

Homework Assignment 2, Due at start of class, Thursday, Feb 12

Solve Questions 12.40, 12.44, 13.5 (a,b only), 13.10, 13.15 (a only), 13.18, 13.24

AND solve the following:

30 points total, 8% of student's final grade

12.40: Not graded (confusion about which equation to use)

12.40 This problem asks that we compute the crack tip radius ratio before and after etching. Let

ρ_t = original crack tip radius, and

ρ_t' = etched crack tip radius

Also,

$$\sigma_f' = \sigma_f$$

$$a' = \frac{a}{2}$$

$$\sigma_0' = 4\sigma_0$$

Solving for $\frac{\rho_t'}{\rho_t}$ from the following

$$\sigma_f = 2\sigma_0 \left(\frac{a}{\rho_t} \right)^{1/2} = \sigma_f' = 2\sigma_0' \left(\frac{a'}{\rho_t'} \right)^{1/2}$$

yields

$$\frac{\rho_t'}{\rho_t} = \left(\frac{\sigma_0'}{\sigma_0} \right)^2 \left(\frac{a'}{a} \right) = \left(\frac{4\sigma_0}{\sigma_0} \right)^2 \left(\frac{a/2}{a} \right) = 8$$

12.44

4 total: 2 points for part a, and 2 points for part b (only full credit for part b if they use the word 'Weibull,' as in the Weibull distribution).

12.44 (a) This portion of the problem asks that we determine whether or not a cylindrical specimen of aluminum oxide having a flexural strength of 300 MPa (43,500 psi) and a radius of 5 mm will fracture when subjected to a load of 7500 N in a three-point bending test; the support point separation is given as 15 mm. Using Equation 12.7b we will calculate the value of σ ; if this value is greater than σ_{fs} (300 MPa), then fracture is expected to occur. Employment of Equation 12.7b yields

$$\sigma = \frac{FL}{\pi R^3} = \frac{(7500 \text{ N})(15 \times 10^{-3} \text{ m})}{(\pi)(5 \times 10^{-3} \text{ m})^3} = 286.5 \times 10^6 \text{ N/m}^2 = 286.5 \text{ MPa} \quad (40,300 \text{ psi})$$

Since this value is less than the given value of σ_{fs} (300 MPa), then fracture is not predicted.

(b) The certainty of this prediction is not 100% because there is always some variability in the flexural strength for ceramic materials, and since this value of σ is relatively close to σ_{fs} then there is some chance that fracture will occur.

13.5 (a,b only)

4 total: 2 points for a and 2 for b.

(a) The **99.8 wt% SiO₂-0.2 wt% Al₂O₃** will be more desirable because the liquidus temperature will be greater for this composition; therefore, at any temperature within the cristobalite + liquid region on the phase diagram, there will be a lower fraction of the liquid phase present than for the 99.0 wt% SiO₂-1.0 wt% Al₂O₃ composition, and, thus, the mechanical integrity will be greater.

(b) The **74 wt% Al₂O₃-26 wt% SiO₂** composition will be more desirable because, for this composition, a liquid phase does not form until about 1750°C [i.e., the temperature at which a vertical line at 74 wt% Al₂O₃ crosses the boundary between the mullite and (mullite + liquid) phase regions]; for the 70 wt% Al₂O₃-30 wt% SiO₂ material, a liquid phase forms at a much lower temperature--1587°C.

13.10

Not graded

The glass transition temperature is, for a noncrystalline ceramic, that temperature at which there is a change of slope for the specific volume versus temperature curve (Figure 13.6).

The melting temperature is, for a crystalline material, that temperature at which there is a sudden and discontinuous decrease in the specific-volume-versus-temperature curve.

13.15 (a only)

(a) Residual thermal stresses are introduced into a glass piece when it is cooled because surface and interior regions cool at different rates, and, therefore, contract different amounts; since the material will experience very little, if any deformation, stresses are established.

13.18

Chemical tempering will be accomplished by substitution, for Na⁺, another monovalent cation with a slightly larger diameter. From Table 12.3, both K⁺ and Cs⁺ fill these criteria, having ionic radii of 0.138 and 0.170 nm, respectively, which are larger than the ionic radius of Na⁺ (0.102 nm). In fact, soda-lime glasses are tempered by a K⁺-Na⁺ ion exchange.

