DEPOSITION OF ALUMINA CERAMIC BIOCOMPATIBLE LAYERS BY PLASMA SPRAYING

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Abstract

Medical implants used in medicine are made by different alloys such as stainless steels, cobalt and chromium alloys, titanium and its alloys. Among these alloys, titanium has the most interest because of its properties: high strength, low density, very good corrosion resistance. To increase the biocompatibility, titanium alloys are coated with ceramic layers by diverse methods. Alumina (\(\text{Al}_2\text{O}_3\)) is a biocompatible ceramic material that is commonly used in orthopedic to cover the metallic implants. In recent years it can be observed the growing interest in making alumina hip prostheses due to the lower operating life of polymer-metal joints often used. From all the thermal spraying methods, in the case of ceramics coating, plasma thermal spraying presents the best results because of the high temperatures developed by the plasma jet which are sufficient to melt the ceramic particles.

The paper presents the experimental results on the deposition of alumina coatings on titanium alloy substrate by plasma thermal spraying method. X-ray diffraction performed on the powders used for coating and on the obtained layers shows that during the thermal spraying process the structure suffered minor changes. Scanning electron microscopy analysis shows that the deposited layers are dense, uniform and without cracks. The roughness of the deposited layers has values between 5.12 and 5.38 \(\mu\)m which will ensure a good osseointegration of the implant in the human body.

Keywords: plasma spraying, biomaterial, microstructure

1. INTRODUCTION

Biomaterials used in medicine include a very wide range of chemical compositions and structures being generally designed for other use but due to the specific characteristics may function in biological environments [1]. Biomaterials are used to replace totally or partially the form and the function of diseased tissue or organ, being also the interface with a biological environment [2].

In various biomedical applications, titanium and other titanium alloys are used for some other great features, such as shape memory properties or superelasticity, completely new properties compared with those of conventional metallic alloys [3].

In recent years, are used more and more these materials for realizing various prostheses (hip, knee, elbow, etc.) for replacement implants of various causes (accidents, disease) or different devices [4]. This justified also the increasing interest in the development of biocompatible materials and methods for obtaining them. Thus, the advantages of titanium and its alloys require research orientation towards achievement of more advanced and improved biomaterials with higher biocompatibility [5].

Alumina (\(\text{Al}_2\text{O}_3\)) is a biocompatible ceramic material that is often used for coating of medical implants and more often to the hip joint due to low friction coefficient, successfully replacing metal-polymer joints which have a lower lifetime due to the particles resulting from contact between the two materials which reach in the human body causing serious problems [6].

Alumina can be deposited on metal implants by various methods: thermal spraying, laser, magnetron sputtering etc [7]. From all the thermal spraying methods, plasma thermal spraying is the most appropriate method to deposit ceramic coatings due to high temperatures during thermal spraying process (\(\approx 16\ 000^\circ\text{C}\)) temperatures sufficient to melt the particles and creating the conditions for achievement the coatings [8].
The paper presents the experimental information regarding deposition of alumina coatings on titanium alloy and the characterization of the coatings.

2. MATERIALS USED
For the experimental program was used Al₂O₃ powder with the particle size of 11-62 μm acquired by Sulzer Metco Company. As substrate we used titanium alloy (Ti6Al4V) discs as Ø20x10mm. Sample preparation used as substrate was done by blasting. After blasting, the samples were cleaned with technical alcohol.

2.1 Thermal spraying equipment
For the experiments we use plasma thermal spraying equipment from Sulzer Metco. As plasma gas was used Ar+6%H₂ and as carrier gas pure argon was used. Figure 1 shows a schematic diagram of the plasma spraying process.

Due to the high temperatures, alumina powder melts and is driven by the plasma jet directly to the substrate. Particles reached the substrate surface in plastic state adhere based on specific mechanisms. Parameters used to achieve alumina coatings of are presented in Table 1.

<table>
<thead>
<tr>
<th>Plasma Current (A)</th>
<th>Plasma Voltage (V)</th>
<th>Primary Gas Flow (l/min)</th>
<th>Carrier Gas Flow (l/min)</th>
<th>Powder Feed Rate (g/min)</th>
<th>Spray Distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>75-80</td>
<td>50</td>
<td>15</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

2.2 Equipment used for investigation
Scanning electron microscope (SEM) Inspect S model coupled with the Energy-dispersive X-ray spectroscopy (EDX) was used to characterize the external surfaces. For the phases composition was used X Ray Diffractometer X’Pert Pro MPD PANalytical. For the coating thickness was used Easy Check F-N device, and for the coatings roughness Surftest 201 (SJ-201), Mitutoyo device was used.
3. EXPERIMENTAL RESULTS

3.1 X Ray Diffraction

Figure 2 shows the X-ray diffraction analysis of the alumina powder (Al₂O₃) and in Figure 3 is shown X-ray diffraction analysis of the alumina coating deposited by plasma thermal spraying.

![X-ray diffraction analysis of the of alumina powder](image1)

**Fig. 2** X-ray diffraction analysis of the of alumina powder

![X-ray diffraction analysis of the alumina coating](image2)

**Fig. 3** X-ray diffraction analysis of the alumina coating

X-ray diffraction analysis of the deposited layers shows that structure is formed by α-Al₂O₃ and γ-Al₂O₃. This suggests that the particles were sufficiently melted before reaching the substrate.

3.2 SEM analysis of Al₂O₃ powder

Figure 4 presents the morphology of alumina powder used for deposition by plasma thermal spraying in Figure 5 is presented the EDX analysis of the powder.
Fig. 4 SEM analysis of Al₂O₃ powder: a) 500x, b) 1000x

Fig. 5 EDX analysis of the powder
3.3 The microstructure of the $\text{Al}_2\text{O}_3$ coatings

In figure 6 are presented SEM images of alumina coating deposited by plasma spraying.

![SEM images of alumina coating](image)

**Fig. 6** SEM analysis of $\text{Al}_2\text{O}_3$ coating deposited by plasma thermal spraying: 1000x, b) 2000x

SEM analysis shows that alumina particles were melted by the plasma jet and were deposited with high speeds leading to the formation of dense and rough layers. The thicknesses of the deposited layers have values between 150 and 180 $\mu$m. The roughness values have values between 5.12 and 5.38 $\mu$m values that will ensure a good osseointegration of the implant in the human body due to increased contact surface.

4. CONCLUSIONS

1. The experimental program of realization and quality assessment of alumina coatings obtained by plasma thermal spraying aimed to determine the structure, characteristic microstructures and their roughness.
2. X-ray diffraction analysis of the deposited coating by plasma thermal spraying method shows that the structure is formed by $\alpha$-$\text{Al}_2\text{O}_3$ and $\gamma$-$\text{Al}_2\text{O}_3$, because the particles were melted before reaching the substrate.
3. SEM analysis shows that the alumina coatings are dense, compact and without thermal spraying defects such as cracks.

4. The roughness of the coatings has values between 5.12 and 5.38 μm, so the implant coated with alumina will provide a better osseointegration in the human body.

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LITERATURE


