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Characteristics of ZrB_2-ZrO_2-$MoSi_2$-Al coating on carbon/carbon composite obtained by a new multi-chamber detonation accelerator

M G Kovaleva[1], I Yu Goncharov[1,2], V Yu Novikov[1], M N Yapryntsev[1], O N Vagina[1], I N Pavlenko[1], V V Sirota[2], Yu N Tyurin[3] and O V Kolisnichenko[3]

[1]*Belgorod State National Research University, Belgorod, Russia*
[2]*Belgorod State Technological University V.G. Shoukhov, Belgorod, Russia*
[3]*E.O. Paton Electric Welding Institute NASU, Kyiv, Ukraine*

E-mail: kovaleva@bsu.edu.ru

Abstract: The ZrB_2-ZrO_2-$MoSi_2$-Al coating was prepared by a new multi-chamber detonation accelerator on carbon/carbon (C/C) composites without adhesion sublayer. The microstructure of the coating showed the laying characteristics of completely molten and partially molten areas had as lamellar-like structure. The coating was dense, homogeneous, and well connected with C/C composite substrate without sublayer. Void content in coating is 0.5±0.05% as determined by image analysis.

1. INTRODUCTION

Carbon/carbon (C/C) composites compared with traditional materials have higher strength characteristics, resistance to thermal shocks and other advantages. [1]. However, application of C/C during prolonged exposure to high temperature is limited by the internal reactivity of carbon with oxygen above 500ºC [2-4]. In this study, a ZrB_2-$MoSi_2$-Al coating was chosen as the oxidation protective coating for C/C composites, and a new multi-chamber detonation accelerator (MCDS) was used to form this coating.

2. EXPERIMENTAL

The composition of powder 80 (71ZrB_2 - 24$MoSi_2$ - 5Y_2O_3) – 20 Al, all in wt% (figure 1a) with particle size in range of 1-25 µm was used to deposit a dense layer on the carbon/carbon composites. Flat specimens (10×10×5 mm) of 3D C/C composites (density of 1.9 g/cm^3) were used as substrates. The composite powder was prepared by solid state mixing route. Yttrium oxide was added as a stabilizer of zirconia [5,7]. Aluminum was added to bind the oxidizing agent to the spraying process and to relieve internal stresses [6,7].

In the present study, a new multi-chamber detonation accelerator (MCDS) [7–9] was employed to deposit the ZrB_2-ZrO_2-$MoSi_2$-Al coating. The coating was deposited with a frequency of 20 Hz, the movement speed - 1500 mm/min, the distance - 80 mm, the powder feed rate - 850 g/h. A barrel with a throat diameter of 16 mm and length of 500 mm was adopted. The flow rate of the fuel mixture components (m^3/h) was oxygen (4.0*/3.6**), propane +butane (0.75*/0.68**) and air (0.12*/0.12**) (*cylindrical form combustion chamber, **combustion chamber in the form of a disk). The powder and cross-section surfaces of the samples were investigated using a scanning electron microscope (SEM) (Quanta 600 FEG). Porosity was determined by metallographic method using an Olympus

GX51 microscope. The phase composition was determined by diffractometer Rigaku Ultima.

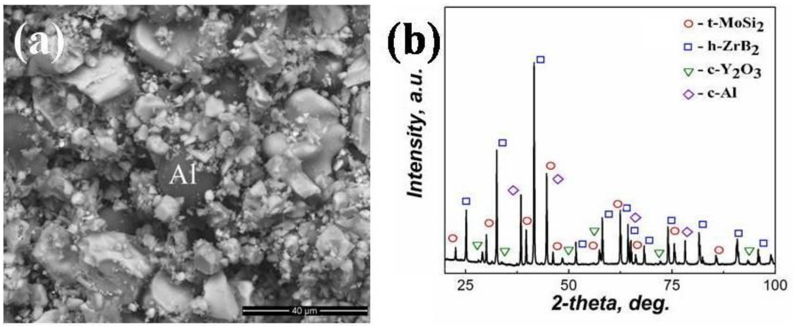

Figure 1. SEM-BSE micrograph (a) and XRD diffraction pattern (b) of the composite powder.

3. RESULTS AND DISCUSSION

Thickness of the coating was 200-250 μm (figure 2a). The porosity of the coating was 0.5±0.05%. The coating shows a very dense microstructure consisting of well-flattened particles (figure 2b), and small amount of unmelted particles. There is a good adhesion between the coating and the substrate. The penetration of coating particles into C/C composites occurs due to the destruction of the binding material between the carbon fibers. Such a mechanism of engagement provides high adhesion bond strength. (figure 2c).

