



Enhancement of Corrosion Resistance in Ti6Al4V Alloy Coated with MgO Film for Biomedical Applications

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Article's Information	Abstract
Received: 07.06.2025 Accepted: 18.04.2026 Published: 15.09.2026	This study aims to modify the surface of the Ti6Al4V alloy by coating it with MgO films with different deposition times (3 and 6 hours) using radio frequency (RF) magnetron sputtering system. All films were subsequently annealed at 300°C for 1 hour. The sample was analyzed using optical microscope (OPT) then as a sample before and after coating. The images revealed a clear effect of etching as pitting on the surface; when coated with MgO films, the effect of coating time is evident in the increased thickness of coating layer. The thicknesses (2.43 μm and 3.36 μm) were determined via cross-sectional Scanning Electron Microscopy (SEM). Crystal structure of the samples before and after a coated conducted using X-ray diffraction (XRD) technique confirmed the presence of MgO crystal surface with nanoscale dimensions (27.91 nm and 29.59 nm), consistent with results from Energy Dispersive Spectroscopy (EDS) confirmed the elemental composition of MgO. With program image indicated grain size (177.5 and 264 nm), Atomic Force Microscopy (AFM) determined the average size (84.4nm and 93.4 nm) with roughness of the samples (of 12.23 and 36.54 nm). The corrosion behaviors were studied using electrochemical techniques, namely, potential dynamic polarization (Tafel), Open Circuit Potential (OCP), and Electrochemical Impedance Spectroscopy (EIS) measurements in simulated body fluid (SBF). The OCP shifted to more positive potentials with increasing thickness of coating which means a passivation in increasing the thickness of the coating layer. The polarization resistance increased reaching 887.252 $\text{k}\Omega \cdot \text{cm}^2$ for high thickness (3.36 μm), compared to 41.110 $\text{k}\Omega \cdot \text{cm}^2$ for the uncoated sample. Additionally the protection efficiency reaches 96.91% for the sample coated for high thickness.
Keywords: Radio frequency, Magnetron sputtering, Ti6Al4V alloy, MgO films, Corrosion test.	
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1. Introduction

The biomaterials are used in many areas of engineering and high-tech manufacturing applications; thin film, free surface coatings are applied to surfaces with specific topographies or patterning. They are also used in medicine applications for a wide range of purposes, such when prosthetic limbs implanted [1]. The typically thin films are deposited on a metal, ceramics, polymers, or plastics and metal using different methods. The composite material has a distinct role and widely used applications in a coating layer or manufacturing compensatory part [2-3]. The concentration of

composite materials affected the structure and mechanical properties of the manufactured product [4]. The surface of titanium alloys exhibits high stability due to passive to layer that makes it an excellent corrosion resistance [5]. This can be reconstituted at the degree of body temperature and in physiological fluids if compromised. The growing prominence of titanium alloys as significant biomedical attributed to their low modulus approached to properties of the human body, greater biocompatibility, and better corrosion resistance in comparison to traditional biomaterials such as CO-Cr alloys and stainless steel [6-8]. The main components

of Ti6Al4V and its alloy are used for dental and biomedical implant applications. Ti6Al4V the most widely used titanium alloy worldwide, accounts for over 50% of titanium alloy production [9]. The surface of a biomaterial implant greatly affected by corrosion behavior because the fluids of human body contain many types of ions, such as Cl^- , PO_4^{3-} , HCO_3^- , OH^- , Ca^{2+} , Mg^{2+} , H^+ , K^+ , Na^+ . etc. this contributes in transporting sugar to the muscles to obtain energy and stimulating damaged cells to grow. However, the presence of reactive passive coatings at the nanoscale on the surfaces of these alloys is a crucial determinant of their corrosion resistance and enhance the biocompatible. Materials for traditional metallic implants are therefore chosen for their corrosion resistance, namely their capacity to form protective passive coatings. The Ti6Al4V alloy has exceptional resistance corrosion because of the thermodynamic stability of its metal oxides. The formation of additional oxides on the surface of Ti6Al4V has also been documented [10]. Despite its numerous advantages, Ti6Al4V exhibits significant reactivity. The surface quality can be enhanced through various treatments [11]. Earlier investigations indicated that the heat treatment improved the corrosion resistance Ti6Al4V alloy in both simulated body fluid (SBF) and Ringer's solutions model on the resistance of corrosion. Other studies have suggested that the Ti6Al4V with quick cooling of post-solution treatment can preserve the phase of beta in the titanium alloy by inhibiting the diffusion process. Consequently, it is anticipated that the mechanical characteristics can be significantly altered through treatment of solution at elevated temperatures within the alpha + beta phase region, succeeded using fast cooling [12]. Heat treatment can enhance the corrosion resistance of Ti6Al4V, it is a martensitic $\alpha+\beta$ alloy ($K_\beta = 0.3$) and is the most prevalent titanium alloy. Its extensive use to stems of implant from an optimal equilibrium of mechanical quality, excellent castability, weldability, and heat treatability. The inclusion of aluminum stabilizes and strengthens the α -phase, elevates the $\alpha+\beta \leftrightarrow \beta$ transition temperature, and decreases the density of the alloy. Vanadium a β -stabilizer decreases the transformation temperature of $\alpha+\beta$ to β and enhances hot working by increasing the volume fraction of the β phase. This study aims to investigate the microstructure and corrosion behavior of Ti6Al4V alloys intended for implant orthotics manufacturing. Current literature contains numerous papers in this field. However, the corrosion research utilizing electrochemical impedance spectroscopy EIP remains inadequately examined, prompting our investigation

of Ti6Al4V alloys using employing this technique [13–16]. Magnesium (Mg) is an important element for its enhanced osteogenic and angiogenic properties in vitro and in vivo. The objective of this study is to modify the surface of the Ti6Al4V alloy by applying a biocompatible MgO layer for medical applications through advanced RF sputtering techniques to enhance corrosion resistance within the human body.

