Effect of Applied Voltage on Properties of Micro-arc Oxidation Coating on TC4 Alloy

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Keywords: Micro-arc oxidation, Yttrium nitrate, Micro-hardness

Abstract: In order to resolve biological toxicity of TC4 titanium alloy, the micro-arc oxidation (MAO) technology was introduced to fabricate ceramic coating on the surface of TC4 titanium alloy. Yttrium nitrate was introduced into the silicate electrolyte system as additive. The micro-structure, phase composition, surface morphology and micro-hardness of MAO coatings were characterized. When applied voltage increased, the content of rutile-TiO_2 in the coating increased. The maximum value of surface roughness was about 11μm as applied voltage was 300V. The maximum micro-hardness was about 5210MPa.

1 INTRODUCTION

Ti-based alloys are widely used in aerospace, weapon and other fields owing to their low density, high specific strength and excellent corrosion resistance (Boyer, 1996; Wang, 2015; Wang, 2017). TC4 alloy has biological toxicity, so it is seriously limited in the clinical medicine applications. Therefore, various modifying techniques such as salt cyaniding (Lai and Wu, 1993), plasma immersion ion implantation treatment (Yilbas and Shuja, 2000), laser treatment (Yerokhin, 2000), micro-arc oxidation (Mandl, 2007) and PVD process, were introduced to improve performances for practical applications. The main purpose of surface treatment is to keep vanadium elements in titanium alloy matrix and avoid its releasing.

Micro-arc oxidation technology (MAO) has distinguished advantage to prepare ceramic coating on the Mg, Ti and Al alloys. The ceramic coating can improve both wear and corrosion resistance of alloys. Rare earth materials have important scientific research value, so they are widely used in the field of metal matrix modification. In this work, yttrium nitrate was introduced into the silicate electrolyte system as additive. The TC4 alloy was oxidized under different applied voltages by MAO method. The micro-structure, phase composition, surface morphology and micro-hardness of MAO coatings were characterized.

2 EXPERIMENTAL

Before micro-arc oxidation treatment, TC4 alloy were cut into the size of 20mm×20mm×2mm. The specimens were polished by SiC sandpapers with grit sizes of 600#, 1000# and 2000#, respectively. And they were rinsed by distilled water, acetone several times and dried. The electrolyte is composed of 30g/L $Na_2SiO_3 \cdot 5H_2O$, 10g/L EDTA-2Na, 2g/L KF and 1.5g/L $Y(NO_3)_3$ in aqueous solution. In MAO process, applied voltage was designed as 240V, 270V, 300V, 330V and 360V, respectively. And the samples were correspondingly nominated as S1, S2, S3, S4 and S5. The MAO equipment with power of 100kW was composed of an AC power supply and ultrasonic systems. The stainless steel container and TC4 alloy were used as cathode and anode separately. For comparison, MAO was carried out at 330V without $Y(NO_3)_3$ in the electrolyte, and the sample was nominated as S6. After MAO treatment, the samples were rinsed with distilled water and dried. X-ray diffraction device (Bruker D8 Advance) was used to analyse the phase structures with a scan rate of 4°/min. Surface morphology and roughness was analysed by Olympus self-focusing microscope and field emission scanning electron microscope. At least five areas within 480μm×640μm were measured to calculate surface roughness. The hardness was tested by digital micro-hardness tester (HVS-1000A, Huayin L.L.C., China). The average hardness was surveyed at least five spots. The Olympus

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metallographic microscope was utilized to take images of indentations.

3 RESULTS AND DISCUSSION

The XRD patterns of MAO coatings on the TC4 alloy with different applied voltages is illustrated in Figure 1 The coatings are composed of rutile-TiO_2 and anatase-TiO_2. As the applied voltage increased, the intensity of diffraction peaks of rutile-TiO_2 increased gradually, while those from TC4 alloy became weaker. It was possible that TiO_2 coating became thicken as applied voltage increased, therefore the intensity of diffraction peaks from TC4 matrix became weak. Meanwhile, the enhanced diffraction peaks of rutile-TiO_2 meant the increased content of rutile-TiO_2. As applied voltage increased, the heat released per unit time also increased, which facilitated the transformation from anatase to rutile.

