Misan Journal for Academic studies
Vol 22 Issue 47 September 2023
مجلة ميسان للدراسات الاكاديمية
مجلد 22 العدد 47 أيلول 2023

ISSN (Paper) 1994-697X

Online 2706 -722X

https://doi.org/10.54633/2333-022-047-028

The microhardness Property of the Biomedical commercially pure titanium-strontium oxide composite alloy after anodic oxidation

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Abstract

high level of corrosion resistance, a high strength to weight ratio, and bio-compatibility, titanium as well as its alloys are extremely valuable today because of its enchanted qualities. With the use of sulfuric acid as electrolyte in the electrochemical circuit, the formation of anodic films and variations in aesthetic appearance regarding anodized titanium titanium-strontium oxide composite alloy surface are examined in the work that is currently being presented. This article concentrates on the most recent advances of a novel, commercially pure titanium-strontium oxide composite alloy that has been anodized. With regard to biomedical applications, strontium oxide was added in a particular quantity (6%) by wt.%. With the use of microhardness testing device, the impact of strontium oxide additions and anodic oxidation were examined. The findings show that strontium oxide additions increase microhardness. Additionally, titanium alloys with 6 wt.% strontium oxide microparticle additions that have been anodized exhibit no difference than those that have not been anodized. The produced strontium oxide-cp titanium composite alloy offers significant potential for use as a biomaterial, particularly in dental applications, as evidenced by high wettability and increased roughness.
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Keywords commercially pure Titanium · strontium oxide· Powder metallurgy· microhardness ·

1 Introduction

Because of their highly advantageous physical, chemical, physiological, and mechanical qualities, titanium (Ti) and its alloys were extensively employed as bio-medical materials and have found multiple uses as artificial bones and as other forms of bio-compatible implants. They meet several selection criteria, but in particular, their chemical resistance when in contact with the fluids and tissue that are found in the human body makes them appropriate materials for the implants [**Kim et al 1997, Ducheyne et al 1986].**Numerous works have shown that modifying surfaces with inorganic metal ions including zinc (Zn), magnesium (Mg), and strontium (Sr) insertion can achieve rapid osseointegration and encourage the production of new bone [**Martin et al 2017, Safi et al 2019].** Marie et al.'s newly released review study detailed how SrO influences bone formation and resorption by promoting osteoblast differentiation and survival and pre-osteoblast replication. Pre-osteoclast differentiation was also observed to be decreased concurrently by SrO **[Marie et al 2011, Tukmachi et al 2023].**

To create homogenous TiO_2 coatings with a low level of roughness, anodic oxidation approach could be utilized with oxidation voltage values that are below those that cause the phenomenon of the spark discharge **[Vera 2013].** This impact restricted the oxidation voltage utilized in the current study since, as was already indicated, hemocompatible applications call for homogeneous and low-roughness coatings**[Vera et al 2017, Al-Khafaji et al 2021].**

For example, the most widely-used surface treatment method that creates protective layer on Al, Ti, and valve metals is anodization (anodic creation of a surface oxide). There's a considerable potential drop between oxide layers on metallic substrate since anodic oxide layers have a low electrical conductivity in comparison with electrolytes or bulk, metallic Ti. The O^{2-} and Ti^{4+} ions subsequently migrate across oxide layer due to the strong electric field created by this potential decrease across the oxide film. An electric field provided from outside the anodic oxide layer causes ions to be driven through it, which encourages anodic oxide growth. The ions will be driven through anodic oxide film, which will keep expanding throughout anodization as long as electric field is sufficiently strong. Numerous works have noted that oxide film thickness and the applied voltage typically have a linear relationship[**Ohtsuka and Nomura 1997].**

However, the embedded materials must be solid and resilient enough to survive the physiological loads applied and required to operate for a much longer duration or until a lifetime without loss or revision surgery. An important equilibrium between strength and rigidity is also necessary to match that of the bone. **[Al-Murshdy et al 2021].**

The final goal of this research is presenting a novel bio-medical ceramic-metal composite type, which is called bio active composite metal, produced using a successful PM process. For obtaining uniform and smooth coatings of TiO2 through anodic oxidation regarding biomedical ceramic-metal composite alloy in the sulfuric acid as electrolyte, for use in the construction of orthopedic and dental appliances.

2 Experimental Procedure

2.1 Particle size measurements

Powders of (CP Titanium, strontium oxide) were usedin this study, CP titanium (China. Particle size 32 µm) and strontium oxide powder (mo.sci, USA. Particle size 3-10 µm) were measured by using particle size analyzer type (Bettersize) for the particle size of the starting materials.

2.2 Preparation of Sample

After that, the strontium oxide powder of was also dried at 125 °C by using vacuum dry box and added to the milled titanium powder and the mixture was blended for 5 hours. The percentages of addition of the strontium oxide powder to the titanium were **6%,** as showed in the Table 1. All blending cycles were performed at room temperature and under controlled conditions. By using a calculated hydraulic press (carver, USA), cold compaction was carried out in a uniaxial manner. Samples with a 12mm diameter were created using a pressing mold.

