CERAMIC AND COLLOIDAL PROCESSING - EXERCISES

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Exercises 12 - Solutions

1. What are the main driving forces (energies) involved in sintering?

Solution

Driving forces (energies):
-Surface energy and interfacial (most important contribution): it is a function of the specific surface energy of the powder and the grain boundaries formed during sintering. To minimize the free energy of the system one has the tendency to decrease free energy by formation of the grains together with an interfacial energy (ceramic-ceramic) which is lower than the ceramic-gas surface energy.
-Energy linked to the existence of an excess of physical defects (vacancies) in the vicinity of curved surfaces
-Energy related to the existence of tensions/forces derived itself from the curved surface

2. Give a solid phase sintering mechanism i) with shrinkage and ii) without shrinkage

Solution

Solid phase sintering:
With shrinkage:
- volume diffusion via the grain boundaries
- diffusion via the grain boundary
- viscous flow

Without shrinkage:
- surface diffusion
- volume diffusion - from grain surfaces
- evaporation - condensation

3. How can the homogeneity of the green body influence the microstructure of a sintered ceramic?

Solution

The arrangement of particles during sintering is influenced by the formation of necks and in the final stage grain growth – the relative changes depend on particle contact area (neck area) and grain boundary energies.
If the green body is not homogeneous, the sintering occurs at different speeds in different parts of the ceramic, for example if the matrix sintered faster than the agglomerates, the matrix will be subjected to internal stresses causing cracks and we can observe:

- small pores disappear
- large pores increase in size

4. What are the different stages of sintering in i) solid phase

Solution

i) Solid state sintering
There are 3 stages 1) initial, 2) intermediate and 3) final

1) Growth of bridges/necks between particles, depending on the transport mechanism it can be with or without densification. $\rho \sim 50\%$ -60%

2) Densification with formation of cylindrical pores between grains - grain size can change a little, $\rho \sim$ from 60% to 90%

3) Final stage $\rho > 90\%$, start to form closed and isolated pores at the triple points between the grains. $\rho > 94\%$, most pores are closed and grain growth is accelerating. Densification towards 99%.