ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2014 SESSION

Open-book examination
Calculators: authorized models only
Duration: 3 hours

STRUCTURE OF MATERIALS
14-MT-A4

- *The exam contains a maximum of 112 marks, which will be converted to 100.*
- *Please, answer all questions.*

Question 1. (5+5+5+10 points)
1) Why does atomic bonding occur?

2) Describe the different types of atomic bonding.

3) Calculate the fraction of vacancies in copper at (a) at $700^{o}C$ and (b) at its melting point ($1082^{o}C$). Assume an energy for vacancy formation of 0.90 eV/atom.

4) For two elements, A and B, that are ionically bonded, the attractive and repulsive energies, E_A and E_R (in electron volts per A-B pair) depend on the distance (r in nanometers) between the two resulting ions, as follows:

$$E_A = \frac{-1.32}{r} \quad \textbf{and} \quad E_R = \frac{6.55 \bullet 10^{-6}}{r^8}$$

Assuming the net potential energy, E_N, is the sum of attraction and repulsion, plot all three energies as a function of interatomic distance on one graph, and determine the equilibrium spacing between the two elements. What is the theoretical force of rupture?

Question 2 (5+5+5+5+5 points)
1) Why real materials are generally polycrystalline and have isotropic properties?

2) Why ceramic materials are brittle?

3) Explain how grain boundaries influence both strength and fracture.

4) What is the effect of temperature on the stress-strain curve of a metal?

5) At the atomic level, what is the difference between plastic and elastic deformation?

Question 3 (10+6+10 points)

1) Many ceramic materials crystallize with the sodium chloride structure (rock salt). One is MgO (magnesium oxide). (a) Compute the unit cell dimensions of this structure and (b) calculate the atomic packing factor. (r_{Mg2+} = 0.072nm and R_{O2-} = 0.14nm)

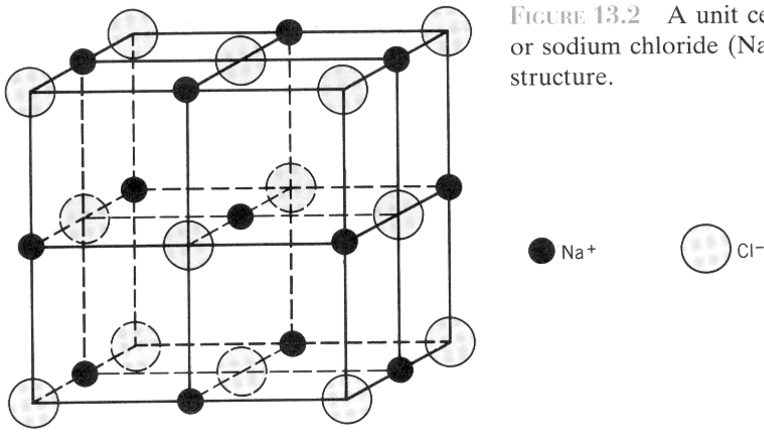


FIGURE 13.2 A unit cell for the rock salt, or sodium chloride (NaCl), crystal structure.

2) Draw, compute and compare the linear densities of [100], [110] and [111] in (a) BCC and (b) FCC crystal structures. Assume a pure metal, a lattice parameter of “a”, and an atomic radius of “r”.

3) Calculate the planar densities of (100), (110) and (111) for (a) BCC and (b) FCC crystal structures. (c) What is the significance of these values? Assume a pure metal, a lattice parameter of “a”, and an atomic radius of “r”.

Question 4 (5+5+5 points)

1) An alloy has a modulus of elasticity of 350 GPa, a yield strength of 872 MPa, and a 0.3 engineering flow stress of 1000 MPa at engineering strain 0.3. If this alloy necks at 0.45 engineering strain, determine the engineering UTS.

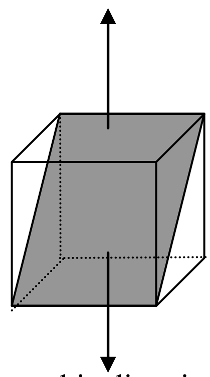
2) With regard to the above alloy, if you load a rod of this alloy of initial diameter 10 mm up to, but not beyond, the point of necking, and immediately unload, what is the final diameter of the rod, taking into account „springback“?

3) For metallic materials, the yield strength can be varied through the grain size by controlling thermo-mechanical processing. For a given metal, a grain size of 7µm results in a yield strength of 640 MPa, while a grain size of 10µm results in a yield strength of 550 MPa. What grain size would be required to generate a yield strength of 1000MPa?

Question 5 (5+6 points)
1) Why are TV cabinets made out of plastic as opposed to wood or metal?

2) Wood, steel and concrete are all used as load bearing materials in the construction industry. Give the advantages and disadvantages of each material in this role.

Question 6 (5 + 5 points)
Suppose the active slip plane of a single crystal is the shaded one, and a tensile stress is applied as per the arrows.



1) If the crystal is FCC, which crystallographic direction will give rise to the lowest tensile yield strength?

2) If the critical resolved shear stress of this alloy is 300 MPa, calculate the yield strength for this slip direction that you think is the most favourable.