Ceramic Materials Engineering

A.Y. 2018-2019

Homework n. 2

Some data and universal constants are not given and shall be found elsewhere or hypothesized.

1. Estimate the maximum amount of mullite than can be produced in a ceramic mixture for porcelain consisting of 55% kaolin, 30% quartz, 15% nepheline.

2. Compare the drying shrinkage for particles of 1.0 and 0.01 µm in simple cubic packing when the interparticle binder+liquid contracts from 5 to 1 nm on drying.

3. Compare the energy required to heat water from 20 to 100°C to the energy required to evaporate it at 100°C.

4. The drying shrinkage of a cast product having a mean particle size of 3 µm is $\Delta L/L_0$ = 0.9%. Estimate the shrinkage if the particle size is reduced to 0.7 µm and the packing density after drying is the same.

5. What is an estimate of the volume of gas evolved for the thermolysis of 2 wt% polyvinyl alcohol PVA $[-CH_2-CHOH-]_n$ from an alumina powder compact having PF = 0.6. Assume that the gas is evolved at 350°C and the combustion product gases are CO_2 and H_2O.

6. Estimate the maximum amount of mullite that can be formed in a porcelain produce by using 60 wt% kaolin, 30 wt% quartz, 10 wt% nepheline (this latter with chemical composition = 60 SiO_2, 24 Al_2O_3, 2 CaO, 8 Na_2O, 6 K_2O).

7. Assuming that a powder has a surface energy of 1.2 J/m^2, estimate the maximum amount of energy that is available for densification for spherical particles with diameter of 0.5 µm compacted to a green PF of 55%. Assume that there is no grain growth.

8. Consider a hypothetical oxide with a dihedral angle of 150°. If the dihedral angle is changed to 90° but the surface energy remains the same, would the oxide densify more readily or less? Explain why.

9. The lattice diffusion coefficient for Al^{3+} ions in Al_2O_3 is 4.0x10^{-14} cm^2/s at 1400°C and the activation energy is 580 kJ/mol. Assuming that sintering is controlled by lattice diffusion of Al^{3+}, estimate the initial rate of sintering for an alumina powder compact of 1 µm particles at 1300°C.

10. A ZnO powder compact is formed from particles with an average size of 3 µm. Assuming that densification occurs by a lattice diffusion mechanism with an activation energy of 250 kJ/mol, estimate the factor by which the densification rate will change if: (a) the particle size is reduced to 0.3 µm, (b) the compact is hot pressed under 40 MPa pressure and (c) the sintering temperature si raised from 1000 to 1200°C. The specific surface energy of ZnO can be assumed to be 1 J/m^2.

11. For a dense, pure polycrystalline ZnO in which the grain growth follows normal parabolic kinetics, the average grain size after annealing for 120 min at 1200°C is found to be 5 µm. Annealing for

60 min at 1400°C gives an average grain size of 11 µm. If an average grain size at time = 0 is 2 µm, estimate what the average grain size will be after annealing for 30 min at 1600°C.

12. Plot the limiting porosity in a powder compact as a function of the grain size (in the range 0.1-100 µm) when sintering is carried out in an insoluble gas at atmospheric pressure. Assume that the pore size is 1/3 the grain size and that the specific surface energy of the solid-vapour interface is 1 J/m^2.