Anodic Oxidation of Titanium for Biomedical Application

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Abstract
Anodic oxidation is a chemical method which used to produce bioactive layer (oxide) of titanium (Ti). The aim of this study is to evaluate the effect of Ti anodic oxidation in an acetic acid ($C_2H_4O_2$). The anodic oxidation was performed by varying the applied voltage (10 – 200 V) and the concentration of electrolyte (0.5, 1.5 and 3.0 M of $C_2H_4O_2$). The Ti specimens were soaked in simulated body fluid (SBF) to observe the precipitation of hydroxyapatite (HAP). The anodized Ti was characterized using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The precipitation of apatite after soaked in SBF was observed using SEM. From this study, the applied voltage range from 100 to 200 V and/or high concentrations of acetic acid resulting in more porous surface (show peak formation of anatase) due to the arcing process which lead more nucleation (more sites for HAP growth) after soaked in SBF. The SBF result shows that the anodized Ti is suitable to be applied in biomedical as implant.

Keywords: Anodic oxidation, Titanium, Simulated Body Fluid, X-Ray diffraction,

Introduction

Titanium has used widely for biomedical application, especially as a hard tissue replacement due to desirable properties such as relatively low modulus, good mechanical properties, high corrosion resistance and biocompatibility [1]. This biocompatibility titanium needed surface modification to enhance the tissue compatibility and bonding between implant and bone called as bioactive layer. Anodic oxidation is a simple process and allows controlling the formation of a protective oxide surface layer which is much thicker than that formed naturally [2]. Fig. 1 shows the schematic diagram of the anodic oxidation apparatus [3]. The formation of apatite on the Ti surface can be done by using *in vitro* test (SBF) and the recipe same as prepared by Kokubo *et al* [4].

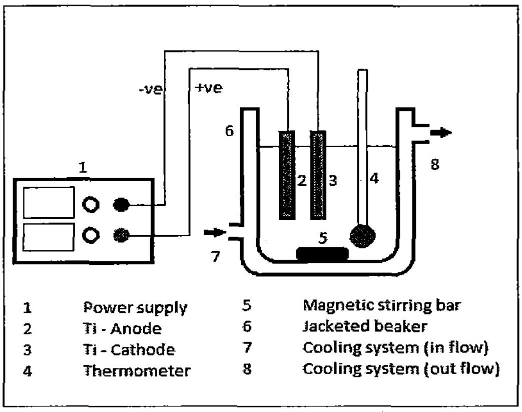

Fig. 1. Schematic diagram of the anodizing apparatus [3].

Experimental Method

The high purity titanium foil is polished using 1200 grit (~1 μm) abrasive paper, followed by rinsing with distilled water, and drying using compressed air. Anodic oxidation is done in an electrochemical cell containing aqueous solutions of acetic acid. The parameters for anodic oxidation are as shown in Table 1. After anodic oxidation, the anodized specimens are cleaned by dipping in distilled water and then dried in still air. Then, the anodized Ti specimens were soaked in 50 mL of SBF at ~37°C for six days. The mineralogical compositions of the films were determined using X-ray diffraction (XRD). The microstructures were examined using scanning electron microscopy (SEM).

Table 1. The parameters used for anodic oxidation

Parameter	Values(s)
Electrolytes	0.5, 1.5 and 3.0 M $C_2H_4O_2$
d.c voltage (V)	10, 20, 30, 50, 70, 100, 150 and 200
Temperature (°C)	~25
Duration (min)	10

Results & Discussion

The anodic oxidation changes the surface structure of Ti foil from amorphous to anatase under certain parameter. From the anodic oxidation, it shows that at low voltage (below 100 V) does not produce any arcing. It is because the acid that's been used in this study classified as a weak acid compared to other acids especially sulfuric and hydrochloric acid. The process needs high voltage to be able to do arcing process during anodic oxidation. The XRD images showed that through the anodic oxidation using voltage 100 to 200 V, resulting in anatase formation. This is because high voltage will result in a greater intensity of arcing (porous surface). More porous of the surface, more sites for nucleation will occur. Fig. 2 shows the mineralogy of the specimen by using XRD analysis. Fig. 3 shows supporting SEM micrographs of the Ti surfaces and validated the XRD analysis result.

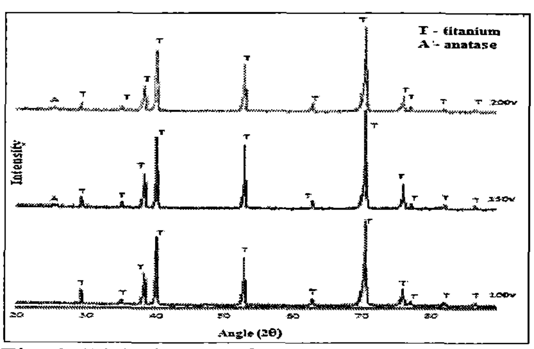

Fig. 2. XRD image of anodized Ti in 1.5 M of acetic acid (cell potentials 100 – 200 V)

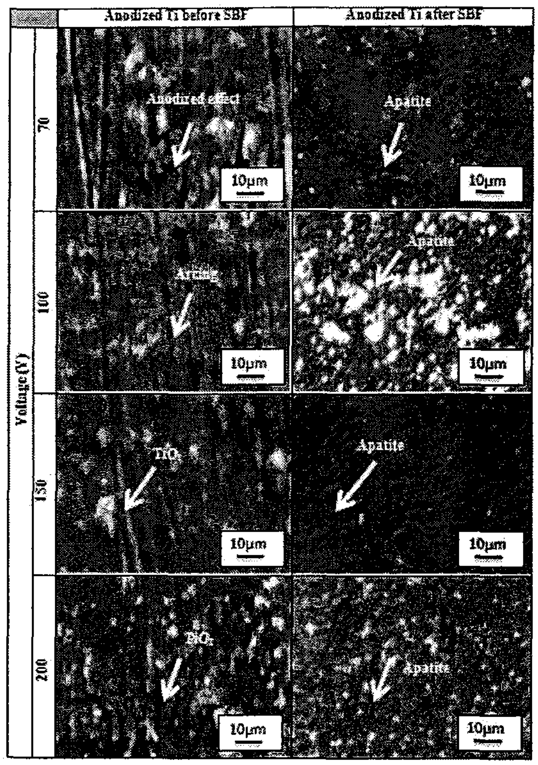

Fig. 3. SEM images of anodized Ti before and after soaked in SBF (1.5 M of acetic acid and voltage 70 – 200 V)

Conclusion

Anodic oxidation in $C_2H_4O_2$ with voltage 100 to 200 V provided a porous surface of Ti foil. The porous surface will lead more sites for apatite formation. All specimens are able to produce apatite after soaked in SBF. This anodized Ti has potential for bone growth and it is suitable to be used in biomedical application such as implant for hard tissue replacement.

References

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