Microstructure and High Temperature Oxidation Behavior of ZrB_2-ZrO_2-$MoSi_2$-Al Coatings for the Protection of Carbon/Carbon Composites

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The ZrB_2-ZrO_2-$MoSi_2$-Al composite coatings were prepared on the carbon/carbon composite using a new multi-chamber detonation accelerator by thermal spraying methods from micro-powders. The initial powders ZrB_2-x$MoSi_2$ (x = 24, 35, 45 wt %) with 5 wt % Y_2O_3 and 20 wt % Al. Y_2O_3 were successfully used as a stabilizer of the high temperature tetragonal and cubic modification of zirconia. Aluminum was added as an oxidizing agent during spraying and creating "plastic" lamellae and nano-dispersed inclusions, relieve internal stresses. In the present work, the microstructure, elemental and phase composition of coating were investigated by scanning electron microscopy (SEM) and X-ray diffraction (XRD) before and after annealing at 1500°C in air for 1 h.

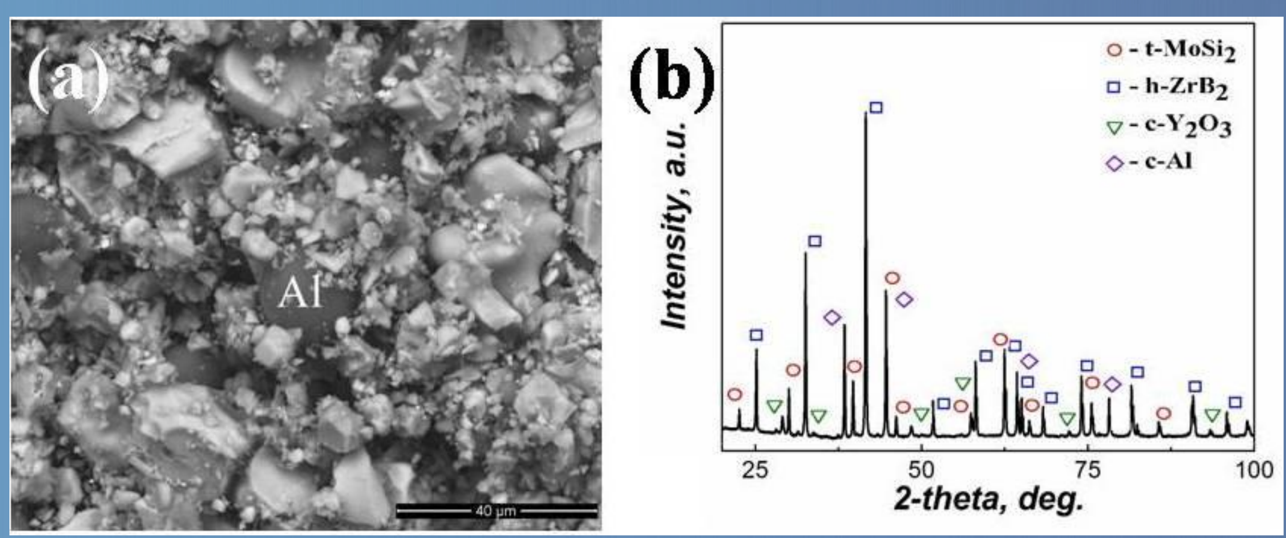


Figure 1. SEM-BSE micrograph (a) and XRD diffraction pattern (b) of the composite powder ZrB_2-$MoSi_2$-Al.

