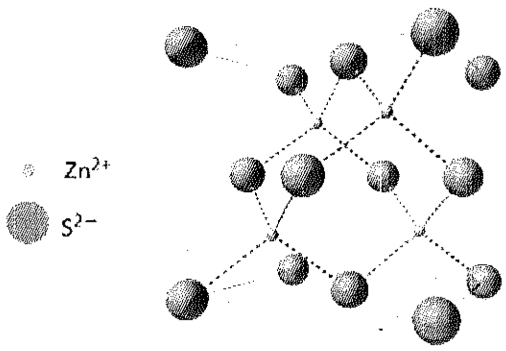
On solidification, there can be up to three distinct zones in the microstructure. In contact with the mold wall, the _(33)_ is formed, in which the grains are fine, equiaxed and have a largely random crystallographic orientation. As solidification continues towards the center of the casting, the grains 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)_.

31.(4%)(a) nucleation (b) grain growth (c) primary processing (d) secondary processing
32.(4%)(a) Homogenous (b) Heterogeneous
33.(4%)(a)columnar zone (b) chill zone (c) equiaxed zone (d) fusion zone
34.(4%)(a) columnar zone (b) chill zone (c) equiaxed zone (d) fusion zone
35.(4%)(a) positive (b) negative (c) zero

F. Ceramics: (36%)

There are cations and anions in the ceramic structure. Thus, the ceramic structure must consider the charge balance and radius of the ions. The ceramic structure is a mixture of ionic bonds and covalent bonds. When the electronegativity difference between anions and cations is larger, the ceramic formed more __(36)__ bonds.

Zincblende is the name of the crystal structure adopted by ZnS, as the figure shown below. The FCC structure, with S anions at the normal lattice points and Zn cations at __(37)__ of the __(38)__ sites. The coordination number of cations is __(39)__.



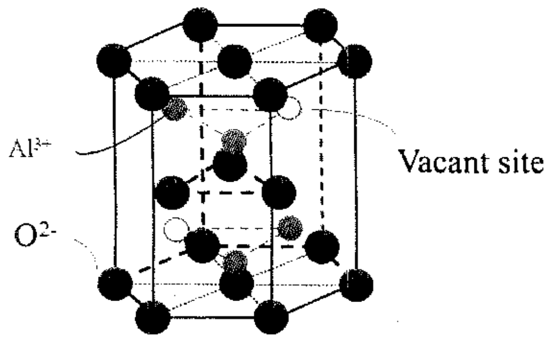
36.(4%)(a) ionic (b) covalent (c) metallic (d) ceramic

37.(4%)(a) 1 (b) 1/2 (c) 1/4 (d) 1/8

38.(4%)(a) tetrahedral (b) octahedral (c) cubic (d) triangular

39.(4%)(a) 2 (b) 4 (c) 6 (d) 8

One of the important structural ceramics is alumina. The structure of α-Al_2O_3 is corundum, as shown in the figure below. Here the oxygen anions are in an __(40)__ arrangement and __(41)__ of the Al sites are occupied by Al. Many researches have shown that a small amount of additive was doped into Al_2O_3 compacted pellets as a sintering aid to get the desired effect. When doping Al_2O_3 with MgO, if it is substitutional, the possible defects in reaction could be __(42)__ ; if it is interstitial, the possible defects in reaction could be __(43)__; if Mg is self-compensating and forms both the interstitial and substitutional defect, the possible defects in reaction could be __(44)__.



40.(4%) (a) FCC (b) SC (c) BCC (d) HCP

41.(4%) (a) 1 (b) 1/2 (c) 2/3 (d) 1/4

42.(4%) (a) Mg'_{Al} (b) $Mg_i^{\cdot\cdot}$ (c) Al'_{Mg} (d) Mg_{Mg}^{x}

43.(4%) (a) Al'_{Mg} (b) Mg'_{Al} (c) $Mg_i^{\cdot\cdot}$ (d) Al_{Al}^{x}

44.(4%) (a) Mg''_{Al} (b) $Mg_i^{\cdot\cdot\cdot\cdot}$ (c) Mg_{Mg}^{x} (d) Mg'_{Al}

G. Polymers: (18%)

45. Polymer and polymeric materials comprise very broad groups of natural and synthetic organic with an exceptional variety of properties. Briefly explain the differences between thermoplastic and thermosetting polymers (a) on the basis of mechanical characteristics upon heating and (b) according to possible molecular structures.

H. Miller indices: (16%)

Determine the indices for the directions (46) **A**, (47) **B**, (48) **C**, and (49) **D** in the cubic unit cell shown below: