The effect of graphene reinforcement on the properties of TiO_2

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Abstract

The effect of graphene nanoplatelets (GNP) reinforcement on the microstructure and mechanical properties of the titanium dioxide matrix composite was studied. For this purpose, TiO_2 matrix composites with various reduced graphene oxide (rGO) concentration of 0, 0.5, 1, and 2 wt% were sintered by spark plasma sintering (SPS) at the1200°C during 5 minute holding time and under 90 MPa pressure. Graphene oxide was mixed with TiO_2 by ultrasonical excitation for 2 hours, leaded by temperature treatment at 300°C -30 min in vacuum environment. Process was accomplished by graphene oxide reduction at 300°C. Conducted process gave uniform distribution of GNP layers in the TiO_2 matrix and covered each particle of titanium dioxide with graphene nanoplatelets. Microstructure and mechanical properties of sintered samples were investigated. The fractured-sectional SEM images of processed samples showed that porosity slightly increases depending on concentration of GNPs. Hardness and fracture toughness were investigated after Vickers indentation analysis. Electrical resistivity measurements were performed by the two-probe method. Resistance measurement was done in two orientations of the samples, perpendicular (σ⊥), and parallel (σ||) to the SPS pressure axis, because of the specific anisotropic nature of the graphene and SPS densification.

Charts presented below as a figure 1 shows Hardness (a), fracture toughness (a) and electrical conductivity (b) values depending on concentration of GNPs. Graphene takes an important role in the prevention of grain growth as well as acting as the barrier for crack propagation and increasing its fracture toughness. Maintained microhardness and 4.5 times increased fracture toughness revealed the advantage of composite with 1wt% of GNPs compared to pure TiO_2. The higher conductivity occurs for all samples in the perpendicular direction due to the TiO_2 crystalline and morphologic textures formed by uniaxial pressing applied during the sintering. Pure TiO_2 shows approximately10 times lower conductivity with comparison to the samples with 1wt % of GNPs. In parallel measurement for 0.25 and 0.5wt%, GNPs additive slightly improves the conductivity of pure TiO_2 but not at the same rate as in perpendicular measurement. The percolation threshold was obtained between 0.5wt% and 1wt% GNPs where the conductivity jumps up from 1 to 9 S/m (Fig. 1b). It turned out that 1wt% GNPs is already a sufficient amount to fill up around the matrix grains, affect the electrical conductivity and acquire 23 times higher conductivity for pure TiO_2 ceramic.

FIGURES

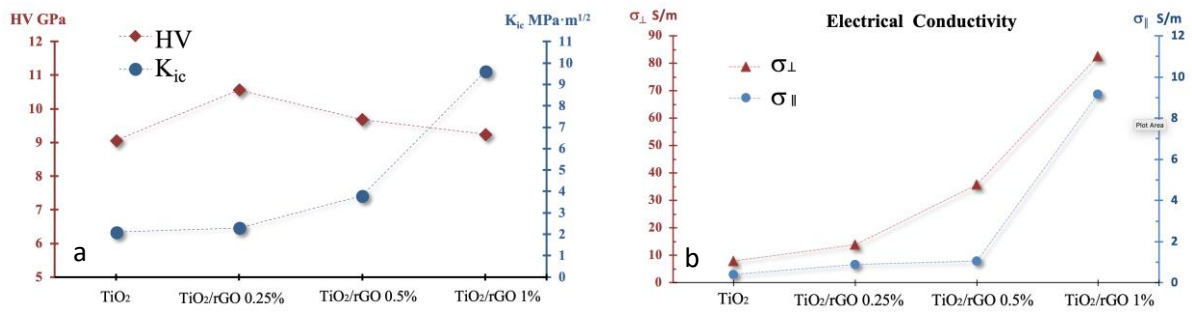

Figure 1: Chart of (a) HV, fracture toughness and (b) electrical conductivity of TiO_2 ceramic with the dependence of GNPs concentration