2 points total, 1 for saying K and 1 for saying Cs substitution.

13.24

6 points total.

(a) Three factors that influence the degree to which vitrification occurs in clay-based ceramic wares are: (1) composition (especially the concentration of flux present); (2) the temperature of firing; and (3) the time at the firing temperature.

(b) Density will increase with degree of vitrification since the total remaining pore volume decreases.

Firing distortion will increase with degree of vitrification since more liquid phase will be present at the firing temperature.

Strength will also increase with degree of vitrification inasmuch as more of the liquid phase forms, which fills in a greater fraction of pore volume. Upon cooling, the liquid forms a glass matrix of relatively high strength.

Corrosion resistance normally increases also, especially at service temperatures below that at which the glass phase begins to soften. The rate of corrosion is dependent on the amount of surface area exposed to the corrosive medium; hence, decreasing the total surface area by filling in some of the surface pores, diminishes the corrosion rate.

Thermal conductivity will increase with degree of vitrification. The glass phase has a higher conductivity than the pores that it has filled.

EX1) Identify 3 ways to improve the mechanical properties of a ceramic part your company is selling.

Choose any 3 of the following, 2 pts each for 6 points total:

- Use in compression
- Decrease influence of internal flaws
 - Decrease size by enhanced processing and optimal raw materials
 - Increase radius
 - Decrease number
- Decrease number of surface flaws
 - Surface polishing
- Minimizing stress-corrosion cracking
 - Protect the component from the environment
- Use below the Weibull 'rated' load
- Decrease component size (fewer flaws)
- Keep temperature as low as possible / use in non-corrosive environment
- Decrease influence of surface flaws
 - Add a compressive layer at the surface (acts to close cracks)

EX2) For the phase diagram of Cr_2O_3 and Al_2O_3 in your textbook,

1 pt. for each part, so 4 pts total

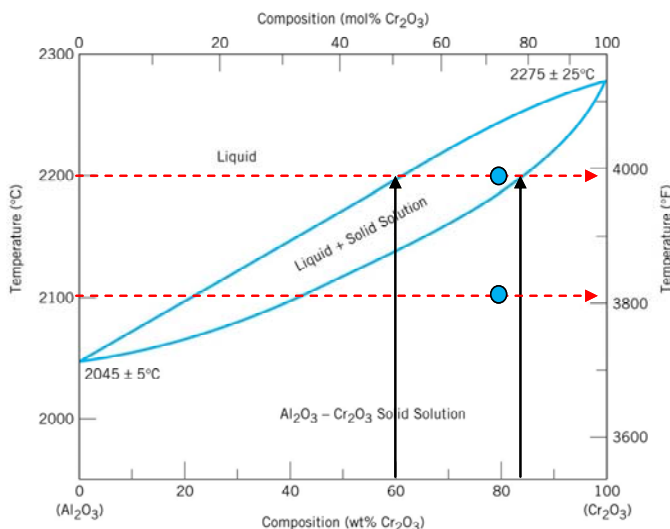
- a) what phase or phases will be present at 2100°C and 20% Al_2O_3 ?
 Cr_2O_3 and Al_2O_3 solid solution
- b) What proportion of each phase/these phases is present?
100% solid solution
- c) what phase or phases will be present at 2200°C and 20% Al_2O_3 ?
Liquid and Cr_2O_3 and Al_2O_3 solid solution
- d) What proportion of this phase/these phases is present?

Use the lever rule

Values within $\pm 5\%$ are acceptable.

$$W_{\text{liquid}} = \frac{85 - 80}{85 - 61} = 21\%$$

$$W_{\text{solid solution}} = \frac{80 - 61}{85 - 61} = 79\%$$



EX3) What is the concentration given the following ternary phase diagram?

4 points total: 2 points each part

a) At the 'o' location

Li: 25%

Nb: 20%

O: 55%

b) At the 'x' location.

Li: 80%

Nb: 0%

O: 20%

