All Sciences Proceedings
http://as-proceeding.com/

2nd International Conference on Engineering, Natural and Social Sciences

April 4-6, 2023 : Konya, Turkey

© 2023 Published by All Sciences Proceedings

https://www.icensos.com/

# Influence of NaF film produced by plasma electrolytic oxidation method on corrosion resistance of Cp-Ti

M. T. Acar *

[1]Erzincan Binali Yıldırım University, Faculty of Engineering, Department of Mechanical Engineering, Erzincan,

*(taha.acar@erzincan.edu.tr) Email of the corresponding author

***Abstract*** **–** In this study, sodium fluoride (NaF) thin film was obtained by the plasma electrolytic oxidation (PEO) method on commercially pure titanium (Cp-Ti) material, which is frequently used in the biomedical field. The aim of this study is to compare the corrosion resistance of the samples with untreated Cp-Ti and coated with NaF. XRD and SEM were used for the structural characterization of the samples. Corrosion experiments were performed in simulated body fluid (SBF). According to the results, the thin film obtained from the NaF coated sample exhibited higher resistance to corrosion.

*Keywords – NaF, Corrosion, PEO, Thin film, Cp-Ti*

## I. Introduction

As a result of scientific studies and technological developments in the biomedical field, the number of biomedical applications is increasing [1]. This has led to an increase in the diversity of materials used in biomedical applications. One of the most preferred materials for use in biomedical applications is Cp-Ti material [2]. Cp-Ti is preferred because it has a biocompatible structure and excellent mechanical properties [3].

However, as in every material, there are some disadvantages in Cp-Ti material [4]. These disadvantages limit the lifetime of biomedical applications produced using Cp-Ti material. One of the most important of these disadvantages is that the corrosion resistance is insufficient in some cases [5]. It has been emphasized in the literature that the corrosion resistance of Cp-Ti material is insufficient under the influence of some environmental conditions and environmental factors. When the studies about eliminating this disadvantage in the literature are examined, it has been seen that in most of the studies, Cp-Ti material is tried to be more resistant to corrosion by making protective coatings [6].

One of the methods used to produce a protective coating is the plasma electrolytic oxidation (PEO) method [7]. Because the PEO method has some advantages over other methods. The most important of these is that the protective coating thickness can be obtained in the desired thickness and in the desired chemical composition [8]. In addition, studies conducted to increase both biocompatibility and corrosion resistance in biomedical applications used in integration with the human body with the PEO method attract attention [9-10].

In this study, NaF coating was produced with the PEO method on the Cp-Ti sample. The aim of this study is to determine the corrosion behavior of NaF coating. XRD and SEM were used for the structural characterization of the samples. By using Potentiodynamic Polarization and Open Circuit Potential (OCP) approaches, electrochemical characteristics were examined.

## II. Materials and Method

Commercially pure titanium (Cp-Ti) samples which are chemical composition given in another study were used in this study [11]. All Cp-Ti samples were ultrasonically degreased for 20 minutes in acetone and ethanol, respectively. The samples were again ultrasonically cleaned in distilled water and dried.

The PEO process was carried out using a simple AC power supply source with a capacity of 300 V and 2 A. For 2 minutes, the specimen was coated in a two-electrode cell with a platinum electrode and an environmentally friendly silicate electrolyte. In deionized water, the electrolytic solution contains 60 g/ L NaOH and 40 g /L Na2SiO39H2O. NaF nano-additives at a concentration of 15 g/L were evenly dispersed in the electrolytic solution. The average particle size of those additives is around 20 nm.

The phase of Cp-Ti samples was determined using a 2θ scale between 10° and 90° utilizing an XRD-GNR-Explorer X-Ray diffraction apparatus and a Cu-K (=1.54059) source at 40 kV and 30 mA. All phases were recognized by comparing them to the International Diffraction Data Center (ICDD) standard cards. Images of the top and cross-section were taken using the FEI QUANTA 250 Scanning Electron Microscope.

Potentiodynamic Polarization was used in electrochemical tests with the GAMRY series G750TM (Gamry Instruments, Warminster, USA) in SBF solution. The electrochemical tests made use of the three-electrode approach. Graphite served as the counter electrode and Ag/AgCl as the reference electrode.

Table 1. Results of corrosion experiment in SBF

| | **$E_{corr}$ (mV)** | **$i_{corr}$ (x$10^{-6}$A/cm$^2$)** | **Film thickness (µm)** |
|---|---|---|---|
| **NaF coated Cp-Ti** | -250 | 5.823 | 3.72 |
| **Untreated Cp-Ti** | -337 | 6.287 | |

## III. RESULTS

The XRD graphs of untreated and NaF coated samples are shown in Fig. 1. Examining the XRD graphs reveals that the Cp-Ti sample has an α-Ti structure. When the XRD graph of the film obtained after the PEO surface treatment is examined, it is seen that the NaF structure is formed on the surface of Cp-Ti [12].

