M. GÓRAL, M. PORĘBA, T. KUBASZEK, K. OCHAŁ, M. DRAJEWICZ

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STRUCTURE AND THICKNESS OF Y_2O_3 COATINGS DEPOSITED BY PLASMA SPRAY PHYSICAL VAPOUR DEPOSITION (PS-PVD) METHOD ON GRAPHITE

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Graphite is one of materials used in metallurgical applications; however, it is characterized by low oxidation resistance. In the article, an yttrium oxide coating was deposited using Plasma Spray Physical Vapour deposition method (PS-PVD) on graphite. Next, the influence of selected process parameters (power current, powder feed rate, or plasma gasses composition) on coating thickness and structure were discussed. The obtained coatings were characterized by hybrid structure with partially formed columns. The linear relationship between power current and coating thickness was observed. There was no significant influence of other analyses' process parameters on coating thickness or microstructure.

Keywords: ceramic coating, Y_2O_3, PS-PVD, thickness, structure

INTRODUCTION

Different types of coatings for protection of graphite were developed such as oxides (Al_2O_3), SiC-based, SiO_2, Si-Hf-Cr, Si-Zr-Cr, Si-Ti, or graded ZrB_2-SiC-Si [1]. The atmospheric plasma spraying method might be used for production of protective coatings for graphite. The Vacuum Plasma Sprayed tungsten on graphite with Ti and SiC bond coats were investigated by Cho and Choe [2]. Plasma spraying of zirconia and alumina oxides was investigated by Mestrati et al. [3]. Application of Y_2O3 by plasma spraying on ultra-density graphite with SiC bond coat was developed by Madhura et al. [4]. Use of different plasma sprayed oxides Y_2O_3, $ZrO_2(Y_2O_3)$ and $CaZrO_3$ was also considered [5]. A combination of alumina and titania oxides was also plasma sprayed on graphite [6]. Pure yttria oxide on graphite was developed by Rao et al. [7]. Another method of SiC formation as a bond coat for Y_2O_3 plasma sprayed coating was investigated by Vertivendan et al. [8]. The other concept of bond coat is SiC-ZrB_2 [9]. Conventional partially –stabilized zirconia usually used in TBCs application is also plasma sprayed on graphite [10]. Among other APS-sprayed materials is tantalum carbide [11]. Plasma spray physical vapour Deposition (PS-PVD) is a promising technology for ceramic coating production for aerospace [12], medical [13], and glass-industry [14] applications. It enables formation of both columnar and dense structure of ceramic coating [15]. Different types of ceramic materials are YSZ [16], $Gd_2Zr_2O_7$ [17], $La_2Ce_2ZrO_7$ [18], and $YbSi_2O_5$ [19]. In our previous research we developed the YSZ coating formation on graphite [20]. The present article discusses the Y_2O_3 coating on graphite surface using PS-PVD method, as developed by ourselves.

M. Goral email: mgoral@prz.edu.pl, M. Poręba, T. Kubaszek, K. Ochal, M. Drajewicz, Department of Materials Science, Rzeszow University of Technology, Rzeszow, Poland.

EXPERIMENTAL PROCEDURE

The FN-1 type commercial graphite was used as base material. Samples with diameter 50 mm were cut for 4 mm thick bars. Amperit 849.007 (Hoganas) ytrria oxide powder was used for experimental (Table 1). A ceramic coating was deposited by the Plasma Spray Physical Vapour Deposition (PS-PVD) Method using LPPS-Hybrid System (Oerlikon-Metco) in Research and Development Laboratory for Aerospace Materials at Rzeszow University of Technology. The samples were pre-heated using plasma torch prior to the deposition process. There is no information about deposition parameters of Y_2O_3 using the PS-PVD process, hence typical parameters previously developed for YSZ were assumed as basic values in the experimental plan (Table

Table 1 **Basic parameters of the powder used in the PS-PVD experimental process**

Powder name	Amperit 849.007
Chemical Formula	Y_2O_3
Chemical Name	Yttria
Particle morphology	Agglomerated, sintered
Particle Sizes Available/μm	90/16
Particle Size Distribution/μm	D 90 / %: 85-99 D 50 / %: 47-57 D 10 / %: 20-30

Table 2 **Parameters used for production of ceramic layers of Y_2O_3 in the PS - PVD experimental processes**

Power Current/A	1 400, 1 800, 2 200
Argon Flow/NLPM	35, 48, 60
Helium Flow/NLPM	60, 48, 35
Powder Feed Rate/g/min	2,5, 5, 10

2). Three factors were altered during the process: power current; powder feed rate, and plasma gas composition. The microstructure of the obtained samples and thickness were examined using an SEM microscope (Phenom XL). The XRD phase analysis was conducted using an X-ray diffractometer ARL X'TRA Thermo Scientific Corporation (CuKα radiation Bragg–Brentano geometry value of the angle 20°–90°).