2. Experimental Work

Wire-cut (Alibaba - machine-7740 1479395532.htm, Denmark) were used to cut the Ti6Al4V discs sample with circular shape has diameter 1.5 cm and a thickness 0.3 cm. The titanium alloys (Ti6Al4V) GR2 ASTM F136 have a chemical composition (Ti:89.2, Al: 5.5-6.5, V:3.5-4.5, Fe:0.4, C:0.1, N:0.5, O:0.20, H:0.012. Ti6Al4V, the base alloy with ($\alpha+\beta$) phase, consisting of Ti and Al with(α)phase and V(β)phase, with crystal structure. The surface of samples was treated using mechanical methods by polishing with SiC paper size starting from 600 ,800, 1000... to 4000 μm , polishing with 3 and 0.25 μm diamond suspensions. The samples alloys were immersed in the Kroll's solution for 1 minute for etching, the Kroll's solution (1 mL HF,5 mL HNO_3 , and 10 mL H_2O). Then the samples cleaned using deionized water in ultrasonic system. After performing, the sample examine the microstructure using through an optical microscope with magnification 500um (MTI corporation, USA) and SEM (JEOL-JSM-5600 USA), to evaluation, a fracture mode and fracture surface details. These experiments were as follows; In table 1. Sample billets were obtained in the form of magnesium (Mg)plates with dimensions of 5cm radius and thickness of 1mm,the surface of the samples was then coated using physical methods to increase the biocompatibility by using (radio frequency) RF magnetron sputtering (TORR. CRC-600 vacuum sputtering Svsstem, Toor international inc. USA) with magnesium as the target to deposition using RF sputtering system. Ti6Al4V samples and silica glass substrates were paced during deposition. Ti6Al4V used to study the corrosion behavior and microstructure of deposition, while glass sample was used to measure the thickness of the coated layer. Deposited Mg films were created with 70% Ar + 30% O_2 mixing gases. During deposition, the substrate was intentionally heated to 100°C. The annealed process was conducted into a muffled furnace in O_2 gas environment. The furnace temperature was seated to 300°C. The samples were kept at 300 °C for 10 minutes and then the furnace temperature was decreased at rate of (3°C) till room temperature. The sputtering conditions are presented in table 1.

Table 1. RF sputtering condition for MgO/Ti6Al4V alloy

Parameter of RF	Condition
Initial Pressure before sputtering	2×10^{-5} mbar
Pressure beginning of the sputter	2×10^{-1} mbar
Substrate	Ti6Al4V alloy
Sputtering gas	30%O ₂ +70%Ar
Deposition time	3&6 hours
Applied voltage	400 V
Discharge current	250 A
Distance from target to sample	20 cm

Thin film thickness of coated sample was measured by using SEM cross section for coated samples [17]. Optical microscopy (MTI corporation, type 50-1000X, USA) was used to evaluate and examined the samples at various magnifications and the X-ray diffraction (XRD) levels (of the kind SHIMADZU with a power diffraction setup along the Cu-K α duct, $\lambda = 1.54056 \text{ \AA}$) was used in this study, with scale angles ranging from 20° to 80°. These samples were also subjected to measurements at the same time using the Röntec EDS and SEM operating at 10.0 kV was employed to analysis the surface morphology. According to the electrochemical research, a potentiostat (Electronic Germany Bank) is connected to computer to show the results and image. As indicated in table 2, the electrolyte was utilized to replicate human body fluid accustom in a lab setting the pH at 7.4. The AFM Digital Instruments, III USA Scanning Probe Microscope (AA3000) was used to study the surface morphology of samples the

formation of particles deposition of the thin-film surface. The biocompatibility of a substance when it interacts with the surrounding medium in real-life situations of exposure, it's effect collapsed and loss their properties by corrosion. We can test the corrosion of alloys suggested for implant systems in the lab using either alternating current (AC) or direct current (DC), or impedance electrochemical test methods (Corrosion system (PARASATE 2273, Princeton Application Research), USA). We used the electrochemical impedance spectroscopy technique (EIS) to study how the alloy behaved electrochemically. The electrode cell used the (CHI 670e China system) and software for electrochemical experiments. The electrochemical impedance measurements the perturbing AC were made in a physiological solution SBF with a pH of 6.5, at open circuit potential with frequency range between 50 kHz and 0.1Hz and signal amplitude of $\pm 0.05\text{V}$.

Table 2. Chemical composition for simulated body fluid[1]

#	Constituent	Weight (gm/L)
1	NaCl	8.036
2	KCl	0.225
3	CaCl ₂	0.293
4	NaHCO ₃	0.352
5	K ₂ HCO ₃	0.230
6	MgCl ₂ 6H ₂ O	0.311
7	Na ₂ SO ₄	0.072

3. Results and Discussion

In the obtained affecting image of the microstructures of the samples, two phases are visible: the base structure, which is derived from beta-Ti, and the (α + β) structure which is a body-centered cubic (bcc) structure exhibiting exceptional applied properties for surgical implantation. Figure 2 XRD data crystal structure of Ti6Al4V alloy as based before and after coated with MgO films. After annealing 1 hour at 300°C, the microstructures were observed under 500um scale magnification using an

optical microscope following etching. The features is distinguished by its exceptional structural homogeneity, solidity, and strong bond with a metal foundation.

Figures 4 and 5 illustrates the macroscopic samples of Ti6Al4V that were generated using these techniques. The SEM was employed to investigate the morphological properties of all films and the thickness of coated layers, while the EDS was employed to determine chemical composition of

coated. AFM was used to determine the roughness of surface

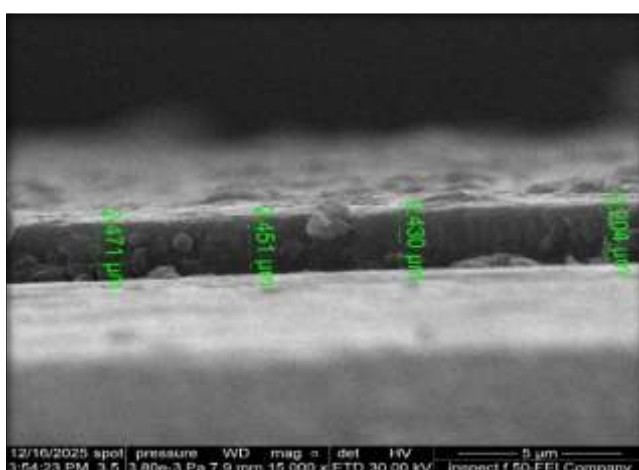
3.1. Cross section

The SEM was used to determine the thickness of coated by side view Croce section of coated lavers. as shown in fig.1. Figure (1.a) the thickness of coated layer with ranger (2.47, 2.43 and 2.20 μm) for 3 hours with scale 10 μm magnification 800x. fig.1. (1. b) the thickness of coated laver with ranger (3.73, 3.18 and 3.32 μm) for 6 hours with scale 5 μm and magnification 15000 x. The thickness of coated layer increasing with increase the time of deposition.

