FLASH SINTERING OF GADOLINIUM-DOPED CERIA

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In the large spectrum of the field assisted sintering techniques (FAST), flash sintering is among the most innovative ones and potentially also the fastest one (as low as <5 seconds [1]). This implies that the mechanisms behind this process are hardly ascribable just by thermal-activated diffusion, applicable for conventional sintering with much longer densification time.

Nevertheless, many ceramic materials, namely oxides, were successfully densified with this sintering technique. Among them, we focus our attention on flash sintering of 10% mol gadolinium-doped ceria (GDC10), which has a large potential in energy-related applications, like gas separation membranes, solid oxide fuel cells and electrolysis cells (SOFC & SOEC) [2]. Hence the densification of such a material is relevant for the transition towards CO_2-free energy sources. The conventional sintering of GDC is reported between 1400-1600 °C for several hours [3], but flash sintering was successful in densifying GDC at furnace temperatures in the range of 500-700 °C range [4-6], showing a benefit for the production costs and a potential improvement of the physical properties by a tunable microstructure.

However the roadmap towards the practical application of such types of techniques need still to be completed, both because of the microstructure optimization and because of the upscaling to dimensions and shapes suitable for industrial components.

Concerning the former issue, a processing map for “safe” flash sintering of GDC10 was developed defining the optimized range of the main process parameters such as current density and electric field for obtaining almost defect-free samples [7]. Outside this range, two main types of defects were observed in the case of excessively high electric fields and/or high current densities, which are crack formation and hot spot formation, respectively. In addition, the study covered the comparison of three methods of flash sintering: the voltage-to-current control, the constant heating with fixed voltage, and the current-rate control method. The latter has shown the best results in terms of microstructure evolution and homogeneity thanks to the reduced current density needed to flash-sinter the samples [8].

Up to now, all systematic parameter studies were done with dog-bone shaped samples, which has less relevance for real applications. Therefore, our ongoing work focuses on transferring the main results on flash sintering of cylinder shaped GDC bulk samples and – even more promising – flash sintering of functional GDC layers, which is expected to open new pathways for effective production of electrochemical devices with layered structure. In the first case, avoiding formation of localized current paths (“hot spots”) when scaling up the sample size is the main challenge. In the second case, understanding the influence of constrained sintering on densification and control of residual porosity are the main keys to success.
Recently, by means the variation of the samples surface-to-volume ratio, we observed a considerable variation of the process parameters. Specifically, with the increase of this ratio, a proportional increase of the needed electric field and density current to set the flash conditions was noticed.

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