國立臺灣海洋大學一００學年度研究所碩士班暨碩士在職專班入學考試試題

考試科目： 材料科學導論(含英文科學論文閱讀)

系所名稱： 材料工程研究所碩士班甲組

※可使用計算器

1.答案以橫式由左至右書寫。2.請依題號順序作答。

1. A solid solution forms when, as the solute atoms are added to the host material, the crystal structure is maintained, and no new structures are formed. It is also compositionally homogeneous; the impurity atoms are randomly and uniformly dispersed within the solid. Impurity point defects are found in solid solutions, of which there are two types: substitutional and interstitial. For the substitutional type, solute or impurity atoms replace or substitute for the host atoms. Please answer the following questions.

   (a) Below, atomic radius, crystal structure, electronegativity, and the most common valence are tabulated in Table 1 for nickel and copper. What kind of a substitutional solid solution would they form? Complete dissolution, partial dissolution or non-dissolution? Why? Please state the reasons for your choice. (9 pts)

   (b) For the crystal structure of nickel, there are two different types of interstitial sites. In each case, one site is larger than the other, and is normally occupied by impurity atoms. The larger one is located at the center of each edge of the unit cell; it is termed an octahedral interstitial site. Besides, the smaller one is found at ¼ ¼ ¼ positions; it is termed a tetrahedral interstitial site. Please compute the radius r of an impurity atom that will just fit into one of these sites.(6 pts)

2. (a) Figure 1 is shown a plot of the logarithm (to the base 10) of the diffusion coefficient versus reciprocal of absolute temperature, for the diffusion of copper in gold. Please determine values for the activation energy and the preexponential. (6 pts)
   [Hint: $\ln X = 2.3 \log X$; $R = 8.31$ **J/mol-K**]

   (b) Think about the values of diffusion coefficients for the interdiffusion of carbon in both α-iron (BCC) and γ-iron (FCC) at 900°C. Which will be larger ? Explain why this is the case. (4 pts)

3. A cylindrical metal specimen 12.9 mm in diameter and 260 mm long is to be subjected to a tensile stress of 28 MPa; at this stress level the resulting deformation will be totally elastic.

   (a) If the elongation must be less than 0.080 mm, which of the metals in Table 2 are suitable candidates? Why? (5 pts)

   (b) If, in addition, the maximum permissible diameter decrease is 1.2×10^{-3} mm, when the tensile stress of 28 MPa is applied, which of the metals that satisfy the criterion in part (a) are suitable candidates? Why? (5 pts)

4. For a 40 wt% Sn-60 wt% Pb alloy at 150 °C, determine the following:

(a) Please write out the Eutectic transition in the Pb-Sn system. (2 pts)

(b) Draw the Eutectic microstructure and describe why it shows this kind of microstructure? (5 pts)

Furthermore, calculate the relative amount of each phase present in terms of (c) mass fraction and (d) volume fraction. At 150 °C take the densities of Pb and Sn to be 11.23 and 7.24 g/cm3, respectively. [Hint: The Pb-Sn binary phase showed in Fig. 2.] (8 pts)

5. (a) Schematic description of electron occupation of the bands in a metal, semiconductor, and insulator. (9 pts)

(b) Please describe the definitions of the intrinsic semiconductor and extrinsic semiconductor. (4 pts)

6. Please draw the **microstructure** to show the effect of annealing temperature on the microstructure of cold-worked metals: (12 pts)

(a) cold-worked

(b) after recovery

(c) after recrystallization

(d) after grain growth.

7. Please explain following terms in detail (**Please note that your answers to this question must be in English-中文作答者不予計分**): (16 pts)

(a) Precipitation hardening

(b) Slip system

(c) Solid-solution strengthening

(d) Stress corrosion

8. English essay reading—Transparent conducting oxide

Transparent conducting oxide (TCO) layers are characteristically described as thin films that exhibit simultaneously high visible wavelength transparency and electrical conductivity. The majority of known TCO materials are n-type semiconductors where defects such as oxygen vacancies, impurity substitutions and interstitials donate electrons to the conduction band providing charge carriers for the flow of electric current. These films are used in low emissivity windows, gas sensors, flat panel displays, thin film transistors, light emitting diodes and solar cells. The resistivity ρ, of a semiconductor is related to the charge carrier density N and the carrier mobility μ by the relation: $(1/\rho) = N\mu e$, where e is the electronic charge. Various strategies have been employed to increase the mobility of TCO thin films while maintaining high transparency and conductivity. Traditionally, the mobility of TCO thin films has been enhanced by improving the crystalline structure by means such as heat treatment, choice of deposition technique as well as choice of substrate. The mobility μ of an electron in semiconductors depends on the relaxation time τ, the electronic charge e and the effective carrier mass m* in the conduction band. The mobility can be increased by increasing τ or by decreasing m*. Increasing τ requires films with fewer defects which may be achieved by lower carrier density, less grain boundaries and less neutral impurities. Decreasing m*, requires semiconductors with a widely dispersed conduction band.