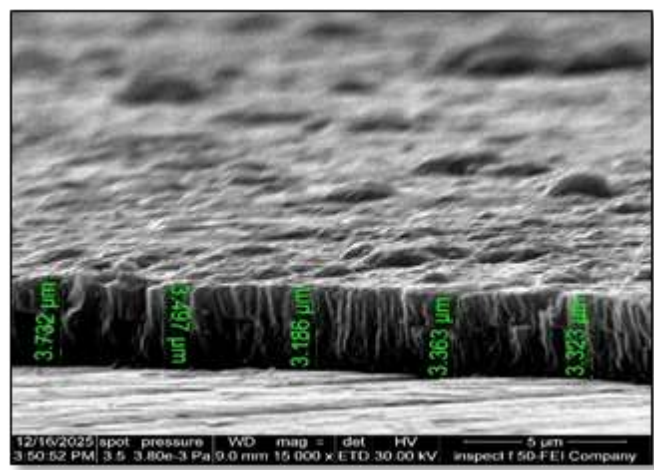
3.2. XRD analyses

The X-ray analysis of the Ti6Al4V alloy before and after coated MgO films for 3 hour and 6-hour deposition times based. The fig.2 the previous peaks is consistent with the standard XRD data sheet (2000 JCPDS- PCPDFWIN v. 2.1) of MgO file NO #300794 and 96-900-6801. (Ti6Al4V) JCPDS file NO #450946 and 03-065-8567. The AlTi with using the well-known Scherrer formula, which is miller indices of (100 and 101) at 2θ (36.0 and 41.3) respectively. The MgO is clear with miller indices (200) MgO at 2θ = 42.6 to low second one (022) at 2θ = 63 with intensity increasing with increasing the thickness at 6 hours. Figure (2) shows polycrystalline X-ray before annealing, we notice amorphous structure but after annealing at 300°C for 1 hour Fig. 3, formed on textured mono-crystalline new peak corresponds to the (200) plane at 2θ = 43 add to low second one (022) at 2θ = 63 for cubic structure, this results agreement

with [18, 19]. The XRD data was used to calculate the particle sizes fixed in table 3. Thin film thickness of coated was measuring by using SEM -cross section. One important microstructure parameter that connects processing conditions to performance is dislocation density, which makes it useful in the development of materials, particularly for structural and biomedical applications. Dislocation density significantly has major impact on mechanical characteristics like yield strength, but also corrosion resistance in medical alloys. Because of it's impact on cell contacts and surface energy, it can also affect biocompatibility. Depending on the preparation technique and heat treatment, dislocation density values for metallic materials usually fall between 1.10 and 10^{16} m^{-2} . The value determined here, almost $2.2 \times 10^{15} \text{ m}^{-2}$, is within this typical range and shows a significant number of dislocations [20]. Calculations for magnesium oxide (MgO) thin films cam in different thicknesses and were made at a substrate temperature of 100°C. The table contains information about dislocation density, macrostrain, lattice constant, and depositions were made under circumstances similar with different substrate, it would be somewhat to compare these results with those of an uncoated alloy. Variations in Material Nature: Ti6Al4V with crystal structure. In contrast, the magnesium oxide (MgO) disposition layer is a ceramic substance with a cubic crystalline structure. These methods a suitable way to study the structure of coated lay compare these results with those of an uncoated alloy [19, 20].



(a)



(b)

Figure 1. The SEM of cross sectional view after (a) 3 h and (b) 6 h coating time.

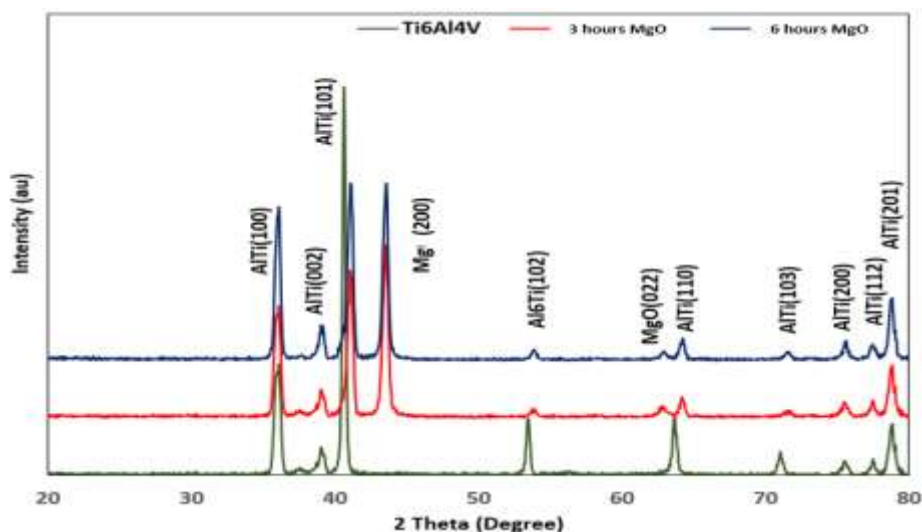


Figure 2. The XRD of Ti6Al4V alloy before and after deposition with MgO films After 1hr annealing at 300°C

Table 3. Crystallite size of MgO thin films and Ti6Al4V samples deposited on glass at 100 °C substrate temperature with different thicknesses

