CURRENT PARADIGMS IN POWDER PROCESSING

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The theoretical work and model experiments on sintering and hot pressing have provided a basis to qualitatively interpret much of the behavior observed in these processes as practiced in the technology. The data base and the modeling, however, are inadequate to quantitatively predict the kinetics of materials responses for these processes (including grain growth) for most systems of interest. In this paper the authors present their biases in a review of the paradigms (current "axioms") in the field, citing the literature sources which support our biases. Several paradigms have changed significantly in the past several years. As a consequence, new directions for the course of productive research are needed; we present our best guesses for them. We also give emphasis to some earlier theoretical and experimental work which we regard as important, the significance of which seems to us not to have been duly appreciated.

Complete characterization of powders, powder compacts, and their evolution during sintering has not been developed for any system and probably never will be on a routine basis. Hence, the framework for understanding is to connect the behavior and changes in behavior to controllable variables and operations, empirically, by measurements; and fundamentally, by theories and models and the materials properties data base. In order to illustrate the scope of the problem, each of these is expanded into a listing of items in Table 1. In what follows, we will emphasize the sub-topics independently in some cases, presuming that the relationships among the major topics are appreciated. For others, the major relationships will be emphasized; some topics will be ignored or given very limited attention.

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H. Palmour III et al. (eds.), Processing of Crystalline Ceramics
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Table 1: Sintering and Hot Pressing with/without liquid in metallic, ionic, or covalent systems

Behavior

General morphology
Evolution of pores and grains
Density \( f(T,t) \)
Grain size \( f(T,t) \)
Dopant effects

Models

Neck growth
Surface area change
Shrinkage
Densification in later stages
Defect reactions at surfaces
Diffusive transport
Evaporation condensation
Plastic flow
Gas pressure effects
Grain growth
Solute drag
Pore drag
Breakaway

Controllable Variables and Operations

Powder preparation
Particle size, shape, distribut'n
Dopant distribution
2nd \( \phi \) distribut'n
Fabrication
density distribut'n pore size
Firing
\( T \) and \( T_{\text{max}} \)
\( \phi_{\text{hp}}(t) \)
\( P_g \), atmosphere

Characterization Measurements

Shrinkage, density
Neck growth
Surface area change
Grain size, pore size, and continuity
Permeability
Strength
Conductivity
Porosimetry
Dopant re-distribut'n
\( f(T,t) \)

Data Base Needed

\( \gamma_{sv} \), \( \gamma_{lv} \), \( \gamma_{sl} \) and
\( \gamma_b = f's(x_{\text{dope}}) \)
\( D_m^x \)
\( D_s^x \)
\( D_m^b \)
\( D_s^b \)
\( D_m^s \)
\( D_s^s \)
D's in liquids
\( k_{m,x} \)
\( k_{b,x} \)
\( p_m^x \)
\( p_b^x \)
Phase equilibria
Gas solubilities
diffusivities
Solute diffusivities
Creep behavior
\( T_y(T) \)