May 01, 2009 MID-TERM EXAMINATION Time: 50 min.

MSE 170

Spring Quarter 2009

1(a). The cubic unit cell of MgO which is 0.42-nm along each edge contains 4 Mg^{2+} ions and 4 O^{2-} ions. Show that the density of MgO is 3.6 g/cm^3 (or 3600 kg/m^3); it is well to note that the atomic weights are: Mg 24.305 (g per mole) and O 16 (g per mole). For the Avogadros's number, you may use $N_A = 6.022 x 10^{23}$ molecules per mole.

1(b). The energy required to break the covalent bond between carbon and nitrogen is $5x10^{-19}$ J. What would be the wavelength (λ) of the photon that can furnish this energy ? The Planck's constant (h) = $6.6256x10^{-34}$ J.sec and the speed of light (c) is $3x10^8$ m/sec.

2(a). Show in a tabular form (or otherwise) the relationship between atomic radius (R) and the unit cell dimension (lattice-parameter, a) for the face centered, body centered, and the simple cubic crystals, respectively. Assume one atom per lattice-site.

2(b). Calculate the number of atoms per m^2 on a (100) plane of copper; make a similar calculation for the (110) plane of copper. The lattice-parameter (a) is 0.3615-nm for Cu.

2(c) Gold has an FCC crystal structure with a lattice parameter of 0.407-nm. Calculate the Bragg angle θ for the (112) diffraction peak when using X-rays with a wavelength λ of 0.1-nm.

3(a). What should be the concentration-gradient for nickel in iron to obtain a diffusion-rate (flux) of 10^7 atoms/cm^2.sec at 1300°K ? The coefficient of diffusion for Ni in Fe is: $D = 0.77 \exp(-33716/T)$ cm^2/sec. Assume that D is independent of concentration.

3(b). What is the composition in weight-percent of a Pt-Cu alloy consisting of 95 atom% Pt and 5 atom% Cu ? The respective atomic weights are: Pt 195.09 and Cu 63.54.

4(a). If the critical resolved shear stress (τ_c) for yielding in aluminum is 0.24 MPa, find the tensile stress (σ_c) that must be applied in order to produce yielding when the tensile axis is [001]. For the FCC crystal, slip occurs on (111) plane along the $[0\bar{1}1]$ direction.

4(b). The *Hall-Petch* equation, $\sigma_y = \sigma_o + k_y[d]^{-1/2}$, links the yield stress σ_y with the grain-size d for polycrystalline solids. For an Fe-B alloy, it was found that $\sigma_y = 196$ MPa at d = 0.0625 mm and $\sigma_y = 314$ MPa for d = 0.0156 mm, respectively. Use these data to estimate the yield stress for a grain-size of d = 0.0278 mm.

4(c). Show that the true stress (σ_{tr}) during plastic deformation of a tensile specimen can be related to the nominal or engineering stress (σ) by the equation $\sigma_{tr} = \sigma(1 + \varepsilon)$, where ε is strain. Assume that the volume of the specimen remains constant.

In questions #**2** and #**4**, you have the choice of completing any two of the three (a,b,c).

MSE 170 : Section A

Spring 2009

Mid-term Examination :

total : 80 points

1(a). 10

(b). 10

2(a). 10
2(b). 10 } only two
2(c). 10

3(a). 10

3(b). 10

4(a). 10
4(b). 10 } only two
4(c). 10

Policy :

1. Procedure is correct; numerical result is incorrect (give at least 5 pts.)
2. Error in calculation: remove 2 points (see example).
3. No points off for incorrect units

1(a). mass of $4Mg^{2+}$ and $4O^{2-}$ $= \dfrac{4(24.305+16)}{N_A} = 2.677\times10^{-22}\,g$

density $= \dfrac{mass}{a^3} = \dfrac{2.677\times10^{-22}\,g}{(0.42\times10^{-7}\,cm)^3} = \underline{3.614\ g/cm^3}$

1(b). $h\nu = 5\times10^{-19}\,J$; ν = frequency

$\nu = \dfrac{5\times10^{-19}}{h} = \dfrac{5\times10^{-19}\,J}{6.6256\times10^{-34}\,J\cdot s} = 7.547\times10^{14}\,s^{-1}$

wave-length, $\lambda = \dfrac{c}{\nu} = \dfrac{3\times10^{8}\,m/s}{7.547\times10^{14}\,s^{-1}} = \underline{3.975\times10^{-7}\,m}$

$(= 397.5\text{-}nm)$

2(a). FCC : $R + 2R + R = a\sqrt{2}$; $a = 2\sqrt{2}\,R$

BCC : $R + 2R + R = a\sqrt{3}$; $a = \dfrac{4}{\sqrt{3}}R$

Simple cubic : $R + R = a$; $a = 2R$

2(b). Cu is face-centered-cubic.