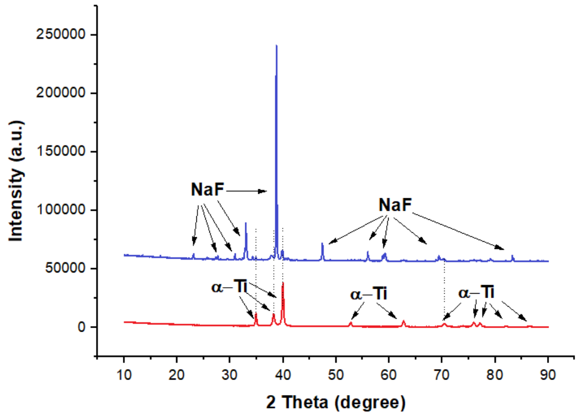


Fig. 1 XRD graphs of untreated Cp-Ti and NaF coated Cp-Ti.

Fig. 2 shows top view SEM images of untreated Cp-Ti and NaF coated samples, as well as a cross-section SEM image of a NaF coated sample. Only the traces left over from the polishing process are visible in the untreated sample. The morphological structure of the surface changes after the PEO process in the NaF coated sample. When examining the cross-sectional image of the NaF film, it can be stated that the film has a homogeneous structure [13].

Fig. 3 and Fig. 4 show open circuit potentials and potentiodynamic polarization curve graphs of untreated Cp-Ti and coated samples, respectively. When the graphs are examined, it is clear that the corrosion resistance improves as a result of the film formed on Cp-Ti. When the OCP graphs are examined, the positive shift of the graph after the PEO coating process indicates that the corrosion resistance increases. In addition, it can be said that the corrosion resistance has increased from the corrosion potential (Ecorr) and corrosion current density (Icorr) values obtained from the potentiodynamic polarization curve and presented in Table 1 [13]. The resulting film kept the SBF liquid from contacting Cp-Ti, increasing corrosion resistance. When the studies on titanium and its alloys in the literature were examined, it was noted that the films obtained demonstrated a barrier effect and thus increased corrosion resistance.

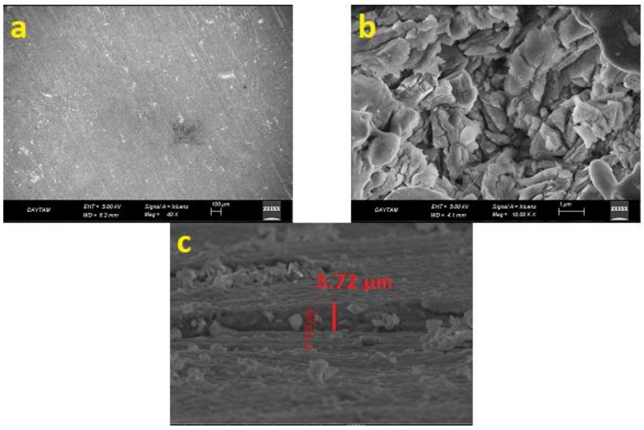


Fig. 2 SEM images of (a) untreated Cp-Ti, (b) NaF coated Cp-Ti, (c) cross-section SEM image of NaF coated Cp-Ti.

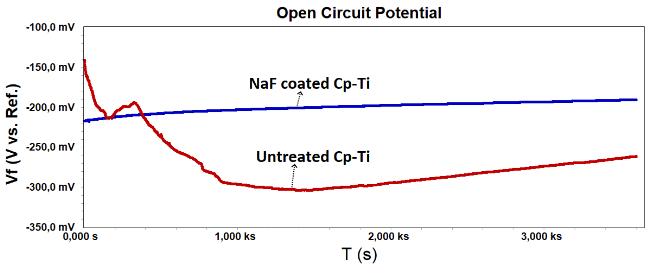


Fig. 3 Open circuit potential graphs of untreated Cp-Ti and NaF coated Cp-Ti.

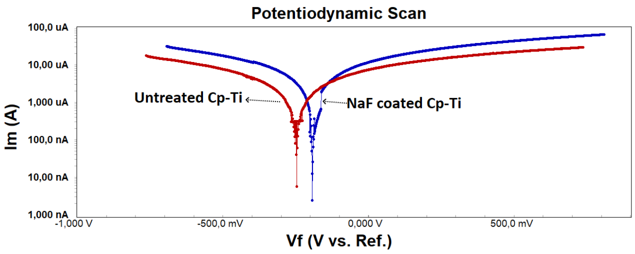


Fig. 4 Potentiodynamic polarization curves of untreated Cp-Ti and NaF coated Cp-Ti.

