Colloids and Surfaces A: Physicochem. Eng. Aspects xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Colloids and Surfaces A: Physicochemical and Engineering Aspects

journal homepage: www.elsevier.com/locate/colsurfa

Effect of electron beam remelting on the characteristics of HVOF sprayed Al_2O_3-TiO_2 coatings deposited on titanium substrate

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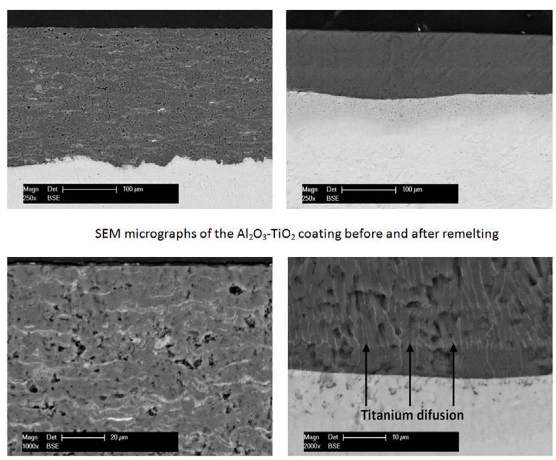
HIGHLIGHTS

- HVOF sprayed ceramic coatings (Al_2O_3 + 13 wt.% TiO_2) were deposited onto the surface of a titanium substrate.
- To improve their characteristics the coatings were further remelted by electron beam (EB) remelting.
- The coatings properties were evaluated in terms of microstructure, phase composition, corrosion and sliding wear resistance.
- EB-remelting of Al_2O_3-TiO_2 coatings surface is a solution for improvement the titanium sliding wear resistance.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 27 June 2016
Received in revised form 11 October 2016
Accepted 14 October 2016
Available online xxx

Keywords:
HVOF sprayed coatings
Corrosion behaviour
Sliding wear resistance

ABSTRACT

The primary objective of this study was to improve the wear resistance of titanium by depositing on its surface a HVOF (high velocity oxygen fuel) sprayed Al_2O_3-TiO_2 coating subsequently remelted by electron beam (EB).

The microstructure of the feedstock material, as-sprayed and EB remelted coatings was investigated by scanning electron microscopy (SEM) and X-Ray diffraction techniques (XRD). The effect of EB treatment on the coatings characteristics especially concerning the morphology, the hardness respectively the corrosion and wear behaviour was also analysed.

The results indicated that remelting process improved the coating properties in terms of porosity, strength and chemical homogeneity. The coating adherence to the substrate was strengthened by means of metallurgical bonding and interdiffusion processes.

The sliding wear resistance and the hardness of the coating were significantly higher in comparison with that of the titanium. The densified material obtained after the EB remelting had the highest sliding wear resistance and its corrosion behaviour was not strongly influenced compared with that exhibited by the substrate material.

1. Introduction

Titanium and its alloys have been developed rapidly due to their promising merits of high strength to weight ratio, high yield

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http://dx.doi.org/10.1016/j.colsurfa.2016.10.034
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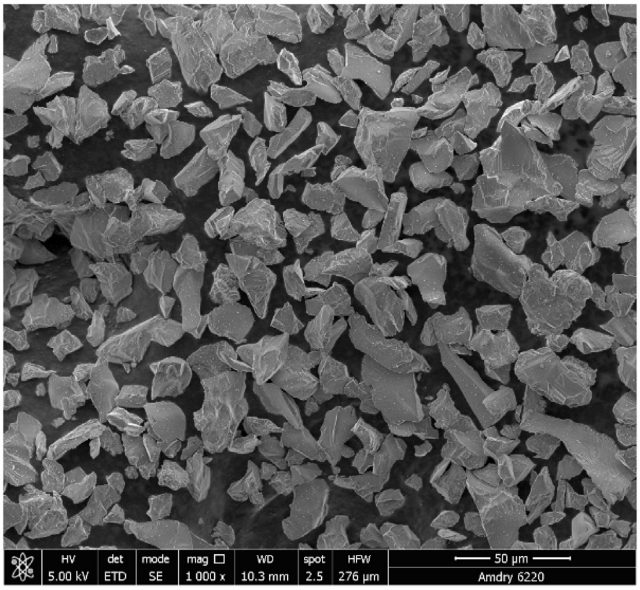

Fig. 1. SEM micrograph of the Al_2O_3-TiO_2 powder.

strength and toughness, good corrosion resistance as well as exceptional biocompatibility being used in several industrial applications ranging from aircraft components, chemical processing facilities to gas turbines engines [1,2]. However, titanium and its alloys have poor wear and abrasion resistance because of their low hardness, which definitely hampers their potential wider applications [3].