(100) plane : number of atoms, $n = 4(\frac{1}{4}) + 1 = 2$

planar density $= \dfrac{n}{a^2} = \dfrac{2}{(0.3615\times10^{-9})^2} = \underline{15.3\times10^{18}\ \dfrac{atoms}{m^2}}$

(110) plane :

$n = 4(\frac{1}{4}) + 2(\frac{1}{2}) = 2$; area $= a(a\sqrt{2})$

planar density $= \dfrac{2}{(0.3615\times10^{-9})^2}\dfrac{1}{\sqrt{2}} = \underline{10.82\times10^{18}\ \dfrac{atoms}{m^2}}$

2(c). Bragg's law : $n\lambda = 2d\sin\theta$

For $n = 1$: $\sin\theta = \dfrac{\lambda}{2d}$

$d_{112} = \dfrac{a}{(1^2+1^2+2^2)^{1/2}} = \dfrac{0.407}{\sqrt{6}} = 0.1662\text{-}nm$

and

$\sin\theta = \dfrac{0.1}{2(0.1662)} = 0.3009$; $\underline{\theta = 17.5^\circ}$

3(a). $D = 0.77 \cdot \exp\left(-\frac{33716}{1300}\right) = 4.197 \times 10^{-12}\ cm^2/s$

$J = -D \frac{\Delta C}{\Delta x} = 10^7\ atoms/cm^2 \cdot s$

$\text{Concentration-gradient} = -\frac{10^7}{4.197 \times 10^{-12}}\ \frac{atoms}{cm^4}$

$\frac{\Delta C}{\Delta x} = \underline{-2.383 \times 10^{18}\ \frac{atoms}{cm^4}}$

3(b). Pt - Cu solid solution: In 1 mole, there are 0.95 mole Pt and 0.05 mole Cu.

$m_{Pt} = 0.95 \times 195.09 = 185.336\ g = \underline{98.315\ wt\%}$

$m_{Cu} = 0.05 \times 63.54 = 3.177\ g = \underline{1.685\ wt\%}$

total mass: $188.513\ g$

4(a). Critical resolved shear stress, $\tau_c = \sigma_c \cos\phi \cos\lambda$

$\cos\phi = \frac{0+0+1}{1 \times \sqrt{3}} = \frac{1}{\sqrt{3}}$; $[001] \measuredangle [111]$

Slip direction : $[0\bar{1}1]$

$\cos\lambda = \frac{0-0+1}{\sqrt{2} \times 1} = \frac{1}{\sqrt{2}}$; $[001] \measuredangle [0\bar{1}1]$

$0.24\ MPa = \sigma_c \cdot \frac{1}{\sqrt{3}} \cdot \frac{1}{\sqrt{2}}$; $\sigma_c = 0.24\sqrt{6} = \underline{0.588\ MPa}$

4(b). Hall-Petch equation : $\sigma_y = \sigma_o + k_y (d)^{-1/2}$

$$\left.\begin{array}{l} 196\ MPa = \sigma_o + k_y (4) \\ 314\ MPa = \sigma_o + k_y (8) \end{array}\right\} \quad \begin{array}{l} k_y = 29.5 \\ \sigma_o = 78\ MPa \end{array}$$

At $d = 0.0278$-nm : $\sigma_y = 78 + \frac{29.5}{0.1667} = \underline{255\ MPa}$

4(c). $A_o l_o = A l$; $\sigma_{tr} = \frac{F}{A} = \frac{\sigma A_o}{A}$

$\sigma_{tr} = \sigma \frac{l}{l_o} = \sigma\left(\frac{l_o + \Delta l}{l_o}\right) = \underline{\sigma(1+\varepsilon)}$

and

$\varepsilon = \frac{\Delta l}{l_o} = \frac{l - l_o}{l_o} = \text{strain}$