Electrochimica Acta 302 (2019) 10–20

Contents lists available at ScienceDirect

Electrochimica Acta

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

DC plasma electrolytic oxidation treatment of gum metal for dental implants

Maciej Sowa [a, *], Michał Parafiniuk [a], Catarina M.S. Mouzêlo [a, b], Alicja Kazek-Kęsik [a], Ivan S. Zhidkov [c], Andrey I. Kukharenko [c], Seif O. Cholakh [c], Ernst Z. Kurmaev [c, d], Wojciech Simka [a, e, 1]

[a] Faculty of Chemistry, Silesian University of Technology, B. Krzywoustego Street 6, 44-100, Gliwice, Poland
[b] Faculdade De Ciências e Tecnologia, Universidade Nova De Lisboa, Calçada de Alfazina 2, 2825-149, Caparica, Portugal
[c] Institute of Physics and Technology, Ural State University, Mira Street 19, 620002, Yekaterinburg, Russia
[d] M.N. Miheev Institute of Metal Physics, Russian Academy of Sciences, Ural Branch, S. Kovalevskoi Street 18, 620990, Yekaterinburg, Russia
[e] Osteoplant Research and Development, Metalowców Street 25, 39-200, Dębica, Poland

A R T I C L E I N F O

Article history:
Received 11 October 2018
Received in revised form
28 January 2019
Accepted 5 February 2019
Available online 5 February 2019

Keywords:
Ti-Nb-Zr-Ta alloy
Plasma electrolytic oxidation
Bioactive coatings
Surface characterization
XPS

A B S T R A C T

Vanadium- and aluminium-free biomedical Ti alloys are getting more and more attention because of the harmful character of these alloying elements. For this reason, it was proposed to substitute them with more biocompatible elements such as Ta, Nb and Zr. So-called gum metal alloys (Ti-Nb-Zr-Ta systems) belong to β-type Ti alloys which are characterized by excellent biocompatibility and possess the modulus of elasticity more closely related to that of a human bone. The present study aims at elucidating the process stages during DC plasma electrolytic oxidation (PEO) of gum metal (Ti-36Nb-3Zr-2Ta alloy) in calcium hypophosphite-based electrolyte system. The effect of the stages on the surface characteristics of the obtained oxide coatings was also determined. The coatings were characterized using SEM/EDS, XPS and contact angle measurements. It was found that the process comprised at least five different stages. The initiation of relatively strong B-type sparks in the third stage of the treatment was necessary to induce significant incorporation of electrolyte components into the oxide coatings. As the treatment continued beyond that point, the composition of the oxide films was getting more similar to that of hydroxyapatite as it was determined from the valence band XPS spectra. The surface morphology of the films was also closely related to the process stage at which the further growth of the oxide was halted. The composition of the electrolyte (regarding the salts used and their concentration) had a tremendous influence on the duration of the process stages and the surface characteristics of the obtained films. The process was also tested for its usefulness in coating gum metal dental implants in order to form bioactive interfaces. Keeping the voltage below a certain limit (before the onset of more powerful surface sparks) was crucial to obtaining good-quality coatings.

1. Introduction

In medicine, metals and alloys are often applied in bone reconstruction because other groups of materials perform poorly under continual loads that are imparted by the motor functioning of the body. In this regard, titanium is an element of particular importance due to its low density, good load-bearing properties and lack of toxicity towards human hosts. Addition of alloying elements into the Ti matrix stabilizes the formation of α and β Ti phases the presence of which modifies its mechanical and corrosion performance. So far, one of the most popular bone implant alloys is Ti-6Al-4V ELI on account of its superior strength when compared to Cp Ti. However, the above-mentioned metallic materials exhibit high Young's modulus, which induces the stress-shielding effect, that is detrimental to the implant's long-term fixation [1–3].

Biomedical alloy researchers, being aware of the fact that both Al and V can exhibit harmful effects to the human body, started to develop a new generation of Ti alloys that were free of the

* Corresponding author.
E-mail address: maciej.sowa@polsl.pl (M. Sowa).
[1] ISE Member.

https://doi.org/10.1016/j.electacta.2019.02.024