Thermal spraying coating deposition using ceramic materials is a viable method for improving the surface characteristics of titanium [4]. During this process the powders are melted and form small droplets which are accelerated toward the substrate, forming by solidification the protective coating. The properties of the resulted coating are usually strongly depend on their microstructure such as phase composition, lamellar stacking characteristics, grain size, porosity and its distribution [5].

Application of post treatments by high energy heat sources (laser, electron beam, welding methods) and triggering of the remelting effect of plasma sprayed coatings seems to be a very interesting solution for removing the above presented drawbacks [6,7].

Electron beam remelting is a well-established technique often used to reduce inherent defects resulted during coating spraying. Furthermore it can be used for surface alloying to enhance the adherence of coating to the substrate and to improve the surface properties. In the current study, Al2O3-TiO2 type coatings were deposited by HVOF thermal spraying method onto the surface of titanium substrate and further electron (EB) irradiated. The aim of this work is to investigate the microstructure and properties of Al2O3-TiO2 ceramic coatings in terms of wear and corrosion resistance before and after EB remelting process.

2. Materials and experimental procedures

Round specimens of 60 mm diameter consisting of commercial titanium were used as substrate material. The feedstock powder Al2O3-13. wt% TiO2 (Amdry 6220 powder from Oerlikon Metco) having a granulation of 5–35 μm was deposited by high velocity oxygen fuel (HVOF) spraying method at the University of Tampere Finland. Before depositions the surface was sand blasted and cleaned with acetone. The coating thickness was about 260 μm.

The powder and the HVOF deposited coating have been characterized in terms of the morphology by means of scanning electron microscopy (SEM: Philips XL-30 scanning electron microscope equipped with EDAX analyser).

The samples were remelted with an EBW700/6–60 CNC electron beam apparatus from firma PTR Praezisionstechnik Gmbh. The input power was 3 kW. The electron beam was focused onto the specimen, the irradiated surface was 100 mm^2. The coatings were remelted keeping constant the voltage respectively the current intensity for different periods of time.

Because of the low thermal conductivity and conductance of the Al_2O_3-13·wt% TiO_2 ceramics and in order to assure a full EB penetration depth, the coatings in as sprayed state were thinned by grounding until a thickness of about 100 μm.

The phase composition of coatings before and after EB remelting has been investigated by X-ray diffraction analysis using a Cu Kα radiation (Philips X'Pert Diffractometer).

The sliding wear behaviour was determined using the pin-on disk testing method by calculating the variation of the wear track depth with applied load. The equipment used was a micro pin on disk tribometer Tr-20 Micro from DUCOM-Material Characterization System. The operation conditions were: normal load 15 N, the relative velocity between the ball (WC) and surface v = 20 cm/s, and the testing distance were up to 1000 m (the trajectory was a circle with a radius of 15 mm).

The hardness of the coatings was determined using a ZHVμ micro Vickers hardness tester from Zwick/Roell Company applying a load of 300 gf (HV0.3).

The corrosion behaviour of the coating before and after EB remelting was determined by cyclic voltammetry using a three electrode cell in 3.5 wt.% NaCl solution.

3. Results and discussion

3.1. Powder and coatings morphology

The morphology of the feedstock material, presented in Fig. 1, shows an angular/blocky shape. The powder was fused and crushed having a fine size distribution (−35 + 5 μm).

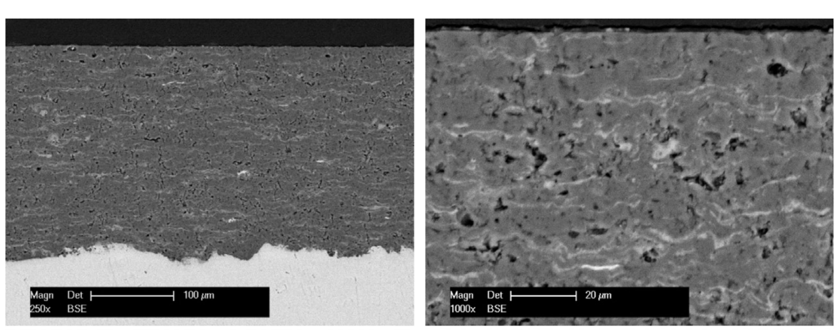

Fig. 2. SEM micrograph of the HVOF-sprayed coating.

Please cite this article in press as: I.D Utu, G. Marginean, Effect of electron beam remelting on the characteristics of HVOF sprayed Al_2O_3-TiO_2 coatings deposited on titanium substrate, Colloids Surf. A: Physicochem. Eng. Aspects (2016), http://dx.doi.org/10.1016/j.colsurfa.2016.10.034