The samples have been sintered in an argon environment in electric resistance programmable vacuum furnace (China). samples were heated to a sintering temperature of 500, ±3°C, and then the temperature was raised to 1000, ±3°C, and the process was repeated for 2 hrs. The rate of heating was set at 3 °C/min. When the process was complete, the furnace has been turned off, and samples have been allowed to progressively cool inside of it while being continuously surrounded by an argon gas stream at a pressure of 5 mbar.

On a grinding machine (mekton/UK), the samples of manufactured sintered compacts have been wet ground with silicon carbide emery papers of (400, 800, 1500, 2000, and 3000 um) grit, respectively. Afterwards, the samples have been organized into categories that were ready for examinations and tests [**Bahador et al 2018].**

2.3 Anodic Oxidation of Titanium and titanium-strontium oxide samples

DC power supply, a reaction beaker, a special sample holder, a magnetic stirrer, an optional current sensing circuit, a silver counter electrode, and a computer to record the results make up the experimental apparatus. We employed sulfuric acid (H_2SO_4) as an electrolyte. To eliminate the naturally produced oxide layer on Ti and Ti-SrO disks (12 mm × 12 mm × 8 mm), 10% aqueous hydrogen peroxide was applied for 10 minutes **[Sawada et al 2019].** Applying a DC electric current between the Ti-alloy anode and Pt cathode, separated from one another by 6 mm in a beaker glass that contains the electrolyte, for 6-7 minutes at room temperature anodized Ti and Ti-SrO disks. The 400-rpm suggested speed for magnetic stirrers. Sulfuric acid (H_2SO_4) solution served as the electrolyte, and its concentration was 1 M. The oxidized samples have been cleaned with de-mineralized water and dried with hot air immediately [**Napoli et al 2018] .**

3 Sampling and groups distribution

The groups of the prepared specimen were split into four main groups (Groups A, B, C, and D), and each main group was further divided into three subgroups for each test. The microhardness measurements have been made with the use of digitals micro vicker hardness tester (UH 250, BUEHLER, GERMANY).

4 Analysis of Variance

A statistical technique for identifying changes between experimental groups is ANOVA. In the case when there are multiple experimental groups within at least one independent (categorical) variable, an ANOVA is appropriate. Levels are collections of independent variables within every factor in ANOVA. Also, ANOVA is a computer technique which examines each parameter change's relative contribution to the overall response variation in experiment. There is a possibility to evaluate effects of every input parameter on the machining process using ANOVA [**Kumanan et al 2014, Atiyah et al 2014].** Multiple comparison test (Games-Howell) that compared between each two groups in the same period. Significant difference between each two groups shows $P \leq 0.01$.

5 results and discussion of microhardness

In this study, vicker microhardness was measured for cp Ti alloy and Ti–SrO specimen's composite alloys. shown in Tables (1,2). In the hardness ratings for the cp Ti and Ti–SrO alloys may be seen in the function of the strontium oxides content. Multiple comparison test (Games-Howell) that compared between each two groups in the same period was shown in the table (3). The table shown that there was highly significant difference between each two groups $P \leq 0.01$, except group A and group B, and group C and D that showed no significant difference. The effect of reinforcing the solid solution and hardening of the fine increases the strontium oxides content. The hardness caused by a martensitic process occurrence in the cp Ti

ISSN (Paper)-1994-697X (Online)-2706-722X

and Ti–SrO alloys systems has highly risen. group A and group B, and group C and D showed no significant difference before and after anodic oxidation, due to Nanostructures could be formed to the implant surface, so that, this Nano-scaled layer cannot have measured by digitals micro vicker hardness tester. [**Kumanan et al 2014**].

Table 1 Descriptive statistics of vicker microhardness t for all groups

Descriptive statistics								
Groups	N	Mean	S.D.	S.E.	5% Confidence Interval fc Mean		Min.	Max.
					Lower Bound	Upper Bound		
A	10	233.300	5.755	1.820	229.183	237.417	225	241
B	10	238.400	7.560	2.391	232.992	243.808	227	250
C	10	436.500	3.951	1.249	433.674	439.326	431	443
D	10	443.300	7.558	2.390	437.893	448.707	432	454

Table 2 **ANOVA** analysis of vicker microhardness of all groups

One way ANOVA					
	Sum of Squares	d.f.	Mean Square	F-test	p-value
Between Groups	416725.275	3	138908.425	3408.563	0.000
Within Groups	1467.100	36	40.753		
Total	418192.375	39			

Table 3 **Games-Hawell** analysis of vicker microhardness of all groups

Games-Howell test						
Groups	Mean Difference		S.E.	p-value	95% CI	
					Upper Bound	Lower Bound
A	B	-5.100	3.005	0.356	-13.651	3.451
	C	-203.200	2.208	0.000	-209.518	-196.882
	D	-210.000	3.004	0.000	-218.549	-201.451
B	C	-198.100	2.698	0.000	-205.972	-190.228
	D	-204.900	3.380	0.000	-214.454	-195.346
C	D	-6.800	2.697	0.101	-14.670	1.070

6 Conclusions

ISSN (Paper)-1994-697X (Online)-2706-722X

A novel and extremely significant composite Ti alloy (anodized Ti-SrO alloy) has been created with the use of PM, in accordance with prior findings. Preparing was done on samples of the Ti-SrO alloy that had 6% by wt.% additions. For the orthopedic and dental implants, such new biomedical alloys will be very conductive bio-composite.

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