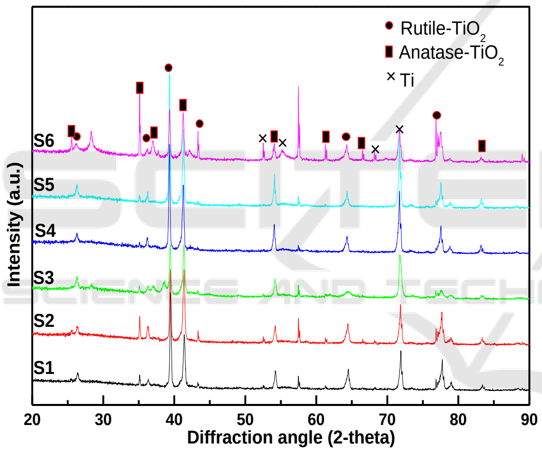

Figure 1: XRD patterns of TiO_2 coating on the TC4 alloy with different applied voltages.

The surface morphology of TiO_2 coatings was showed in Figure 2. It was obvious that many micro pores evenly distributed in the TiO_2 coating. The similar distribution characteristics appeared in all samples. For comparison, larger pore structure was found in S6. The introduction of $Y(NO_3)_3$ in the electrolyte would helpful in reducing the pore size.

Three dimensional topographic contour map of TiO_2 coatings were rendered in Figure 3. The surfaces of the five samples S1-S5 were relatively flat on macro level.

Figure 4 showed the surface roughness of the samples. The surface roughness started to increase as the applied voltage increased, then reduced when the applied voltage reached 300V. The maximum value of surface roughness was about 11μm. It was noted that the additive $Y(NO_3)_3$ in the electrolyte would decrease striking voltage remarkably and make the coating smooth. The striking voltage averagely reduced in the range of 15~25V. In addition, cooling treatment with frozen ice was used to control the temperature of electrolyte. The above conditions would be benefit for obtaining smooth and compact micro-arc oxidation coatings.

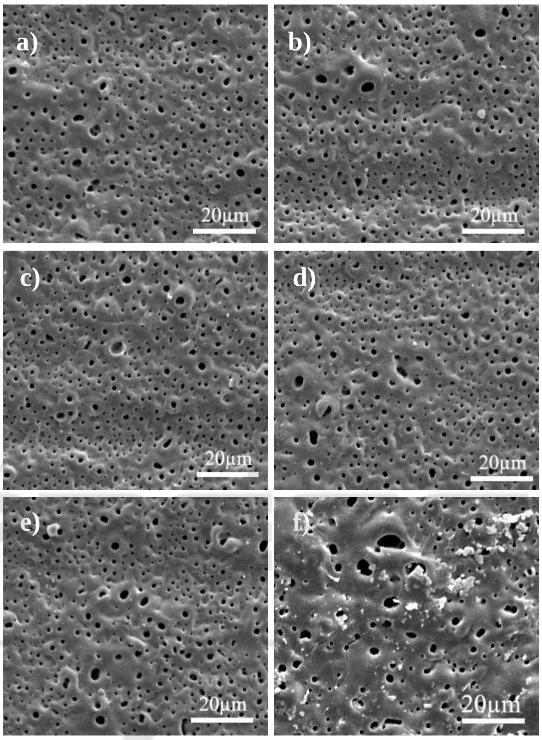

Figure 2: Surface morphology of TiO_2 coatings with different applied voltages, a) S1, b) S2, c) S3, d) S4, e) S5 and f) S6.

Indentation morphologies of the samples were showed in Figure 5 The original TC4 alloy had much deeper indentation than others. With the increase of applied voltage, the depth of indentation decreased. And the minimum indentation occurred as applied voltage reached 330V.

The micro-hardness of TiO_2 coatings was illustrated in Figure 6 The micro-hardness of the coatings showed a trend of gradual increase as the applied voltage increased to 330V. And the maximum value was about 5210MPa. The TiO_2 coating was directly grown on the TC4 matrix, so it was beneficial for improving the micro-hardness.