The scattering mechanisms that govern the electron transport in oxide semiconductors are:

(i) Grain boundary scattering caused by the discontinuity presented by grain boundaries especially in polycrystalline thin film materials. A space charge region formed around the grain boundaries and the resulting potential barrier scatters the electrons crossing this region reducing the mobility.

(ii) Ionized impurity scattering caused by deflection of free carriers by the long-range electrostatic fields associated with intentional dopants and defects such as interstitials and vacancies.

(iii) Optical phonon scattering caused by lattice vibrations of bonds in a polar semiconductor which induce an electric field that interacts with a charge moving through the lattice.

(iv) Acoustic-phonon scattering caused by an acoustic wave propagation through a crystal lattice which causes the atoms to oscillate about their equilibrium positions and interfere with the electron motion.

(v) Neutral impurity scattering caused by non-ionized impurities.

(vi) Piezoelectric scattering which arises from electric fields caused by the strain associated with lattice vibrations in crystals where partially ionic bonds occur such that the unit cell does not contain a centre of symmetry.

Please answer the following questions in Chinese (英文作答者不予計分).

(a) Please describe the correlation between the grain size and electrical resistivity of the TCO thin films. (3 pts)

(b) Impurity dopants will cause local stress fields in the TCO lattice. Please describe the effect of these stress fields on the electrical resistivity of the TCO thin films. (3 pts)

(c) Please briefly explain the effects of substrate and heat treatment on the electrical resistivity of the TCO thin films. (3 pts)

Table 1. The atomic radius, crystal structure, electronegativity, and the most common valence for nickel and copper.

Element	*Atomic Radius (nm)*	*Crystal Structure*	*Electro-negativity*	*Valence*
Ni	0.1246	FCC	1.9	+2
Cu	0.1278	FCC	1.8	+2

Table 2. Room-Temperature Elastic and Shear Moduli, and Poisson's Ratio for Various Metal Alloys

Metal Alloy	*Modulus of Elasticity* GPa	*Modulus of Elasticity* 10^6 psi	*Shear Modulus* GPa	*Shear Modulus* 10^6 psi	*Poisson's Ratio*
Aluminum	69	10	25	3.6	0.33
Brass	97	14	37	5.4	0.34
Copper	110	16	46	6.7	0.34
Magnesium	45	6.5	17	2.5	0.29
Nickel	207	30	76	11.0	0.31
Steel	207	30	83	12.0	0.30
Titanium	107	15.5	45	6.5	0.34
Tungsten	407	59	160	23.2	0.28

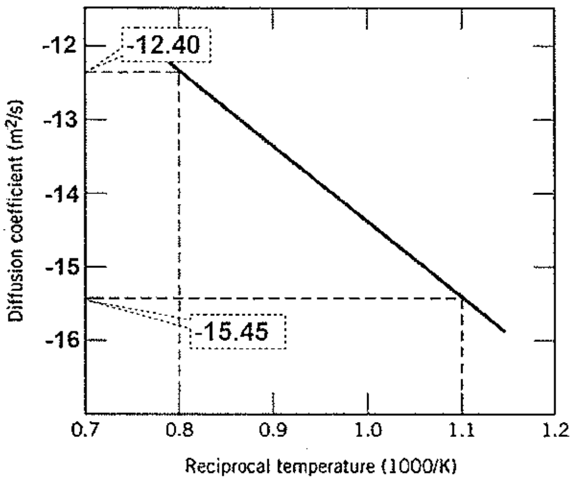

Fig. 1. Plot of the logarithm (to the base 10) of the diffusion coefficient versus the reciprocal of absolute temperature for the diffusion of copper in gold.

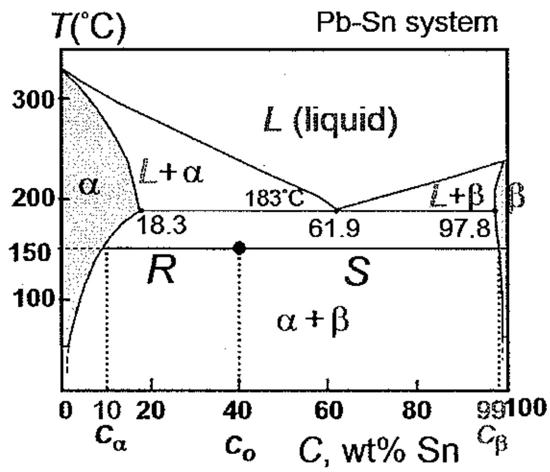

Fig. 2. The lead-tin phase diagram.