Cold sintering for sustainable ceramics

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The primary sintering technology for ceramics has remained relatively constant for the last few thousand years. The application of heat to cause sintering in ceramic materials is generally effective, but requires temperatures often in excess of 1000 °C. The process is then at odds with the drive for sustainable materials synthesis, and also excludes the possibility of retaining bespoke nano- or micro-structures, making many emergent and beneficial structure-function relationships inaccessible.

The cold sintering process (CSP) has been recently discovered as a means to create fully dense ceramics at significantly reduced temperatures. By introducing a small quantity of solvent (e.g. water) to the powder, a supersaturated solution can be formed around each particulate which can then be caused to reorganise and recrystallise with some applied heat (<200 °C) and uniaxial pressure (<600 MPa). The reorganisation enables the formation of a fully dense ceramic body, with the recrystallisation of solvated phase allowing retention of this arrangement once the pressure is released. For some materials (e.g. lithium molybdate) this process is sufficient to create fully dense ceramics at 120 °C, and for others (e.g. barium titanate) where partial dissolution is not possible, the solvent can be altered to produce a hydrothermal-style reaction around each particle, with a secondary anneal step (approx. 900 °C) being required to produce a phase pure product.

Here I will present the underlying concepts of CSP as a way to consolidate ceramic materials using unprecedented low temperatures, as a sustainable method to produce fully dense ceramics. I will summarise previous discoveries and scope, and present the progress we have made in generalising the technique to encompass complex materials such as doped strontium titanate using new solvent combinations.