SIMULATED BODY FLUID EVALUATION OF TITANIUM OXIDE LAYERS EXHIBITING DIFFERENT MORPHOLOGIES FORMED BY ELECTROCHEMICAL PLASMA COATING PROCESS

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Introduction

The passive layer of titanium, however, is bio-inert in nature, which could result in delayed adhesion of bone cells directly to a titanium implant surface [1]. In order for bioactive oxide layer of titanium, electrochemical plasma coating (EPC) process can be the optimum surface treatment to form the rough and porous surface, and nano-crystalline oxide layers with a predominant anatase phase in pure titanium as it allows for the control of electrolytes, current density, coating time, waveform and so forth [2]. Among those variables, the selection of a suitable electrolyte is a very important factor in adjusting properties of the titanium oxide since electrochemical reactions, of ionized chemical elements from the substrate and electrolyte, influence the generation of plasma bubbles and micro sparks [3].

In the present study, two different electrolytes, namely, tripotassium phosphate (TP) and potassium pyrophosphate (PP) were selected due to their harmlessness to the human body and complexing performance during EPC process. Thereafter, EPC coatings were carried out to investigate effects of these electrolytes on the properties of oxide layers associated with electrochemical reactions with dissociation enthalpy, and to observe the tendency of a biomimetic apatite formation in a simulated body fluid (SBF) solution.

Experimental

Commercially pure titanium (Grade II) plates were gradually ground with #200 to 1000 sand papers, ultrasonically cleaned in acetone, and dried at room temperature. The electrolytes were prepared by dissolving them in distilled water. For both electrolytes, the values of pH and electrical conductivity were approximately ~13 and ~23 mS/cm, respectively. EPC coatings were carried out using a 20 kW AC power supply at current density of 200 mA/cm^2 with a frequency of 60 Hz for 300 sec.

Results and discussion

Fig. 1 shows SEM images revealing surface morphologies of the EPC-treated samples under both conditions. The average size of pores found in the sample treated in TP electrolyte was fairly larger than that treated in PP electrolyte. The pit-like pores were present on the surface of the oxide layer from TP electrolyte (Fig. 3(a)),

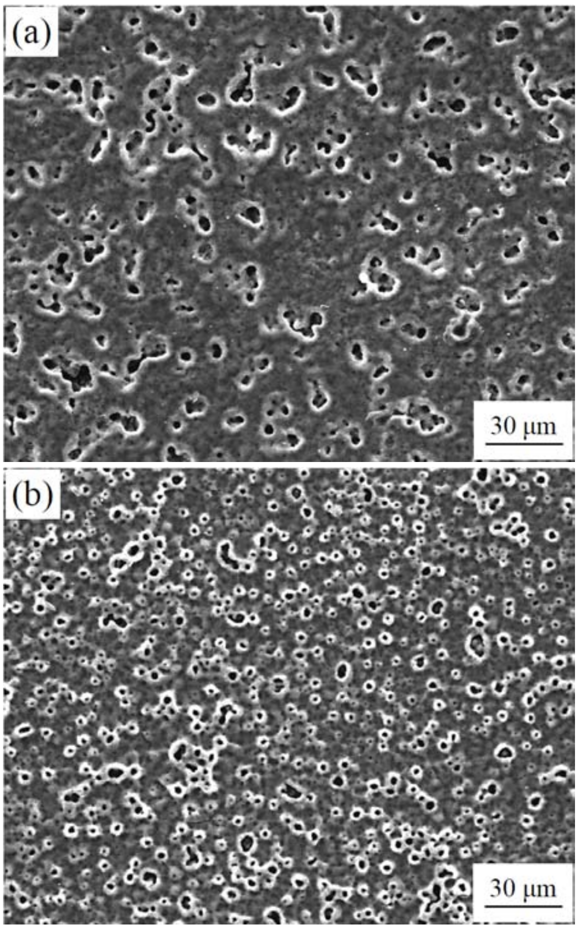

Fig. 1. Surface morphologies of oxide layers coated in (a) TP and (b) PP electrolytes.

whereas crater-like pores observed in the case of PP electrolyte (Fig. 3(b)). It has been established that the formation of micro pores was closely related to chemical interactions during plasma electrolysis.
Accordingly, The crater-like pores were, allowed us to predict that the surface roughness of the oxide layer coated in PP electrolyte was much rougher than that in TP electrolyte. This expectation was in quantitative agreement with the measurements where the values of R_a in the oxide layers coated in TP and PP electrolytes were estimated to be 2.28 ± 0.23 and 2.83 ± 0.35 μm, and R_q to be 3.18 ± 0.29 and 3.49 ± 0.33 μm, respectively (Fig. 2).

