Electrochemical Impedance Characteristics of Anodic Oxide Layer Formed on Titanium Binary Alloy Surface

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Abstract: In this study, electrochemical impedance characteristics of anodic oxide layer formed on titanium binary alloy surface have been investigated. Titanium oxide layers were grown on Ti-$_X$Ta and Ti-$_X$Nb(X=10, 20, 30 and 40 wt%) alloy substrates using phosphoric acid electrolytes.

1. Introduction

Titanium and Ti-6Al-4V have long been used as implant materials in dental and orthopedic application [1]. However, the Ti-6Al-4V alloy is currently utilized and should be replaced, since the release of Al and V ions causes long-term health problems. And it can also lead to resorption of adjacent bone tissue due to the great elastic modulus difference between the implant and bone [2-3]. Thus, there are efforts for developing new titanium alloys with non-toxic elements. Nb and Ta are found to reduce the elastic modulus when alloyed with titanium in certain preferred quantities. Recently, titanium oxide layer has been used for improving the biocompatibility of implants. The advantage of using titanium oxide layer is that it can be grown directly on the Ti and Ti alloys surfaces, by cost-effective techniques such as anodic oxidation. In this study, electrochemical impedance characteristics of anodic oxide layer formed on titanium binary alloy surface have been investigated.

2. Materials and Method

The Ti-Ta and Ti-Nb alloys were manufactured by arc melting on a water-sealed copper hearth under an argon gas atmosphere with a non-consumable tungsten electrode. These specimens were melted six times by inverting the metal for homogeneous structure. Ti-Ta and Ti-Nb alloys were homogenized in argon atmosphere at 1000℃(which is above the β transformation temperature) for 24h followed by a rapid quenching in ice water. The samples were incrementally polished by utilizing 120 grit emery paper down to 1200 grit emery paper. So chemically clean/etching for 5 min in 5.5M HNO_3 with HF (ACS grade, Fisher Scientific, Pittsburg, PA), rinse by distilled water and dried at nitrogen blowing. Titanium oxide layers were grown on Ti-$_X$Ta and Ti-$_X$Nb(X=10, 20, 30 and 40 wt%) alloy substrates using phosphoric acid electrolytes. The polished and cleaned binary alloy disks were anodized in solution containing typically 1 M H_3PO_4 at room temperature. A direct current (D.C) power source was used for the process of anodization. The applied voltages were given at the range of 140 to 260 V.

For electrochemical inpedance measurements, the cell consisted of conventional three-electrode configuration with Pt rod and a saturated calomel electrode (SCE) as the counter and reference electrode, respectively. All experiments were carried out in 0.9 % NaCl solution at 36.5±1℃. All the electrochemical data were obtained using a Potentiostat(EG&G Co. Potentionstat 2273, USA). The obtain data were analyzed using ZSimpwin (version 3.20) for EIS results.

3. Results

From the microstructure analysis, homogenized Ti-Ta alloys showed the martensite structure of α + β phase. Homogenized Ti-Nb alloys showed the equi-axed structure of β phase. Anodized surface, pore size and numbers were increased with increasing applied voltages. The polarization curves result of anodized binary Ti-Ta and Ti-Nb alloys were higher than those of the non-anodized Ti alloys in 0.9% NaCl solution. From EIS results, R_P values of anodized binary alloys were higher than those of the non-anodized binary alloys. (*Corresponding author : hcchoe@chosun.ac.kr)

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