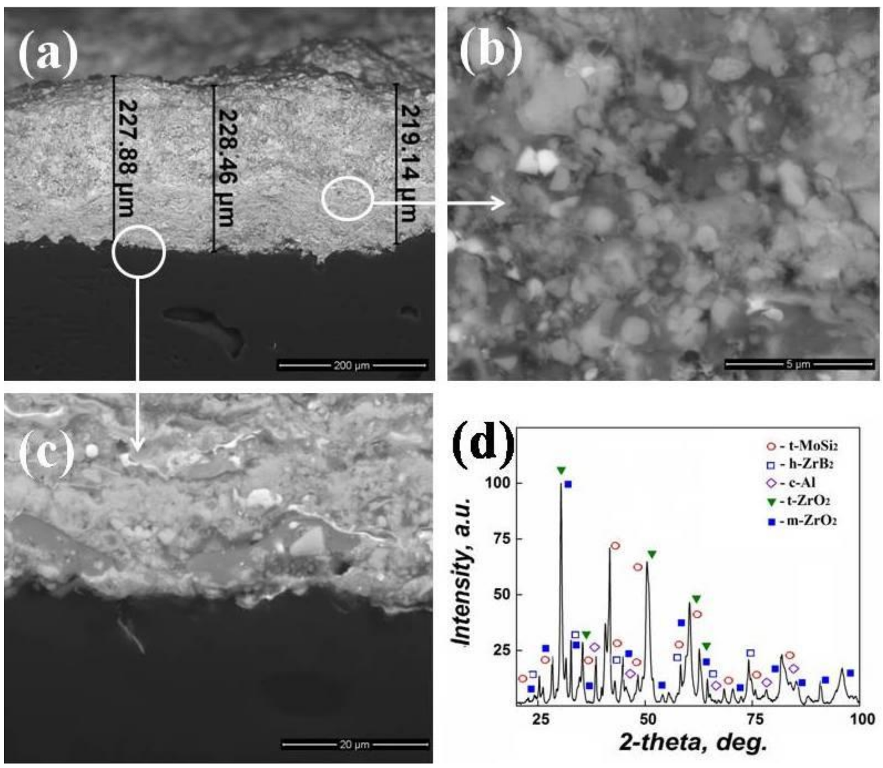

Figure 2. Cross-section SEM-BSE micrographs of the ZrB_2–$MoSi_2$-Al coating: general view (a), high magnification (b), coating–substrate interface (c), and XRD diffraction pattern (d).

The XRD pattern of the as-received powder is shown in Figure 1b. It can be seen that the powder was composed of t-$MoSi_2$, h-ZrB_2, c-Y_2O_3, and c-Al phases (figure 1b). The material of the powder partially reacted with the oxygen to form new phases during spraying process [3,4]. The tetragonal $MoSi_2$, hexagonal ZrB_2, cubic Al, some monoclinic zirconia (m-ZrO_2), and yttria-stabilized tetragonal zirconia were identified in the coating (figure 2d). MoO3 and B2O3 were hardly detected by XRD due to its fairly low concentration. (figure 2d).

4. CONCLUSIONS

It was established that no cracks in coating, and the coating well bonded with the C/C substrate. Experimental results confirmed that the ZrB_2-ZrO_2-$MoSi_2$-Al coating could be synthesized on C/C composite by MCDS without adhesion sublayer. The resistance to oxidation of ZrB_2-ZrO_2-$MoSi_2$-Al coating may be related to the positive effect of Y_2O_3, which stabilized ZrO_2. The results of the work open up prospects for the further development of a new technology for producing a high-quality ceramic layer that can improve the properties of carbon-carbon composites and can also serve as the basis for the formation of protective heat-resistant coatings.

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REFERENCES

[1] Devi G, Rao K 1993 *Def. Sci. J.* **43** 369.
[2] Jacobson NS, Curry DM 2006 *Carbon* **44** 1142.
[3] Lu W, Qian-gang F, Ning-kun L, Sun J 2016 *J. Therm. Spray Technol.* **25** 1280.
[4] Niu Y, Wang Z, Zhao J, Zheng X, Zeng Y, Ding C 2017 *J. Therm. Spray Technol.* **26** 100.
[5] Liu X, Han W, Wen K, Deng C, Liu M, Zhou K 2017 *Ceram. Int.* **43** 16659.
[6] Li CJ, Ohmori A 2002 *J. Therm. Spray Technol.* **11** 365.
[7] Kovaleva M, Goncharov I, Novikov V, Yapryntsev M, Vagina O, Pavlenko I, Sirota V, Tyurin Y, Kolisnichenko O 2019 *Coatings* **9** 779.
[8] Vasilik N, Tyurin N, Kolisnichenko O 2012 *RU Patent* 2506341.
[9] Kovaleva M, Tyurin Y, Vasilik N, Kolisnichenko O, Prozorova M, Arseenko M, Danshina E 2013 *Surf. Coat. Technol.* **232** 719-725.