Abstract

Fully stabilised zirconia (8 mol% yttria) does not exhibit any transformation toughening effects such as those found in partially stabilised zirconia (3 mol% yttria), hence to produce a quality bioceramic a composite ceramic must be made, and this can further be aided by using nanopowders as the staring material. In this work nanosized reinforcing powders, titanium carbide and titanium nitride, were sintered with a nanosized fully stabilised zirconia matrix. These composites were sintered using spark plasma sintering, which allows for rapid heating and cooling rates and hence shorter sintering times. These allow for improved hardness and fracture toughnesses because of minimal grain growth during sintering.

When dealing with nanopowders, processing problems are increased due to the higher agglomeration tendencies and oxidation of the reinforcing powders. This agglomeration problem was mitigated by creating a suspension of the powders, using a suitable dispersant and solvent, thereby allowing for homogenous nanocomposites to be made. First a suitable dispersant that could disperse each of the powders had to be found. Furthermore the solvent for the dispersant had to prevent oxidation of the reinforcing powders. The dispersant and solvent were found by testing various dispersants on micron sized powders, since micron sized powders are significantly cheaper than nanosized ones. The dispersant found was Lubrizol 2155 with hexane as the solvent. Composites materials made from micron sized powders, ZrO_2-50%TiC and ZrO_2-50%TiN, were prepared and sintered using Lubrizol 2155 and hexane to determine whether it would produce a homogenous distribution of the powders in a sintered sample. These were analysed using SEM, which proved that Lubrizol was a successful dispersant. The micron sized composites were used as a comparison for the nanocomposites

Rheology studies were then carried out on the nanopowders to determine the optimal amount of dispersant and solid loadings. These were carried out on the individual nanopowders and on the ZrO_2-10vol% TiC, ZrO_2-50vol% TiC, ZrO_2-10vol% TiN and the ZrO_2-50vol% TiN nanocomposite systems. The results obtained were used to create suspensions of the nanocomposites for sintering of 3, 10, 30 and 50 volume percent of TiC and TiN respectively to the fully stabilised zirconia, these were mixed by a ball mill prior to sintering. The samples were then sintered using various conditions in the spark plasma sintering furnace.

The densification of the nanocomposites showed that there was a decrease in density with increases composition of the reinforcing powders. This was particularly apparent for the composites that contained above 30 vol. % of the reinforcing component. It is believed that this is as a result of the percolation limit being surpassed. The oxygen content also proved to be a factor in the densification.

The hardness values of the ZrO_2-TiN system were found to typically be higher than in the ZrO_2-TiC system. In both systems the highest hardness were found in the 30 volume percent samples. For the ZrO_2-TiC nanocomposites hardness values of up to 13.75 GPa were achieved, with hardness values of up to 15.79 GPa achieved for the ZrO_2-TiN system. The hardness values determined were in accordance with those found in literature.

An increase in fracture toughness with increasing the reinforcing component composition was found in both systems with higher fracture toughness found in the TiN system. The highest fracture toughnesses were found for samples with a relative density above 97 percent, were 2.65 and 3.64 $MPa.m^{1/2}$ respectively for the TiC and TiN systems. These values were slightly higher than those found in literature for fully stabilised zirconia, however were significantly lower than partially stabilised zirconia composites found in literature.