IRRADIATION BY A LOW-ENERGY PULSED ELECTRON BEAM OF ZIRCONIA-BASED COMPOSITE*

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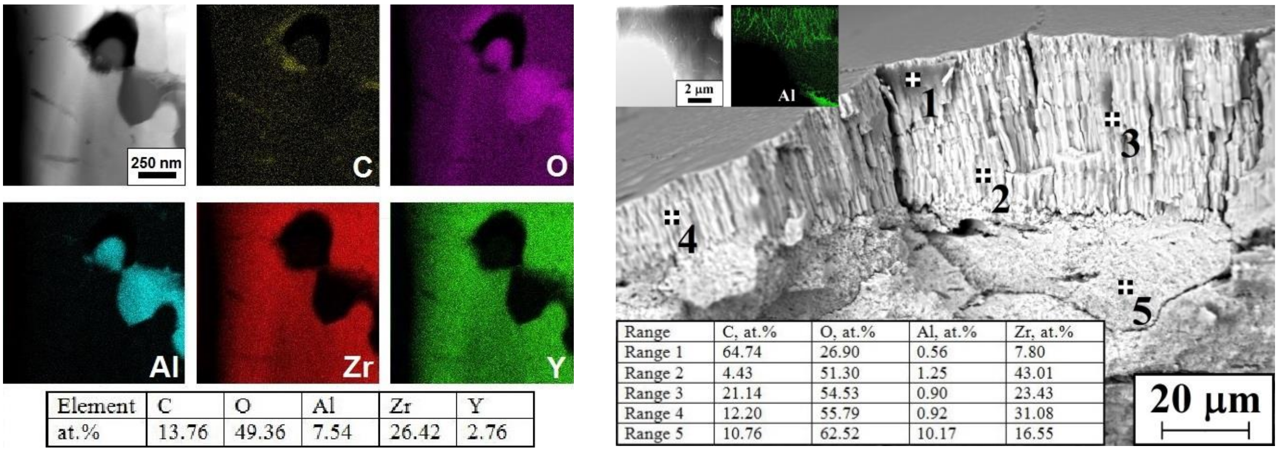
In this work, tetragonal zirconia-based composite prepared by spark plasma sintering, modified by 5 wt% alumina nanofibers and 0.5 wt% single-walled carbon nanotubes, was investigated. Similar composites were investigated in previous work [1]. Irradiation by a low-energy pulsed electron beam of the submillisecond duration was carried out on the device "SOLO" [2] in the following mode: beam energy density – 15 J/cm^2, pulse duration – 200 μs, pulses quantity – 10, 20, 30, and 40, and pulse repetition rate – 0.3 Hz.

The initial composite material (Fig. 1a) consists of ZrO_2 matrix, in which there are alumina grains of complex elongated shape and carbon nanotube bundles, which are uniformly distributed in the matrix. Such composite possesses improved mechanical properties (microhardness and fracture toughness increase by 1.4 % and 17.2 %, respectively), as compared to ZrO_2 ceramics without additions.



Element	C	O	Al	Zr	Y
at.%	13.76	49.36	7.54	26.42	2.76

Range	C, at.%	O, at.%	Al, at.%	Zr, at.%
Range 1	64.74	26.90	0.56	7.80
Range 2	4.43	51.30	1.25	43.01
Range 3	21.14	54.53	0.90	23.43
Range 4	12.20	55.79	0.92	31.08
Range 5	10.76	62.52	10.17	16.55

(a) (b)

Fig. 1. STEM image of the sample before irradiation and element mapping of same area (a); SEM image of the cross section of composite after electron beam processing at 40 pulses. Areas are marked and numbered for which the elemental composition (table) is determined (b).

It has been established that electron beam treatment leads to the formation of modified surface, the thickness of which varies from 5–10 μm to 100 μm. Modified volume is multi-layered (Fig. 1b): the upper layer has a columnar structure; the intermediate layer between the surface layer and the base material consists of equiaxed grains with sizes from 0.5 μm to 1 μm, that more grain size (~ 0.25 μm) of the initial material.

XRD analysis showed that, the initial composite contains tetragonal modification of zirconia (t-ZrO_2) and a small amount of α-Al_2O_3. In the irradiated samples, in addition to t-ZrO_2 and α-Al_2O_3, a new compound Zr–Al–O (zirconium aluminum oxide) appears.

According to the EDS method results, Al atoms in the initial composite form Al_2O_3 nanofibers, which are preferentially, located parallel to the sample surface. In the modified layer, when irradiated by an electron beam, the Al atoms form thin interlayers along the boundaries of the columnar grains (inset in the upper left corner of Fig. 1b).

REFERENCES

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