Effect of time in plasma electrolytic oxidation process on titanium substrate with addition nano alpha alumina powder in electrolyte and investigate wear behavior of coating

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1. Introduction

Titanium and its alloys have wide applications in industry and recently researches have been expanded in this area. The main reasons are unique features of titanium such as biological behavior, corrosion resistance and high strength to weight ratio . The fundamental problem of titanium is low wear resistance that leads to be worn in industrial applications.

Plasma electrolytic oxidation(PEO) is a novel method to create ceramic coatings on metals and improve wear resistance. Base of this method is similar to electrochemical coating methods with difference the high voltage discharge phenomenon. In this research hard nano alpha-alumina particles (hardness of 9 Mohs) were added to the electrolyte for improving wear properties of titanium.

2. Experimental Details

Pure Titanium discs with 28mm diameter and 5mm thickness were used as substrate. System includes power supply, magnetic stirrer, cooling copper pipe, cathode(stainless steel) and anode(titanium sample). Wear tests were done according to ASTM G99-05 standard by alumina pin, 6.21N vertical force, 0.27m/s speed and 70m route. Table 1 shows components and concentrations of electrolyte.

Table 1.Electrolyte components and concentrations

Component	Concentration (gr/lit)
Sodium Silicate	15
Nano alpha alumina powder	6
potassium hydroxide	3
sodium phosphate	2
Triethanolamine (TEA)	0.048

Three samples with 10, 20 and 30 minutes process times and constant parameters of current density, frequency and duty cycle were prepared. Nano

alpha alumina powders with average 80nm particle size were added to electrolyte.

Table 2. PEO parameters during process

Sample name	Time (min)	Current density (A/cm2)	Duty cycle (%)	Frequency (Hz)
S1	10	0.2	50	50
S2	20	0.2	50	50
S3	30	0.2	50	50

SEM (model VEGA\\TESCAN-XMU), EDS, eddy current tests and optic microscope were used to study the microstructure, chemical composition, thickness and wear route of coatings, respectively.

3. Results and Discussion

3.1.Coating mechanism with presence of nano particles in electrolyte

Coating mechanism with nano particles in electrolyte is combination of cataphoretic effect and spark ignition. Since isoelectric point of alumina is 6-7 and electrolyte has pH=12, alumina particles get negative charge and related to cataphoretic effect absorb to substrate that has positive charge(anode) .PEO process is based on Spark ignition, that causes melting substrate during electrical discharge channels and sintering nano particles to the surface. According to Fig 1 nano alpha alumina particles and discharge channels are seen that confirm cataphoretic and spark ignition mechanisms.

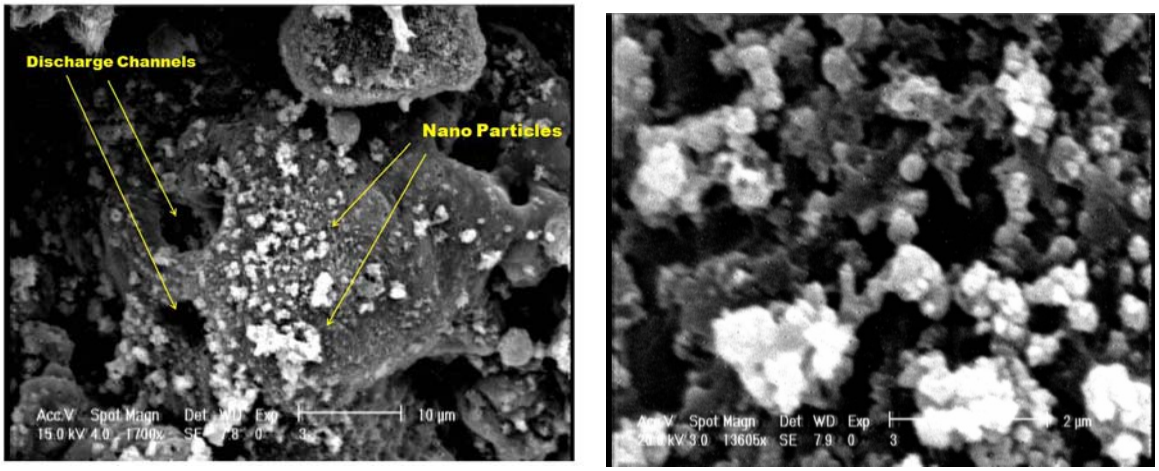

Fig 1. SEM image of sample S3

3.2.Microstructure and chemical composition of coating

Fig2 (a,b,c) shows SEM images of samples. It can be seen that by increasing process time, small pores are filled by nano particles and large pores get larger. Time of process has important role in absorbing nano particles to the surface by cataphoretic and spark ignition mechanisms.EDS analysis of samples shows that aluminum and silicium element percent is increased and decreased,respectively by increasing process time, due to more absorption of nano particles by sintering time and reduce in silicium elemet of paste background (table3).

