Flash sintering – towards faster, cheaper, greener, better ceramics

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"Flash sintering" refers to the rapid densification of ceramics at low furnace temperatures by passage of an electric current and was first reported by Raj and co-workers in 2010 using the ionic conductor 3 mol% yttria stabilised zirconia (3YSZ). Since then it has been demonstrated in many other ceramics, including covalent semiconductors, electronically conducting oxides and whitewares. The low furnace temperatures, rapid turnaround times and possibilities of producing novel microstructures offer significant commercial advantages but controlling the process is essential as severe localisation of the temperature can occur under some conditions. In order to do this, the process needs to be understood so that that predictive process models can be developed.

The presentation begins with a description of flash sintering, illustrated using 3YSZ and other ceramics. The possibility of producing new microstructures is described. It is then shown that the thermal and electrical response during the flash event can be explained and modelled well in terms of classical thermal runaway of Joule heating resulting from the negative temperature coefficient of resistivity exhibited by most ceramics under the relevant conditions of high temperature and electric field.

The second part of the presentation concerns the origin of the rapid sintering observed. There is consensus that the passage of an electric current through the specimen leads to significant heating above the furnace temperature but simplistic extrapolations from conventional sintering experiments cannot explain the rapid sintering by this factor alone. Experiments are described in which 3YSZ powder compacts are heated and cooled with a temperature profile similar to that of flash sintering but without the application of an electric field. The results show an acceleration in sintering rate of more than 2 orders of magnitude compared with conventional sintering at the same temperature but without the involvement of electricity. It is concluded that the rapid heating in flash sintering rather than the electric current responsible for it is a major cause of the accelerated sintering observed. Possible explanations for this "ultra-fast firing effect" are discussed.