## IV. DISCUSSION

In this study, NaF was coated on Cp-Ti alloy using the PEO method, and corrosion resistance was assessed after structural analysis. When the XRD graphics were examined, the results showed that NaF coating was successfully obtained on the Cp-Ti surface following the PEO procedure. When the SEM images are examined, the surface morphology changes after the surface treatment, and the structural formations of NaF are visible. Electrochemical experiments revealed that the resulting film reduces contact between SBF liquid and Cp-Ti, improving corrosion resistance.

## V. CONCLUSION

As a result, the film obtained by the PEO method on Cp-Ti changed the surface morphology. The changed surface morphology and obtained thin film made it difficult for the SBF liquid to reach the substrate, resulting in improved corrosion resistance.

## ACKNOWLEDGMENT

The author would like to thank Atatürk University East Anatolia High Technology Application Research Center (DAYTAM), and Erzurum Technical University High Technology Application and Research Center (YUTAM) for their assistance on the study.

## REFERENCES

[1] M. Niinomi, Recent research and development in titanium alloys for biomedical applications and healthcare goods, Sci. Technol. Adv. Mater. 4 (2003) 445.

[2] L.-C. Zhang, H. Attar, Selective laser melting of titanium alloys and titanium matrix composites for biomedical applications: a review, Adv. Eng. Mater. 18 (2016) 463–475.

[3] M.T. Acar, H. Kovacı, A. Çelik, Improving the wettability and corrosion behavior of Cp-Ti by applying anodization surface treatment with the addition of boric acid, graphene oxide and hydroxyapatite, Mater. Today Commun. 31 (2022) 103683.

[4] M.T. Acar, H. Kovacı, A. Çelik, Investigation of corrosion and tribocorrosion behavior of boron doped and graphene oxide doped TiO2 nanotubes produced on Cp-Ti, Mater. Today Commun. 32 (2022) 104182.

[5] B. Van der Bruggen, M. Mänttäri, M. Nyström, Drawbacks of applying nanofiltration and how to avoid them: a review, Sep. Purif. Technol. 63 (2008) 251–263.

[6] M.T. Acar, H. Kovacı, A. Çelik, Enhancement of the tribological performance and surface wettability of Ti6Al4V biomedical alloy with boric/sulfuric acid anodic film, Surf. Topogr. Metrol. Prop. 9 (2021) 035024.

[7] A. Fattah-alhosseini, R. Chaharmahali, K. Babaei, Effect of particles addition to solution of plasma electrolytic oxidation (PEO) on the properties of PEO coatings formed on magnesium and its alloys: A review, J. Magnes. Alloys. 8 (2020) 799–818.

[8] R.O. Hussein, X. Nie, D.O. Northwood, An investigation of ceramic coating growth mechanisms in plasma electrolytic oxidation (PEO) processing, Electrochimica Acta. 112 (2013) 111–119.

[9] T. Monetta, P. Parnian, A. Acquesta, Recent advances in the control of the degradation rate of PEO treated magnesium and its alloys for biomedical applications, Metals. 10 (2020) 907.

[10] M. Razavi, M. Fathi, O. Savabi, D. Vashaee, L. Tayebi, In vivo study of nanostructured akermanite/PEO coating on biodegradable magnesium alloy for biomedical applications, J. Biomed. Mater. Res. A. 103 (2015) 1798–1808.

[11] M.T. Acar, H. Kovacı, A. Çelik, Comparison of the structural properties, surface wettability and corrosion resistance of TiO2 nanotubes fabricated on Cp-Ti, Ti6Al4V and Ti45Nb, Mater. Today Commun. 33 (2022) 104396.

[12] O.Y. Yu, M.L. Mei, I.S. Zhao, Q.-L. Li, E.C.-M. Lo, C.-H. Chu, Remineralisation of enamel with silver diamine fluoride and sodium fluoride, Dent. Mater. 34 (2018) e344–e352. https://doi.org/10.1016/j.dental.2018.10.007.

[13] H. Soliman, M.K. Ahmed, R. Elbadewy, Enhanced corrosion resistance of plasma electrolytic oxidation coatings prepared on Mg alloy ZX using nano-Al 2 O 3 and NaF incorporated electrolyte, Surf. Eng. 37 (2021) 246–252. https://doi.org/10.1080/02670844.2020.1771810.