Electric Field Assisted Sintering of Oxide Ceramics: Fields Matter!

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Sintering as a consolidation, densification and coarsening process depends on numerous different intrinsic and extrinsic factors: materials composition, particle size distribution and morphology, temperature programme (heating rate, maximum temperature, dwell time), atmosphere, pressure, microstructure of the green body, etc.

The use of external electric fields offers additional degree of freedom to accelerate densification and taylor microstructure. In order to use their full potential, systematic investigations under well-controlled experimental conditions are required.

Taking the example of doped ceria, sintering parameters required for continuum mechanical modeling are significantly affected by very moderate fields without the generation of macroscopic Joule heating in the sample. For example, the decrease in viscous Poisson's ratio observed with fields is correlated to a clear decrease in shear viscosity, which can be attributed to an easier grain boundary sliding.

In addition, by increasing the amplitude of the electric field, transition to flash sintering is correlated with the generation of n-type electronic conductivity in air under direct-current bias. Its origin is attributed to partial reduction of the material which propagates from the cathodic-to-anodic region. Current-rate flash sintering with controlled power leads to a uniform grain size. Densification is shown to depend only on the instantaneous value of the current density, whereas the grain size becomes finer at higher current rates. As higher electric fields lower the temperature for the onset of flash, the Debye temperature emerges as a the lower bound, as shown for three oxides.