Abstract

Titanium carbide and titanium nitride were used to reinforce an alumina matrix. The composites were prepared from nanopowders in an attempt to produce composites with nanostructured grains and as a result improved hardness and fracture toughness values. The composite powders were sintered using a spark plasma sintering (SPS) furnace which allows for high heating and cooling rates to be implemented.

For the processing of the powders it was imperative that a dispersant that was able to disperse each of the materials being investigated be found. The dispersant would also have to be used in an organic solvent in an effort to prevent oxidation of the non-oxide materials. Due to the high costs associated with the nanopowders, micron sized powders were used in the determination of an effective dispersant. The dispersant that was found to meet all the criteria was Lubrizol 2155 when using hexane as the solvent. An optimum dispersant amount for each of the micron powders was determined through rheology studies. Two samples of each µm particle reinforced composite material (Al_2O_3-50%TiC and Al_2O_3-50%TiN) were prepared, the properties measured and the cross-sections analysed using SEM. From the SEM analysis it was seen that there was homogeneous distribution of the various phases within the sintered micron composites and as a result it was decided that Lubrizol 2155 would be used in the preparation of the nanopowders.

Rheology studies were then carried out on each of the individual nanopowders and on the Al_2O_3-10vol%TiC, Al_2O_3-50vol%TiC, Al_2O_3-10vol%TiN and the Al_2O_3-50vol% TiN nanocomposite systems. These results were used to prepare composites for sintering with additions to alumina of 3%, 10%,30% and 50% (by volume) of TiC and TiN respectively. The samples were then sintered using various conditions in the SPS furnace.

For the Al_2O_3-TiC and Al_2O_3-TiN composites it was evident that the densification of the materials containing 30% and 50% (by volume) of the reinforcing component was below 97%, whereas for the lower additions of the reinforcing components full densification was observed. This gives strong evidence of the hindrance of the sintering by the reinforcing elements. The oxygen content of the starting powders (TiC=3.5wt% and TiN=8.4wt% oxygen) was found to strongly affect the densification behaviour of the nanocomposites and is also assumed to have resulted in deterioration of the mechanical properties. The XRD analysis showed the presence of a solid solution between Ti_3O_5 and $AlTi_2O_5$ in the sintered materials.

The hardness values of the Al_2O_3-TiC nanocomposite materials were higher than those of the Al_2O_3-TiN nanocomposites. For the Al_2O_3-TiC nanocomposites hardness values of up to 23.1 GPa were determined. In the Al_2O_3-TiN nanocomposites, hardness values of up to 20.6 GPa were observed. The hardness values achieved were in line with those achieved in literature however this was particularly for the nanocomposites containing up to 30% of the reinforcing material. The nanocomposites containing 50% of the reinforcing material were typically found to have hardness values lower than expected, and they also had hardness and fracture toughness values that were lower than those of the micro-composites that were investigated.

The fracture toughness values obtained for the materials were relatively similar when comparing the Al_2O_3-TiC and Al_2O_3-TiN nanocomposites which contained similar amounts of the reinforcing components (TiC/TiN). The fracture toughness values determined were in the range of 2.2-3.1 MPa.$m^{0.5}$, however the Al_2O_3-3% TiC and the Al_2O_3-10% TiC nanocomposites sintered at 1800°C at a pressure of 30 MPa were the only samples with a fracture toughness higher than 3.0 MPa.$m^{0.5}$. The fracture toughness values achieved for the nanocomposites were lower than those reported in the literature for nano and micro-composites, as well as those obtained for the microcomposites sintered in this work.