RESULTS AND DISCUSSION

Surface morphology and phase composition

The x-ray diffraction phase analysis (XRD) showed the presence of Y_2O_3 compliant with the Amperit 849.007 powder composition (Figure 1). On the surface, the presence of formed columnar crystals and small spheroidal particles was observed (Figure 2). This type of structure is usually formed when coarse powders have been used [15].

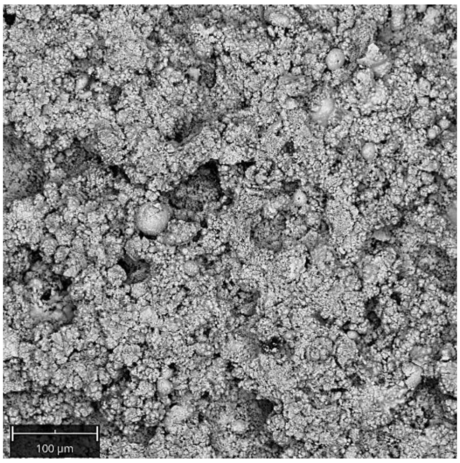

Figure 1 Surface morphology of a Y_2O_3 layer made with 2 200 A power current

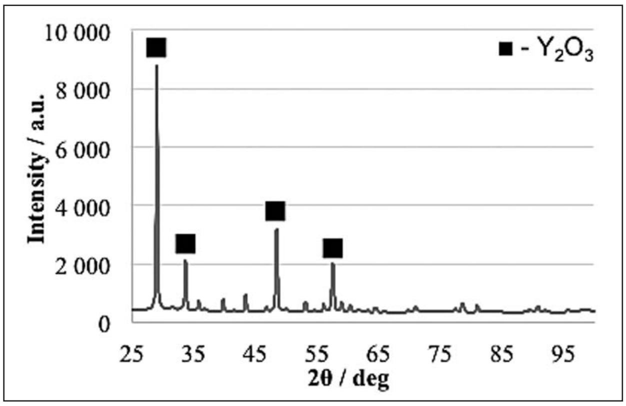

Figure 2 An XRD pattern of the Y_2O_3 layer made in PS-PVD process using 2 200 A power current

The influence of power current

Microstructure of the obtained coating was characterized by hybrid structure. Columns and spheroidal grains were observed [17] (Figure 3). Between the columns, there were observed small spheroidal particles. They were formed as a result of secondary crystallization of material observed in longer spray distance of PS-PVD processes reported by Zhang et al. [21]. When the power current was increased, coating thickness rose from about 95 µm (1 400 A) to almost 170 µm (2 200A) (Figure 4).