Crystallite size for MgO films							
Thickness (μm) MgO/glass	2 Theta (degree) Ca.	2 Theta (degree) st.	Crystalline size (nm)	D (Å) calculate	Lattice constant (Å)	ε micro- strain	dislocation density <u>δ(lines/m⁻²)</u>
2.43	42.8653	42.916	27.91	2.917	5.834	0.547	2.44×10 ¹¹
3.36	42.8653	42.916	29.56	2.917	5.834	0.610	2.71×10 ¹¹
Crystallite size for Ti6Al4V							
Thickness (nm) MgO/glass	2 Theta (degree) Ca.	2 Theta (degree) st.	Crystalline size (nm)	D (Å) calculate	Lattice constant (Å)	ε micro- strain	dislocation density <u>δ(lines/m⁻²)</u>
Ti6Al4V	35.75	35.75	37.86	2.510	2.46	0.001	2.2×10 ¹⁵

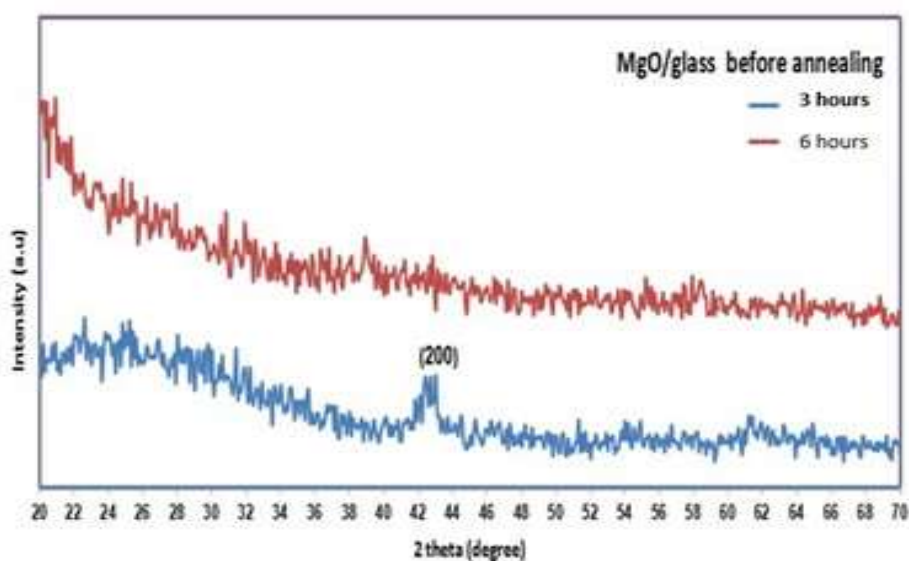


Figure 3. XRD for MgO films deposited on glass substrate before annealing

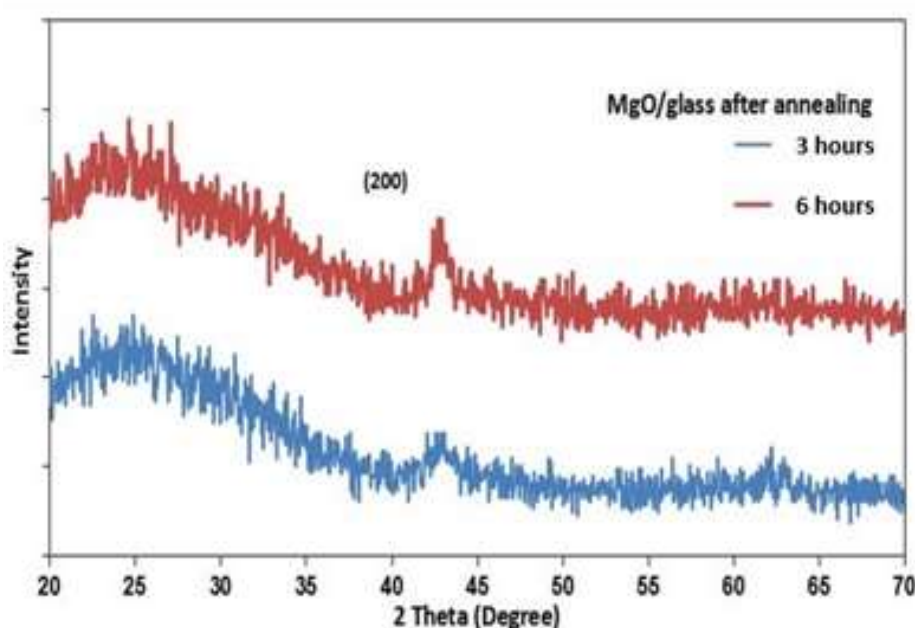


Figure 4. XRD of MgO film deposition on glass substrate with 1hr annealing at 300°C.

3.3. OPT Microscopy

The OPT optical microscopy images with 500 μm scale magnification in fig.5(a) for Ti6Al4V alloy uncoated before etching the effect of grinding appear on the surface, while (b) after etching with the K with (500 μm magnification). The effect of etching is clear as with several pits forming on the surface, in order to increase surface roughness. This agrees with the results [21, 22]. Figure 5: shows the Ti6Al4V alloy coated with MgO films with different thicknesses: (a) 3-hour time (2.43 μm) and (b) 6-hour time (3.36 μm) deposition. After coated, the image shows the coated layer cover Ti6Al4V alloys and increasing with increasing the time of and reveals complex interactions between the substrate the deposited films affected by thickness of coated that is clear from the differences in fig.6 between (a) and (b) with 500 μm scale magnification [23].

3.4. SEM-EDS Analyses

Figure 7 illustrates SEM images of Ti6Al4V alloys with 5 μm scale magnification, while fig. 8 illustrates EDS analysis with table (4). Blocs of species like sheets and small crystals were synthesized to form the deposit at 100°C fig. 7(a) Ti6Al4V uncoated alloy

and (b and c) coated, clearly show the presence of MgO particles that agreement with results [18]. The Ti6Al4V alloy have thermal expansion coefficient ($9.2 \times 10^{-6} / ^\circ\text{C}$ at 250 $^\circ\text{C}$) lower than MgO ($13.6 \times 10^{-6} / ^\circ\text{C}$ at 250 $^\circ\text{C}$), and fractures are composed of the MgO coating [24-25]. The thermal shrinkage discrepancy results between substrate and the coated layer results in the formation of crevices when the MgO coating is cooled eclectic temperatures. Also, during annealing, there is a sparking shrinkage, which causes coatings to develop fractures [15]. These cracks make the bond between the MgO and the Ti6Al4V weaker. But, the common place for RF sputtering. The first layer of coating with a nano size as well as hot substrate during deposition leads to high adhesive of coated layer crated passive layer on substrate [1]. The crack appears in upper layer with increasing deposition thickness. Particles with nano size gathers in clumps due to high surface charge especially at the crystalline boundaries. The crack is considered good feature that helps in the adhesion of tissues between the coating layers of implanted biomaterials.

