Enhancing Biological Properties of Porous Coatings on Tantalum Through the Incorporation of Strontium

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Introduction: Titanium (Ti) and its alloys are ideally suited for implants due to their good biocompatibility. However, Ti lacks the level of osseointegration required for implant longevity. Recently, tantalum (Ta) is gaining more attention for new usages of metallic biomaterial. Ta can serve as a substitute for Ti, providing biological characteristics suitable substrates for osteoblast growth [1]. Implant covered with a porous surface that allows bone ingrowth fixation. In addition, the presence of bioactive CaP coatings improves a direct bone-implant contact the healing process [2]. Strontium (Sr), which increases bone formation and reduces bone resorption, is beneficial for biological applications for bone regeneration [3]. Strontium-substituted calcium of calcium phosphate has been studied [4]. The aim of this study was to fabricate Sr-Ca-P porous coatings on the Ta surface using the MAO technique and evaluated characteristics and biological responses.

Methods: The pure tantalum disks with a size of ϕ12.7×2 mm were used as substrates, and in accordance with the specification of ASTM F560-08. The electrolyte solution contains calcium acetate, sodium phosphate and strontium acetate. Ta disks were treated at an applied pulse voltage of 400 V, a pulse frequency of 1000 Hz and a duty ratio of 50% for 1 min. The compositions of the electrolyte were shown in Table 1. The surface morphology was observed by SEM with EDX for chemical analysis.

Results: Figure 1(A)-(F) presents the surface morphologies of various Ta-MAO specimens. The surface of the Ta became porous following spark discharges at a high applied voltage. These pores are well separated and distributed homogeneously over the surface. Figure 1(a)-(f) shows the results of EDX analysis which indicated that the strontium element in electrolytes can incorporate into MAO coatings. The results for ALP activity are shown in Figure 2. After 10 days culture cells grown on the CPS5 surfaces showed significantly higher ALP activity than other specimens. These findings demonstrate that the presence of strontium MAO coatings could enhance cell differentiation.

Table 1 Composition of the MAO electrolyte.

Specimens	Solution composition (M)		
	calcium acatate	sodium phosphate	strontium acetate
CP	0.13	0.06	-
CPS1	0.129	0.06	0.056
CPS5	0.124	0.06	0.279
CPS10	0.117	0.06	0.558
CPS25	0.098	0.06	1.396
CPS50	0.065	0.06	2.791

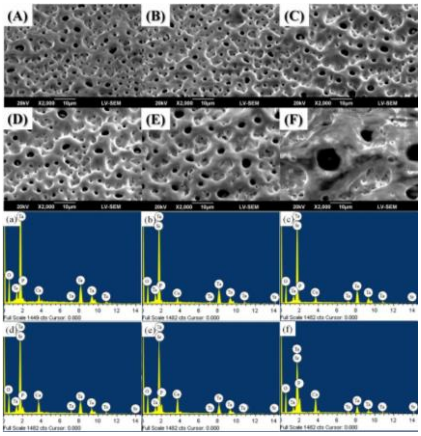

Figure 1. Morphologies of the MAO coatings formed in the electrolytes with different strontium content: (A) CP, (B) CPS1, (C) CPS5, (D) CPS10, (E) CPS25, and (F) CPS50. EDX spectra of the MAO coatings: (a) CP, (b) CPS1, (c) CPS5, (d) CPS10, (e) CPS25, and (f) CPS50.

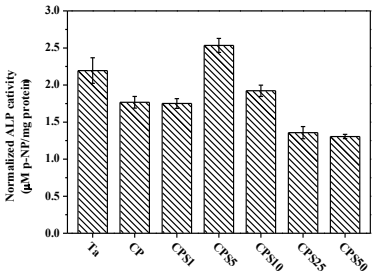

Fig.2. ALP activity of MC3T3-E1 cells on various specimens after 10 days culture.

Conclusions: The MAO process produced three-dimensional structures with open pores on the tantalum surface. The electrolyte containing strontium, calcium, and phosphorus has been applied to produce coatings with Sr-Ca-P phase embedded in the Ta_2O_5 matrix. EDX results indicate that Sr, Ca, and P were successfully incorporated into the coatings. According to in vitro tests, CPS5 specimens were significantly increased in cell differentiation. The modified Ta could be alternative untreated Ta for bone repair applications. All measurements indicate that optimal strontium was incorporated into MAO coatings, which could be beneficial for cell behaviors.

References:

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