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# Mechanical and Tribological Properties of Alumina – Graphene Composites

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## Extended Abstract

Alumina and other structural ceramics capable to work in high temperatures are subject of research in many studies and major programmes over last few decades. They are characterized by high hardness, low density, good thermal shock resistance, creep resistance, high thermal conductivity, corrosion resistance as well as good tribological and wear properties. Those properties make ceramic widely used in materials industry and applied in many fields covering bio-sensors, dental implants, bearing balls, gas turbine engine parts, heat exchangers, transparent conductors or wear resistance parts (Liu et al., 2013). Main problems with ceramic applications is their low fracture toughness and fabrication difficulties as reported by other authors (Porwal et al., 2013).

Due to its unique combination of electrical, mechanical and thermal properties, graphene can greatly improve properties of obtained composites (Walker et al., 2011), and it works as good second phase filler in ceramic composites. Its addition to alumina matrix helps overcoming relatively low fracture toughness of ceramic as previously shown (Wozniak et al., in press). However, there are several problems in fabricating such composites including high graphene quality, homogenous distribution of graphene in ceramic matrix or degradation of graphene during conventional sintering methods.

This study concerns the production method of alumina - graphene composites and influence of second phase on mechanical and tribological properties of obtained sinters. To receive composites with uniform distribution of graphene the powder metallurgy technique was used. To provide required quality following commercial substrates were used: $\alpha$-$Al_2O_3$ powder (Taimei Chemicals CO., LTD.), with chemical purity of 99.99% and the average particle size of 135 nm and commercial Gn powder (Graphene Supermarket) with chemical purity of 99.9% and the average flakes size of 4 nm. The powders were wet blended with the use of attritor type mill in isopropyl alcohol for 8 hours. As previously reported by other authors to be good method for ceramic composites sintering (Wang et al., 2011), Spark Plasma Sintering (SPS) technique was used. It allows for processing with high heating rate and relatively low temperature, which prevents degradation of graphene and grain growth of ceramic matrix.

In order to obtain composites with high mechanical properties, optimization of sintering process was carried on for both $Al_2O_3$ and $Al_2O_3$-graphene where changing parameters were sintering temperature, dwell time and heating rate. In this paper optimal sintering conditions were used to prepare three samples with different graphene weight content $Al_2O_3$-x% wt Gn (where x = 0.5/1/2) and two samples of pure $Al_2O_3$ as reference specimens. Physical properties such as density, hardness, Young's modulus and fracture toughness were analyzed. All sinters reached high relative density (above 98%) and the highest fracture toughness ($K_{IC}$=6.31 MPa*$m^{0.5}$) was measured for composite with 1% wt graphene. Tribological

test were carried out with ball-on-disc method with use of ceramic ball to measure friction coefficient and wear rate. Tests made in room temperature (23°C) showing lowest wear disk rate ($W_{s(disc)}*10^{-6}=0.06$ $mm^3/Nm$) for composite with 1% wt graphene. Further researches will be done on sinters: tribological tests in high temperature (600°C) and machining tests with square cross-section cutting tool to measure tools life and surface roughness parameter.

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