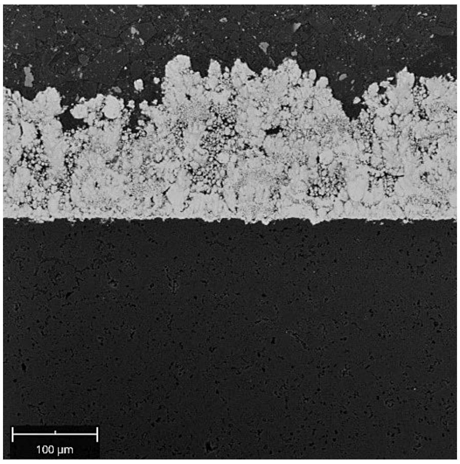

Figure 3 Microstructure of the Y_2O_3 layers made with 2 200 A power current

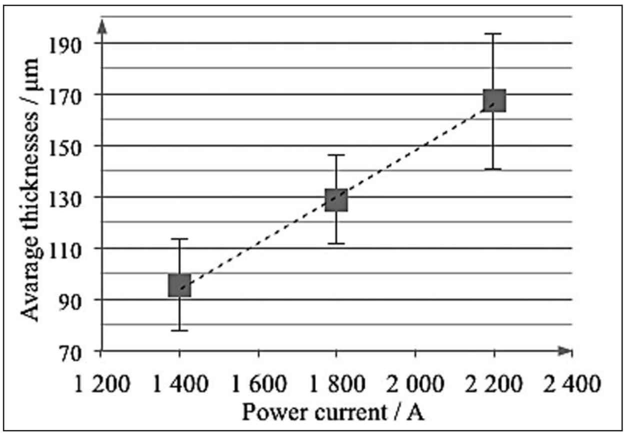

Figure 4 Average thickness for the Y_2O_3 layers produced using different power current values

The influence of powder feed rate

The coatings formed using different powder feed rate (2,5, 5, 10 g/min) were characterized by hybrid structure. There was no significant relationship between powder feed rate and coating thickness. The obtained coatings were characterized by thickness in range 90-130 µm (Figure 5).

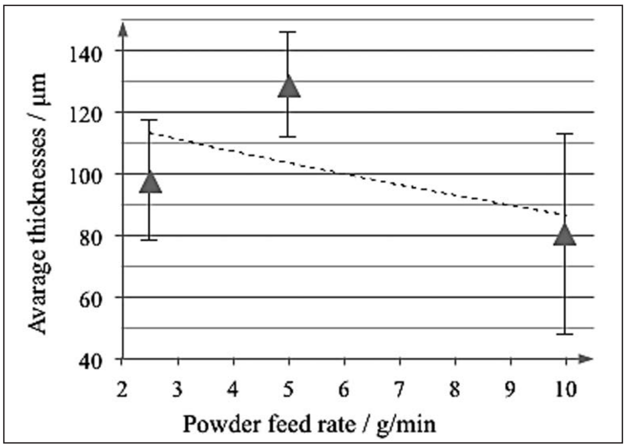

Figure 5 Average thickness for the Y_2O_3 layers produced using different powder feed rate values

The influence of plasma gasses composition

The average thickness of coating was in range 80-100 mm. It was characterized by hybrid structure observed in previously described experimental processes. In coatings obtained using different plasma gas composition, large spread of thickness was observed (Figure 6). The increasing of He content in plasma gasses composition enabled to obtain layer about 130 μm thick. The helium increases the plasma enthalpy and enables to melt and evaporate higher amount of ceramic powder [15, 20].

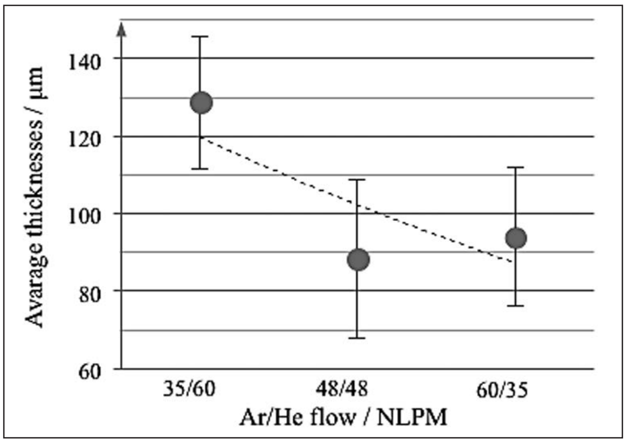

Figure 6 Average thicknesses for the Y_2O_3 layers produced using different Ar/He flow rate values

SUMMARY

The process parameters for deposition of yttrium oxide on the FN-1 graphite using PS-PVD process has been established. Hybrid structure was characterized by presence of columns and lamellar areas [21]. The typical columnar structure characteristics for YSZ coatings produced in PS-PVD process of coating were not formed [12]. In the conducted research, coarser powder was used (Table 1), so as not to allow for complete evaporation of powder. Additionally, there appeared small spheroidal particles between columns. This was observed in coatings produced using powders of fine and coarse grain size [16, 21]. It was a result of secondary crystallization of ceramic material [21]. The achieved results showed that PS-PVD is an effective method of ytrria coating production on graphite for metallurgical application. In further research, fine-grain powder should be used for formation of columnar structure of the Y_2O_3 coating.

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