ZIRCONIA-BASED COMPOSITES REINFORCED BY CARBON NANOMATERIALS*

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In this work, ZrO_2 composites reinforced by single-walled carbon nanotubes (SWCNT “Tuball”, OCSiAl, Russia), multi-walled carbon nanotubes (MWCNT “Taunit”, NanoTechCenter, Russia), and graphene nanoplatelets (GNP, NanoTechCenter, Russia) were investigated. The composites were obtained by spark plasma sintering in vacuum in the following mode: sintering temperature – 1500 °C, holding time – 10 min, and uniaxial load – 40 MPa. ZrO_2 nanopowder was mixed with carbon nanomaterials (CNM) in ethanol using an ultrasonic bath and a magnetic stirrer [1, 2]. The concentration of SWCNTs, MWCNTs, and GNPs in composite powders was 1 wt.%. The influence of various CNM on the relative density (ρ_{rel}), microhardness (H_V), and fracture toughness (K_{IC}) of zirconia-based composites was investigated. Individual SWCNTs have an outer diameter of about 2 nm, but there are bundles with a diameter of about 200 nm (Fig. 1a), specific surface area of SWCNTs is 546 m^2/g. MWCNTs have a bamboo-like structure (Fig. 1b), their diameter is 20-50 nm, and their specific surface area is 103 m^2/g. GNPs with n ~ 15-25 layers (Fig. 1c), thickness of the nanoplates 6-8 nm, and their size 2-10 μm, the specific surface area is 25 m^2/g.

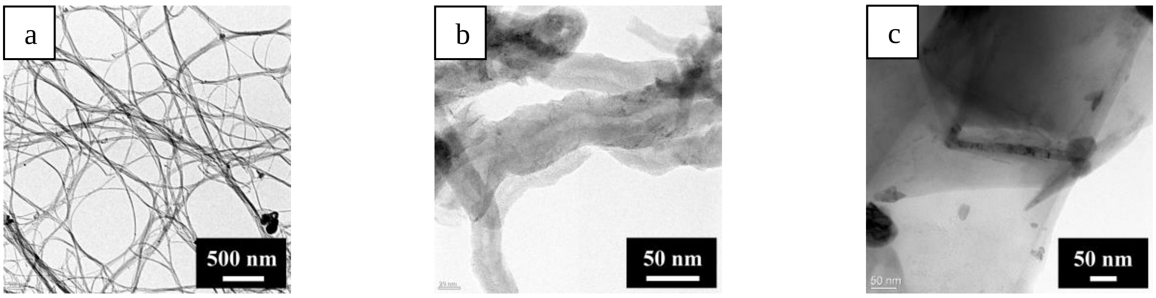

Fig. 1. TEM images showing the morphological features of the SWCNT (a), MWCNT (b) and GNP (c).

The relative density of ZrO_2/SWCNT composite (Table 1) decreases from 98.26 % to 95.50 %, which is associated with the strong agglomeration of SWCNT, which prevents the rearrangement of ZrO_2 particles during compaction/sintering, that increases the free volume. However, in composites with MWCNTs and GPNs, where reinforcing additives are not highly aggregated and have a lower specific surface area, the ρ_{rel} increases, since CNMs can slip during compaction and fill pores. The microhardness of the composites is lower than that of ZrO_2 ceramics (Table 1), because CNMs are a soft phase. The fracture toughness of ZrO_2/SWCNT composite increased by 38 %, ZrO_2/MWCNT composite by 8 % and ZrO_2/GNP by 31 %, compared with ZrO_2 ceramics. Increased fracture toughness of composites is associated with the hardening mechanisms inherent in fibrous/layered composites, which are described in our previous works [3, 4].

Table 1. Properties of the studied samples.

Sample	ρ_{rel}, %	H_V, GPa	K_{IC}, MPa*$m^{1/2}$
ZrO_2	98.26	14.10	3.96
ZrO_2/SWCNT	95.50	11.61	5.48
ZrO_2/MWCNT	99.03	13.47	4.27
ZrO_2/GNP	99.58	13.09	5.19

REFERENCES

[1] A.A. Leonov, E.V. Abdulmenova, “Alumina-based composites reinforced with single-walled carbon nanotubes,” IOP Conf. Ser.: Mater. Sci. Eng., vol. 511, pp. 012001, 2019. https://doi.org/10.1088/1757-899X/511/1/012001.

[2] A. Leonov, “Effect of alumina nanofibers content on the microstructure and properties of ATZ composites fabricated by spark plasma sintering,” Materials Today: Proceedings, vol. 11, pp. 66–71, 2019. https://doi.org/10.1016/j.matpr.2018.12.108.

[3] A.A. Leonov, et al., “Ceramic composite based on zirconia reinforced by single-walled carbon nanotubes,” Nanotechnol. Russia, vol. 14, pp. 118-124, 2019. https://doi.org/10.1134/S1995078019020095

[4] A.A. Leonov, et al., “Effect of electron beam irradiation on structural phase transformations of zirconia-based composite reinforced by alumina nanofibers and carbon nanotubes,” J. Phys.: Conf. Ser., vol. 1393, pp. 012106, 2019. https://doi.org/10.1088/1742-6596/1393/1/012106

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