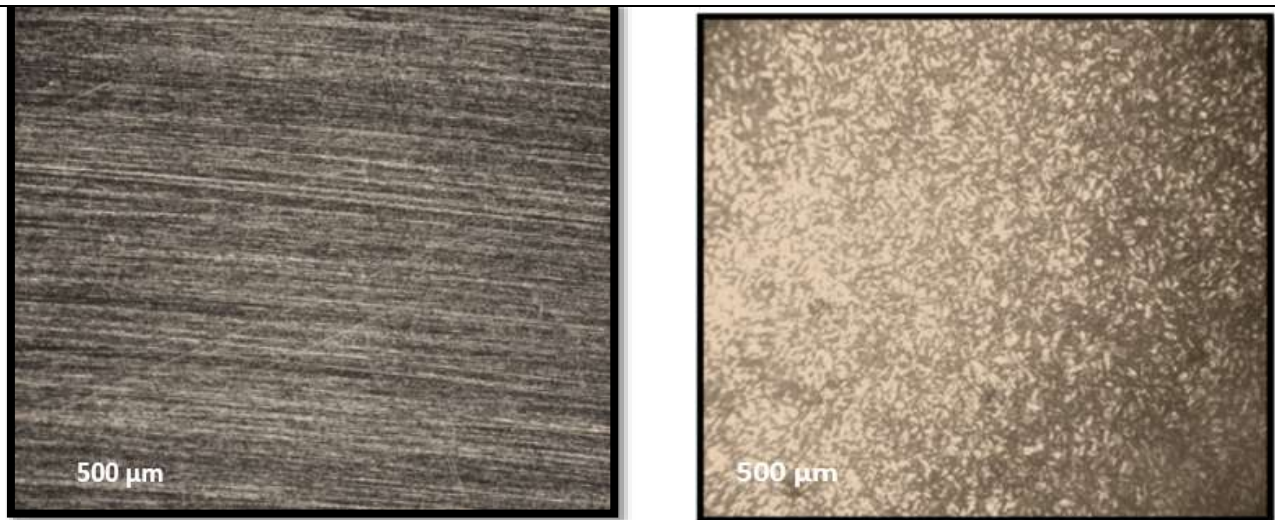


Figure 5. Ti6Al4V alloy Optical microscopy imaging with 500 μm magnification (a) before etching, (b) after etching with the Kroll's reagent respectively.

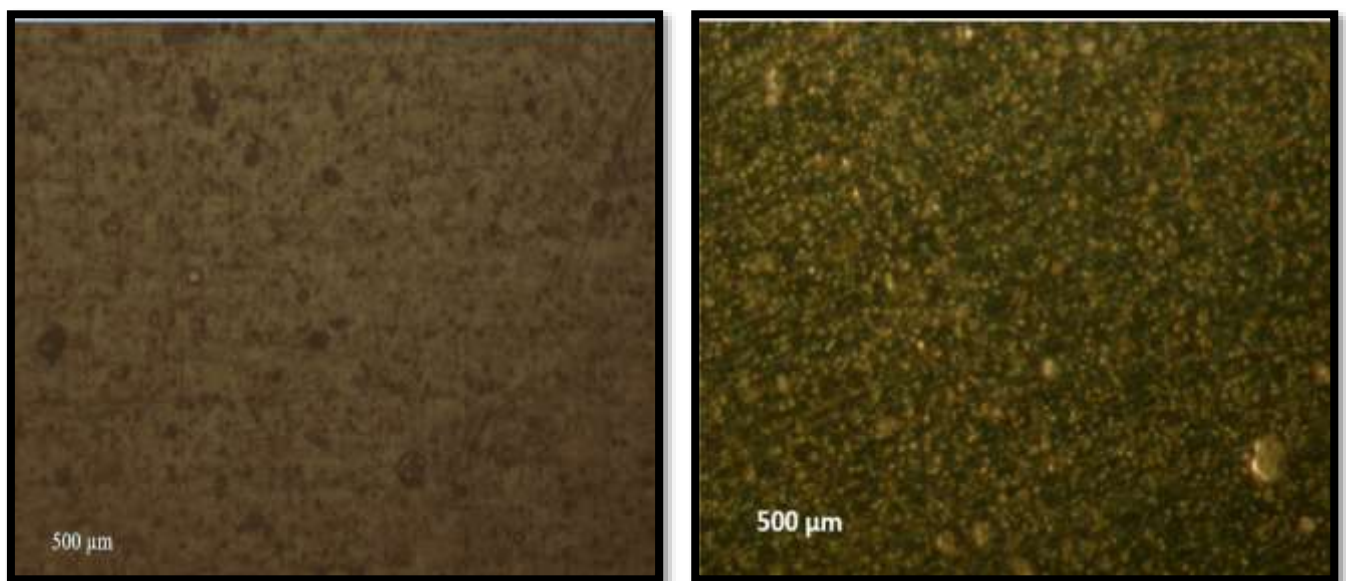


Figure 6. Optical imaging of Ti6Al4V alloy after coating MgO/Ti6Al4V thin films at 300 °C with deposition time (a) 3hrs (2.43μm) and (b) 6hrs (3.36μm).

