C - 12

Applications and Thermal Durability of Aluminium Titanate Ceramics Having High Thermal Shock Resistance

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Abstract

Aluminium titanate (Al_2TiO_5) as structural ceramics is known as a low thermal expansion, a low thermal conductivity, a low Young's modulus, and excellent thermal shock resistant material. These properities allow for the testing as an insulating material in engines for portliner, piston bottom an turbo charger. However, those composites has low mechanical strength due to the presence of microcracks developed by the large difference in thermal expansion coefficients along crystallographic directions exceed the internal strength of material and its tendency to decompose into Al_2O_3 and TiO_2 at temperature below 1300°C limit however the application of aluminium titanate.

It is known that the thermal instability of Al_2TiO_5 can be thermodynamical stabilized by solid solution with MgO, Fe_2O_3, or Cr_2O_3 in the aluminium titanate lattice, which are isomorphous with the mineral pseudobrookite (Fe_2TiO_5), $MgTi_2O_5$, or $(Al,Cr)_2TiO_5$ so that polycrystall aluminium titanate can be existed as metastable or stable form at temperatures below 1300°C. Al_2TiO_5 can be kinetical stabilized by limitation of grain growth and microcracks with additivers as SiO_2, ZrO_2, α-Al_2O_3, or mullite, almost of which form not solid solution with aluminium titanate, so that it was restrained the tendency towards decomposition of Al_2TiO_5.

Attempt to improve the thermal durability (800-1300°C) of aluminium titanate, a new thermal shock resistant material consists of a two phase material based on aluminium titanat-mullite in different proportions will be created by reducing the particle size or by adjusting composition Al_2O_3/TiO_2/SiO_2-ratios.

Aluminium titanate-mullite composites with varying chemical compositions was prepared by the stepwise hydrolysis of $Si(OC_2H_5)_4$ and $Ti(OC_2H_5)_4$ in an Al_2O_3 dispersion. All particles produced by sol-gel-proess were amorphous, monodispesed and with a narrow particle size distribution. Sintered bodies at 1600°C for 2h were subjected to prolonged durability tests - on the one hand annealing at the critical decomposition temperature of 1100°C for 100h and on the other cyclic thermal shock between 750 and 1400°C for 100h. The microstructural degradation of samples studied with the helps of scanning electron microscopy, X-ray micro-analysis, X-ray diffraction, and dilatometer, is presented here. The relation between thermal shock resistance and mechanical strength, Young's modulus, and thermal expansion coefficient is investigated. The study was conducted in order to be able to predict the service life of aluminium titanate-mullite ceramics formed by this processing route.

The thermal expansion properties of the investigated aluminium titanate-mullite composites show several effects not encountered with dense ceramics, e.g. a pronounced non linear stress-strain relationship at room-temperature, as well as the effects of thermal contraction and expansion curves under thermal load. These phenomena are explained by the opening and closing of microcracks. Aluminium titanate was good stabilized by the composition with mullite (20-30 vol%). With increasing mullite content Young's modulus, thermal expansion coefficient, room temperature strength, and relative density increased. Those with 80, 70, and 50 vol% aluminium titanate have excellent thermal shock resistance due to the presence of microcracks.