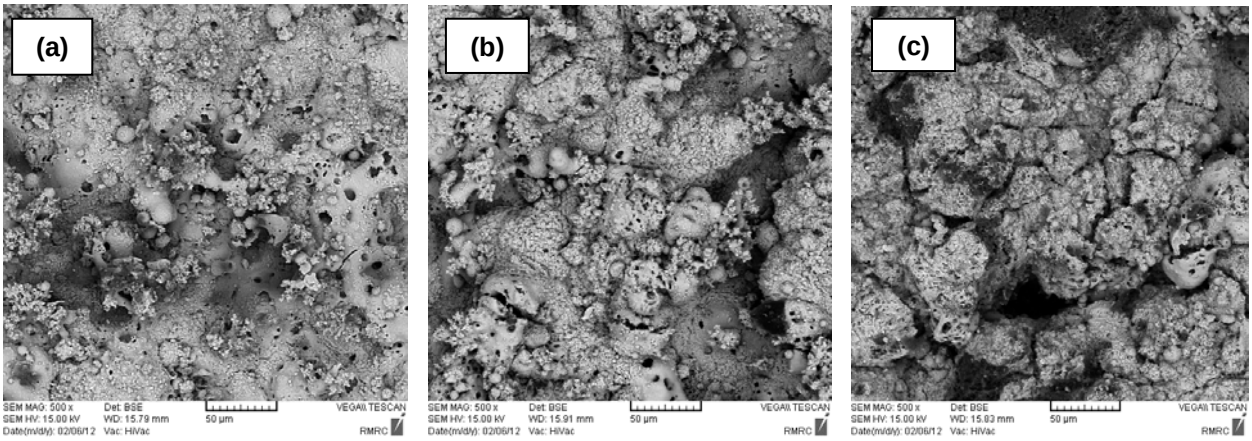

Fig 2. SEM images of samples :(a) S1 (b)S2 (c)S3

Table 3. Element percent composition of samples by EDS analysis of surface

Sample name	O	Si	Al	Na	K	Ti
S1	65.56	23.10	5.86	3.51	1.36	0.61
S2	66.14	22.94	7.06	2.22	0.98	0.66
S3	65.89	19.74	8.34	3.78	1.4	0.85

3.3.Wear behavior of coating

Wear mechanism is combination of adhesive and abrasive mechanisms. There is adhesive force between surface of alumina pin and coating(adhesive mechanism). Alumina pin can cut the materials of coating by passing on surface and makes debris (silicon and alumina particles) that playing role of three-body abrasive mechanism. Fig3 shows weight loss of samples after wear test. Also fig 4 shows wear tracks on coating that confirm sample S3 has worn less than other samples.

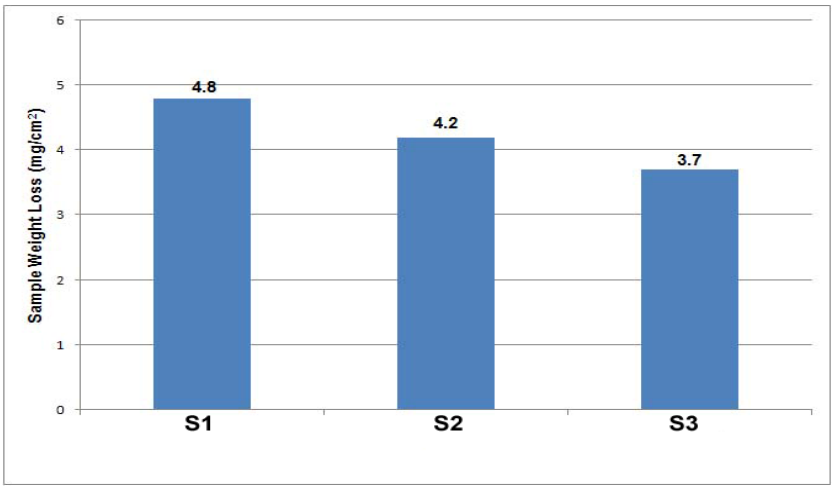

Fig 3.weight loss of samples after wear test

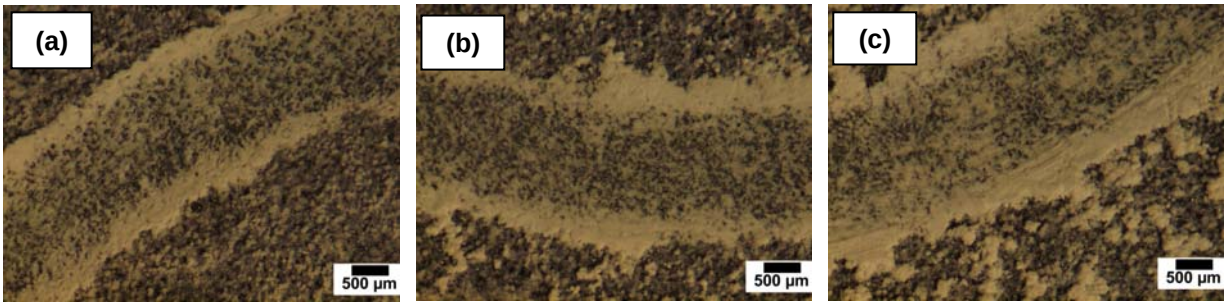

Fig 4. Optic microscope images of wear tracks on coatings: (a) S1, (b) S2, (c) S3

4. Conclusion

Coating mechanism via plasma electrolytic oxidation with nano particles in electrolyte is combination of cataphoretic effect and spark ignition. Nano alpha alumina particles with high hardness have significant role in imroving wear resistance of coating. With increasing time of PEO process nano particles adhere more to the surface due to more sintering time and wear resistance is increased. Coefficient of friction is increased by rising process time due to increase in amount of alumina nano particles in the coating and increase in surface roughness.