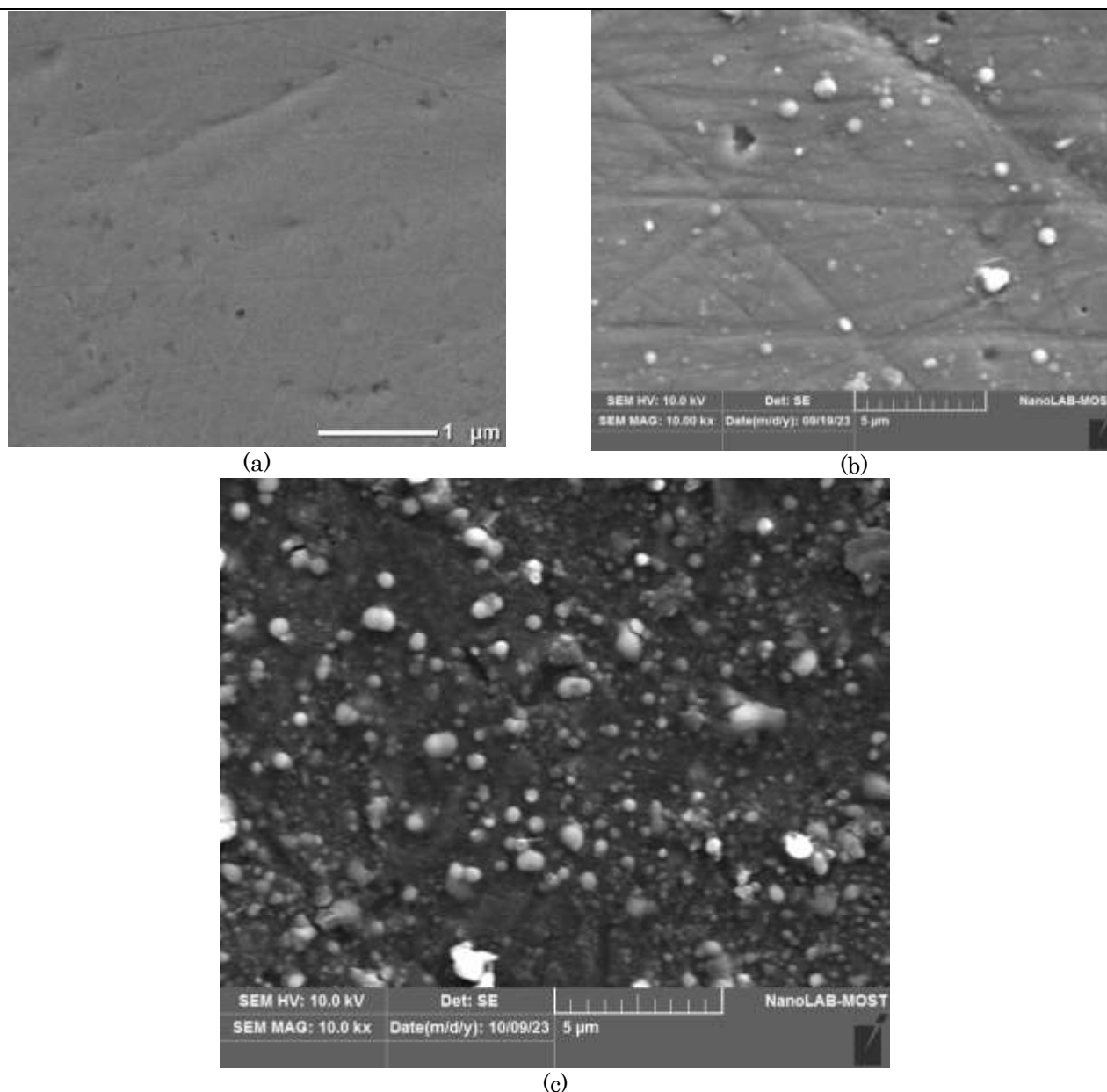


Figure 7. SEM micrographs of Ti6Al4V alloy (a) uncoated MgO/Ti6Al4V thin films annealing at 300°C with deposition time (b) 3hour (2.43μm) and (c) 6hour (3.36μm).

Table 4. EDS result, the Weight percentage for elements in MgO/Ti6Al4V alloys for deposition time 3 hour (2.43μm thickness) and for 6 hour (3.36μm thickness)

Element	Wt.% for elements At 3hour	Element	Wt. % for elements At 6hour
O	59.66	O	40.71
Mg	26.20	Mg	54.32
Al	0.35	Al	1.26
Ti	13.22	Ti	3.59
V	0.57	V	0.11
Total:	100.00	Total:	100.00

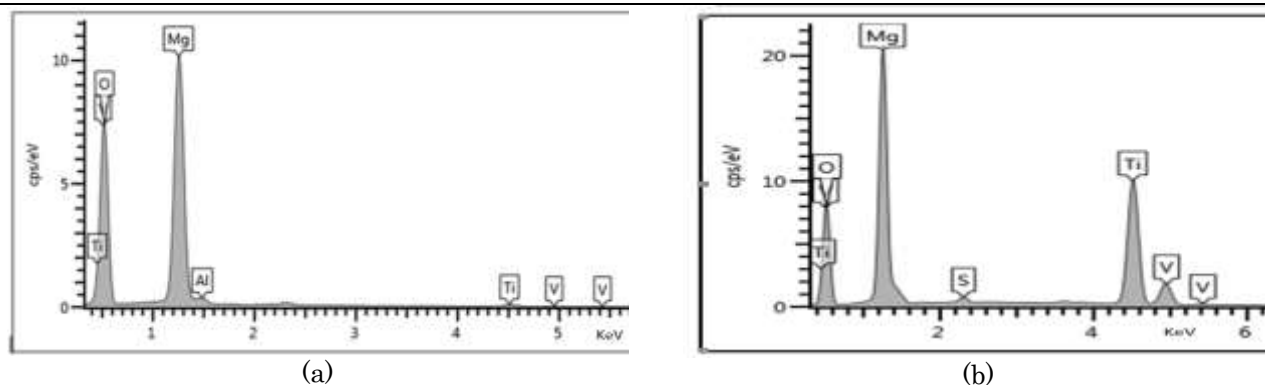


Figure 8. EDS chart for MgO/Ti6Al4V alloy deposition time (a) 3hrs (2.43μm) and (b) 6hrs (3.36μm).

3.5 EDS Results

From EDS of figure 9 and table 5, we notice the percentages material for MgO films deposited on Ti6Al4V alloys as shown in table 4. We notice w% of Mg 54.32 and 40.71 of wt% Oat 3 hour deposition time (2.43μm) thickness and 59.66 wt% of O and 26.20% wt% of Mg for 6 hour (3.36μm) thickness.