MCDS multi-chamber detonation accelerator

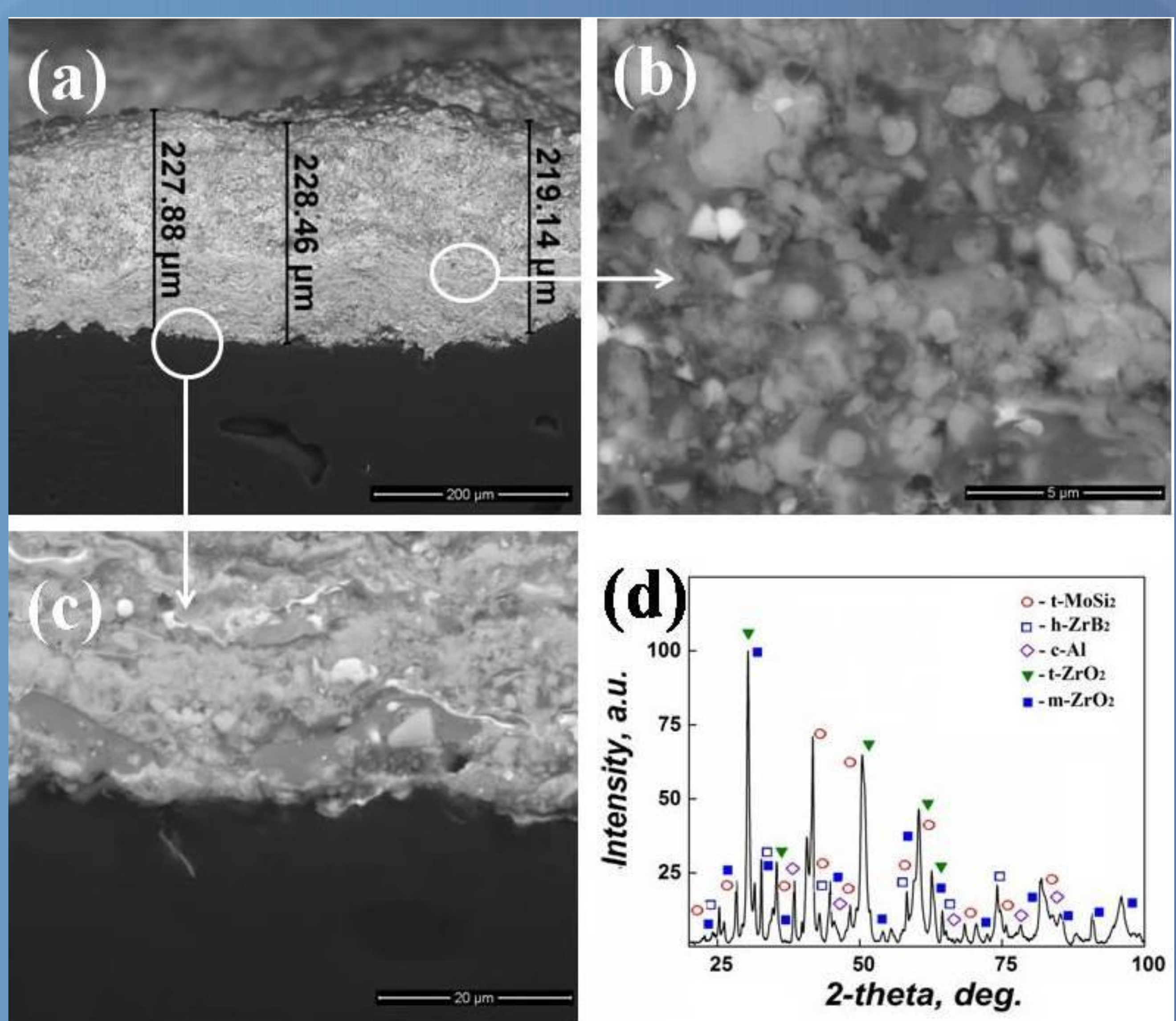
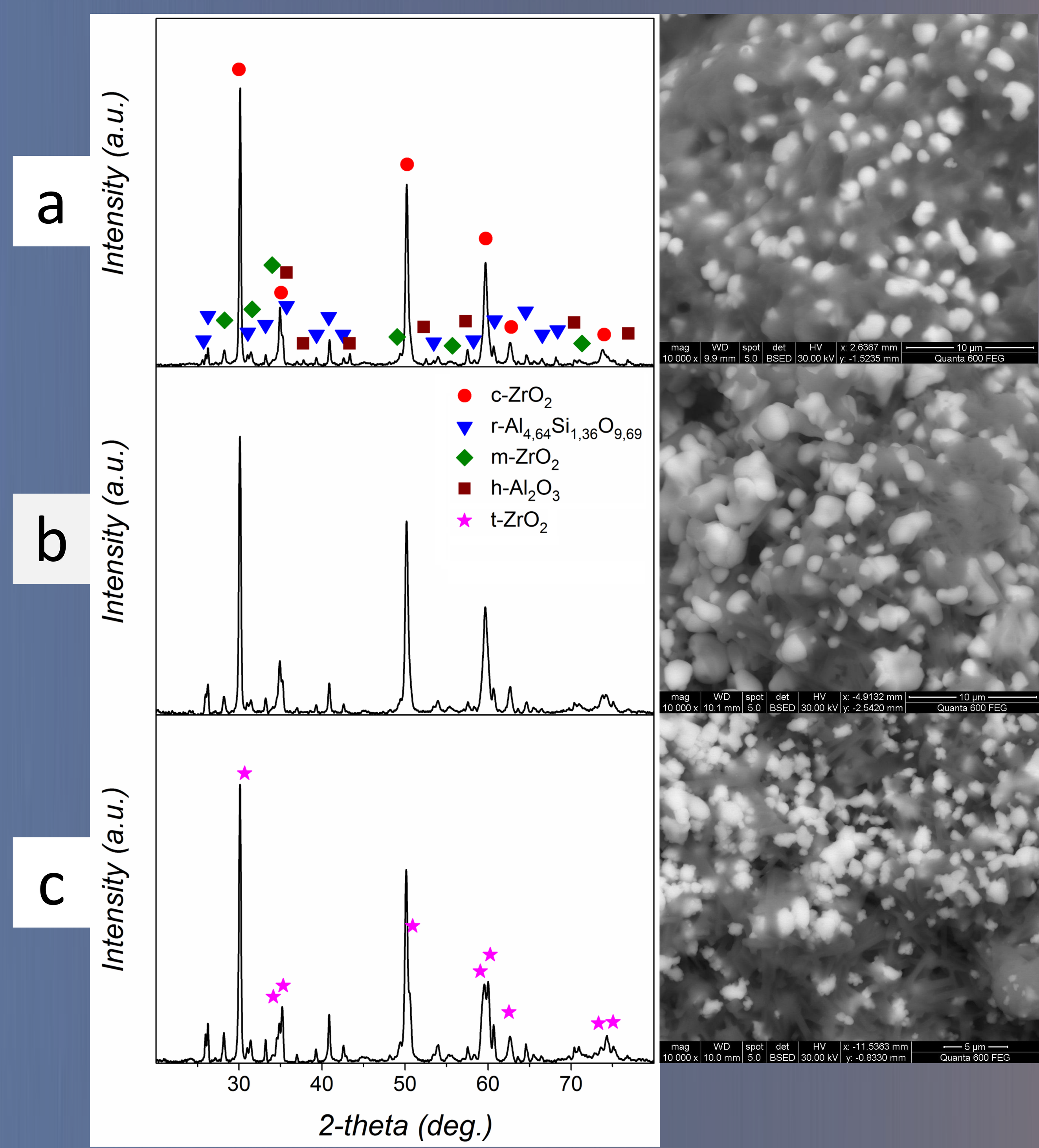


