Cold Sintering of Functional Materials

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Abstract:

The Cold Sintering Process (CSP) is an ultra-low temperature (<300°C) ceramic processing technique that uses a transient liquid phase and uniaxial force to drive a powder compact to densify. Historically, bulk ceramics had been processed at temperatures above ~1000°C. Thus, the introduction of CSP in 2016 by the Randall Group marked a paradigm shift for the processing of such materials. With enabled densification at such low temperatures, CSP is regarded as a promising technique for energy reduction and decarburization within the ceramics industry. Additionally, of scientific interest, CSP enabled for the first time ceramic-organic nanocomposites, greatly expanding the design space of ceramic materials to achieve enhanced functionality. Through the cold sintering process, highly functional piezoelectrics, dielectrics, semiconductors, superconductors, thermoelectrics, electrolytes, and electroactive components have been fabricated.

CSP is a geologically inspired process from pressure-solution creep, which describes a diffusional process through an aqueous solution involving dissolution-transport-precipitation from the grain boundaries to the pores. So, cold sintering is a convergence of geology, chemistry, sintering, and materials science. Some cold sintering studies are currently interested in connecting these fields together to develop models to explain the densification and microstructural evolution during CSP. Guidelines for transient liquid phase selection, and an understanding of the impact of processing parameters such as temperature, pressure, and particle morphology / composition on microstructure are some of the parameters being explored.

Herein, we present our group's efforts to understand the processing–structure–property relationships of the cold sintering process with the goal of accelerating its implementation into industry and designing novel nanocomposites. This poster presents the design of various ceramics and nanocomposites, and their performances guided by these studies.