From fig.9 using program image SEM to determine the grain size of particles coated in the specific area with a magnification 5 μm (1664 and 2445) for 3 hour and 6 also the equivalent diameters with nanograin size of deposition (177.5nm and 264 nm) respective as shown in table 5.

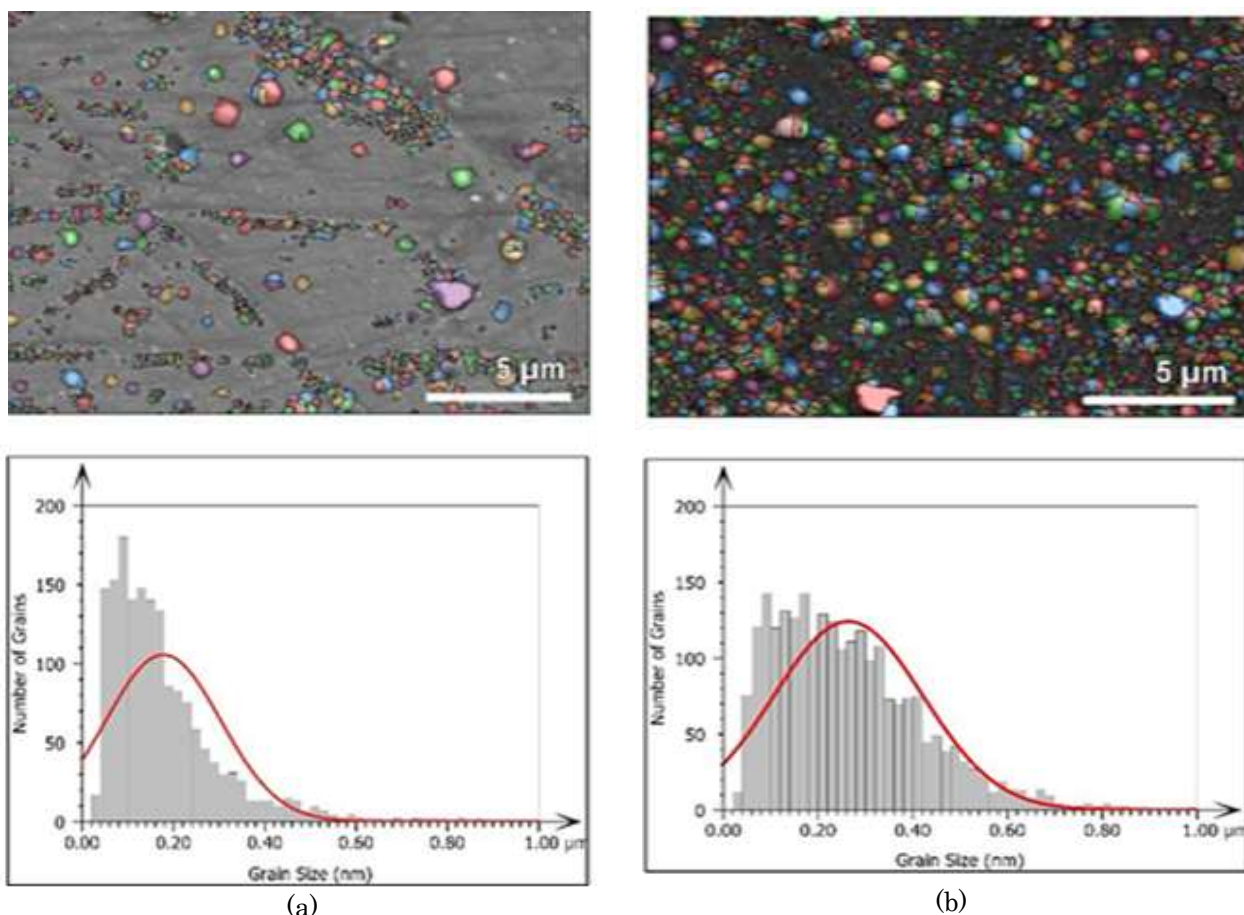


Figure 9. The EDS image and grain size of MgO/Ti6Al4V alloy Deposition time (a) 3hrs (2.43μm) and (b) 6hrs (3.36μm).

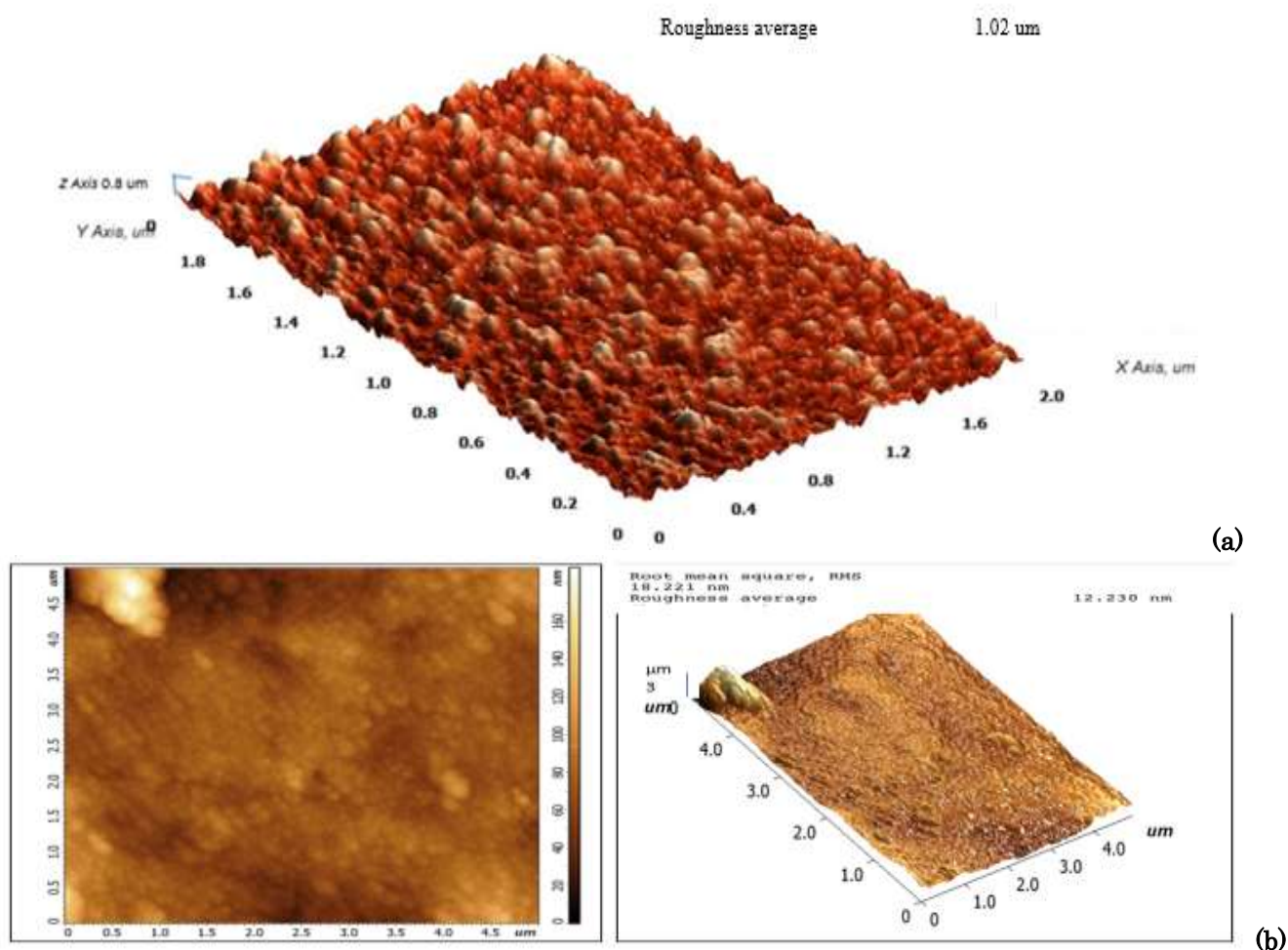
Table 5. Grain size of MgO film at Ti6Al4V from SEM analysis of two thicknesses