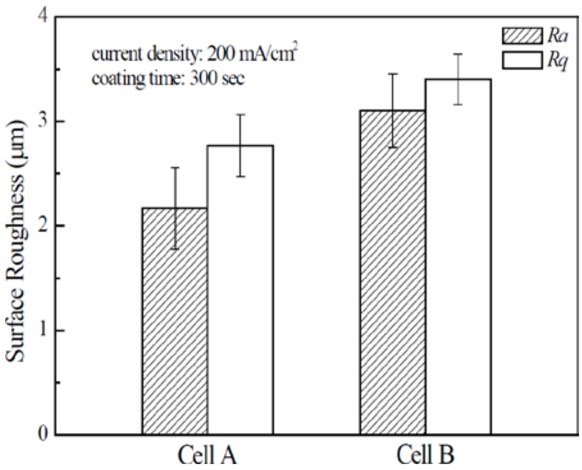

Fig. 2. Surface roughness of the oxide layers

Furthermore, it is worth noting that a great quantity of anatase phase was detected in the oxide layer coated in PP electrolyte by XRD analysis. In accordance with these results, it was predicted with relative certainty that the surface morphology of the oxide layer from PP electrolyte would reveal better biological properties than that from TP electrolyte.
As a result of SBF immersion tests, since the rough surface of oxide layer with the abundant anatase phases provided good sites for accelerating the precipitation and growth of the biomimetic apatite in the SBF solution, the sample coated in PP electrolyte exhibited high biological performance (Fig. 3).

Conclusion

It was found that, as compared to the oxide layer from TP electrolyte, the oxide layer from PP electrolyte possessed rougher surface as well as higher amount of anatase phase, leading to the excellent formation of the biomimetic apatite in the SBF solution.

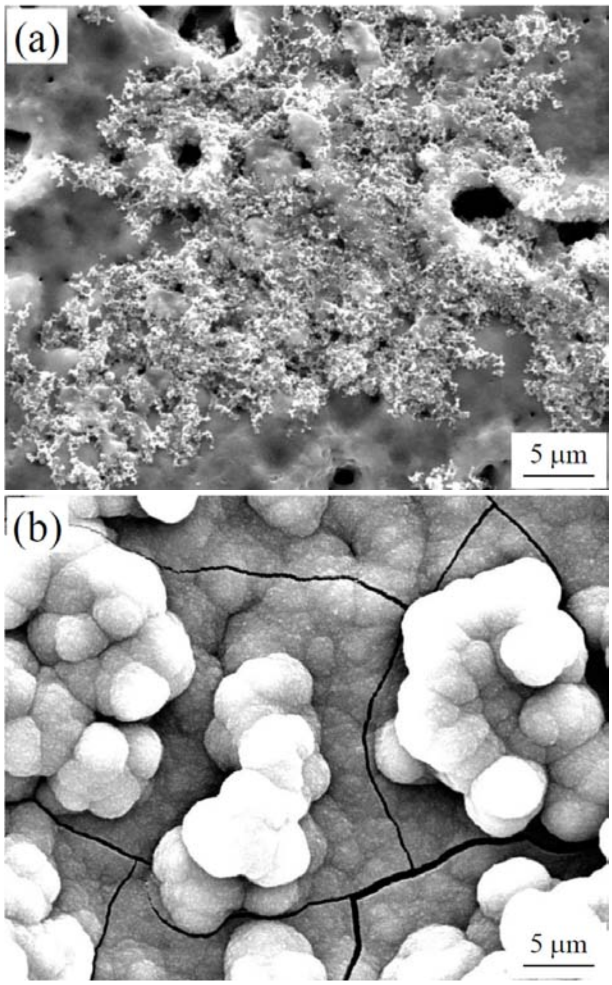

Fig. 3. Formation of the biomimetic apatite in the SBF solution for 14 days; (a) TP and (b) PP electrolytes

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