Figure 2. Cross-section SEM-BSE micrographs of the ZrB_2–$MoSi_2$-Al coating: general view (a), high magnification (b), coating–substrate interface (c), and XRD diffraction pattern.

high-temperature oxidation 1500 °C

White phase (globular grains) consists of ZrO_2, the **light gray phase** is mullite ($3Al_2O_3 \cdot 2SiO_2$), amorphous SiO_2 and Al_2O_3 with a hexagonal crystal lattice.



	Coating	Phase composition, %				
		c-ZrO_2	o-$Al_{4.64}Si_{1.36}O_{9.69}$	m-ZrO_2	h-Al_2O_3	t-ZrO_2
a	Zr24MoY/20Al	35	47	5	13	-
b	Zr35MoY/20Al	35	57	6	2	-
c	Zr45MoY/20Al	5	62	3	-	30

Figure 3. XRD patterns, SEM-BSE micrographs and phase composition of composite coatings ZrB_2-$MoSi_2$-Al after high-temperature oxidation.

- Uniform dense coatings with good adhesion to the substrate were obtained, the bulk of the coating material was deformed and tightly packed, but the presence of unmelted zirconium particles in the coatings was observed. The porosity of the composite coatings was 0.02-1.00%.
- The visible boundary of the adhesion of the composite coatings to the C/C substrate has no defects. In the contact zone of the coatings and the substrate, a mixed structure is observed, consisting of coating islands in the substrate with different shape and size. Some of the powder material has penetrated deeply and is firmly bonded to the substrate material.
- Composite coatings consist of tetragonal and monoclinic ZrO_2, hexagonal ZrB_2, fcc-Al, tetragonal $MoSi_2$.
- It was found that an increase in the content of $MoSi_2$ in the initial powder mixture during high-temperature oxidation of the coating formed from it leads to an increase in the content of mullite ($3Al_2O_3 \cdot 2SiO_2$), which is formed in the form of the finest intertwined needle-shaped crystals.
- It was shown that an increase in the $MoSi_2$ content in the initial powder mixture during high-temperature oxidation of the coating formed from it leads to one-sided diffusion of SiO_2 into the Al_2O_3 grain with the formation of mullite. In place of the initial glass phase SiO_2, pores are formed.

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