NOVEL PROCESSING OF NANOSTRUCTURED CERAMICS USING MICROWAVES

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Nanostructured materials have received much attention in recent years and their projected world market is £600 million in the year 2005. Their appeal is attributed to their potential to display unusual physical and mechanical properties, such as superplasticity in ceramics, transparency for usually opaque materials, very high magnetoresistance, unusual dielectric properties and controlled band gaps in electronic materials amongst others. However, for many practical applications the ability to sinter the powders into dense bodies whilst retaining grain sizes in the nanometer range is a critical step, especially given the challenges of particle agglomeration, high reactivity and inherent contamination that all lead readily to grain coarsening and hence loss of the nanostructure. In the present work we examined both conventional and microwave heating, in which the aim is to suppress grain growth by the use of volumetric, high heating and cooling rates and short hold times, and the use of a two-step hybrid sintering method where the suppression of grain growth is achieved by exploiting the difference in kinetics between the grain boundary diffusion and grain boundary migration. Nanocrystalline yttria stabilised zirconia (YSZ) and ZnO powders were investigated as a case study.

Conventional and microwave sintering experiments have been carried out on dry and wet processed nanocrystalline yttria stabilised zirconia samples. Densification was found to increase with increase in compaction pressure, micronising time and temperature. Full densification was achieved for both the wet and dry processed nanostructured samples at temperatures 200^{o}C lower than required for micron-sized YSZ compacts. The combination of microwave heating and nano powder formulation was found to provide samples with near zero porosity in just 1/5th of the time required for conventional processes. Using the novel hybrid two stage sintering approach and far lower temperatures, dense nano ceramic samples with <85 nm mean grain size was obtained with matching or superior mechanical properties. Interestingly XRD, ED, FTIR and thermal analysis investigations suggested a possible case of grain size dependent shift in the phase boundary composition for the nano YSZ ceramics. This will not only have significant implications in enhancing the mechanical and electrical properties of nano ceramics in Y_2O_3-ZrO_2 system but may also lead to redrawing of the phase diagrams of other technical ceramics in the nano region. A preliminary analysis has also suggested that the combined use of microwave heating and nanopowders has the potential to reduce the cost of fabricating multilayer electroceramic devices by a factor of 120.