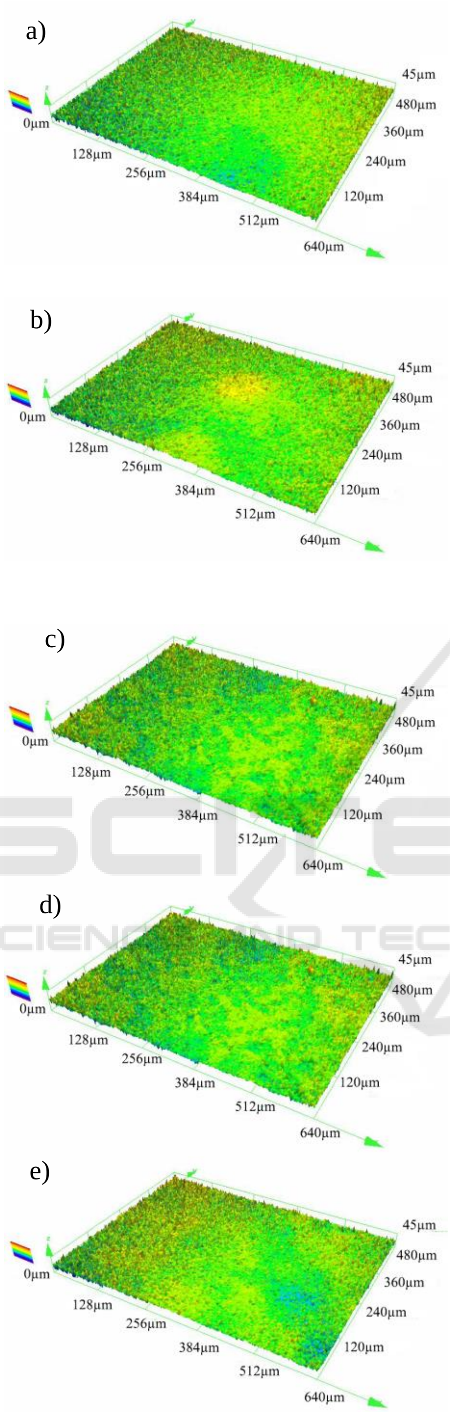

Figure 3: Three dimensional topographic contour maps of the samples: a) S1, b) S2, c) S3, d) S4 and e) S5.

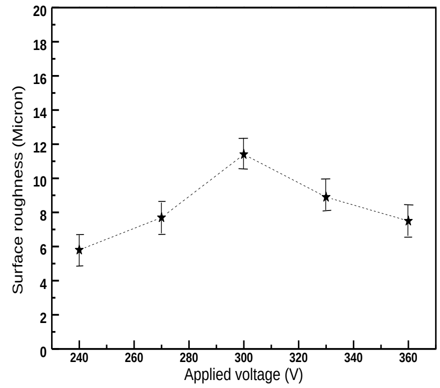

Figure 4: Surface roughness of the samples.

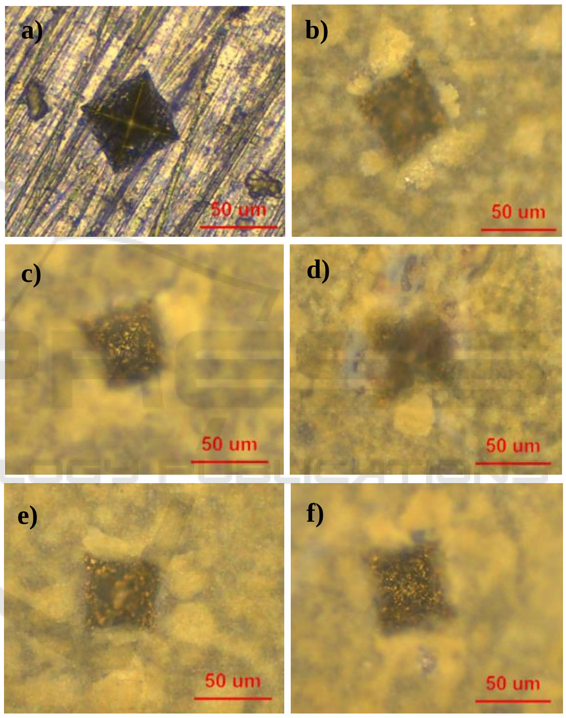

Figure 5: Indentation morphologies of the samples, a) original TC4 alloy, b) S1, c) S2, d) S3, e) S4 and f) S5.

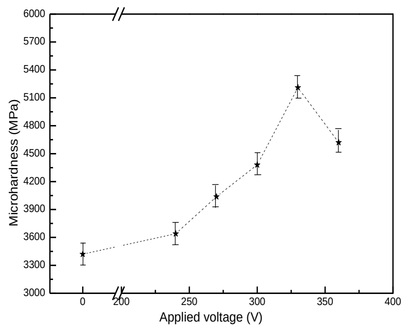

Figure 6: Micro-hardness of TiO_2 coatings.

4 CONCLUSIONS

Micro-arc oxidation technology was utilized to grow TiO_2 coating on the TC4 alloy with different applied voltages in the silicate electrolyte system containing yttrium nitrate as additive. The micro-structure and phase composition of the MAO coatings were characterized. As the applied voltage increased, the intensity of diffraction peaks of rutile-TiO_2 increased gradually. The maximum values of surface roughness and micro-hardness were about 11μm and 5210MPa.

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