Thickness (μm)	Number of particles	Mean Grain Size (nm)
2.43	1664	177.5
3.36	2445	264

3.6. AFM Results

Figure 9 and table 6 presents AFM images of the surface morphology of Ti6Al4V alloy and MgO films deposited on Ti6Al4V, characterized by islands shape with different roughness average values: 1.02 μm of uncoated in fig. 9(a), and 12.36 and 36.53 nm with coated fig.9(b and c), corresponding with average diameters 84.4 nm and 93.4 nm relative to the total thickness of the films (2.43 and 3.36 μm) and the RMS value of roughness samples are 18.22 nm and 46.14 nm respectively. The potentially coating of Mo creating a rougher or smoother surface, the value reduces after coated from 1.02 μm to 12.23 nm size and 36.54 nm doubling deposition the deposition time leads to a doubling the thickness and tripling the

values of RMS and average roughness, but the average sizes for both samples found by AFM are almost same. The painting process was done under the same condition and so on for particle size belong to aggregation of particles deposited. The even steepest valleys between the islands are hollow connectivity among themselves, at least as discerned through the resolution of the AFM probe [26]. Table 6 the EDS image (using the ImageJ program) average sizes for both samples doubling compared to result AFM that belong to aggregation, but are in nano size the similar found in table 3(A), belong to rapprochement to crystallin sizes of paint particles of two thicknesses.



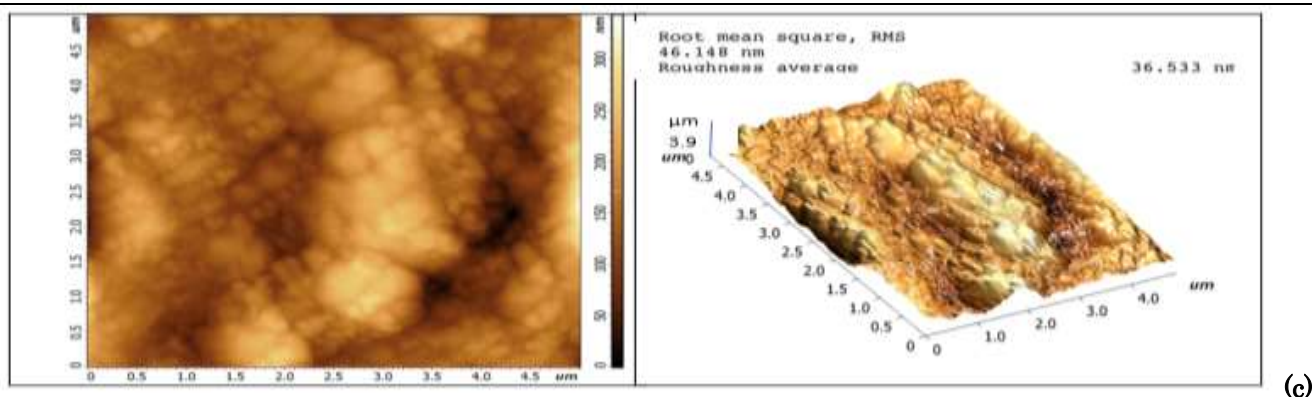


Figure 9. AFM images of the uncoated Ti6Al4V (a), MgO films on Ti6Al4V (b) 3hrs (2.43μm) and (b) 6hrs (3.36 μm).

Table 6. RMS and average roughness of MgO/ Ti6Al4V at substrate temperature 300°C from AFM analysis

Thickesses	2.43μm (3hrs)	3.36 μm (6hrs)
RMS (nm)	18.22	46.14
Average size (nm)	84.4	93.4
Average roughness (nm)	12.23	36.53

3. Electrochemical results

3.1. Corrosion analysis

Figure 10 shows the behavior of open circuit potentially evident, we obviously see the sample coated at 6 hour was passive than the other samples, where the OCP become (0.123 V) while the OCP for the uncoated sample was (-0.631V). From fig.11, it

represent the change in polarization curve (tafel) and table 8 the corrosion characteristics for all samples we see that the corrosion rate was reduced to (4.535×10^{-4} mmpy) for MgO deposition on Ti6Al4V alloy at 6 hour and (1.470×10^{-2} mmpy) for the uncoated Ti6Al4V. The corrosion rate was reduced to about 33 times.

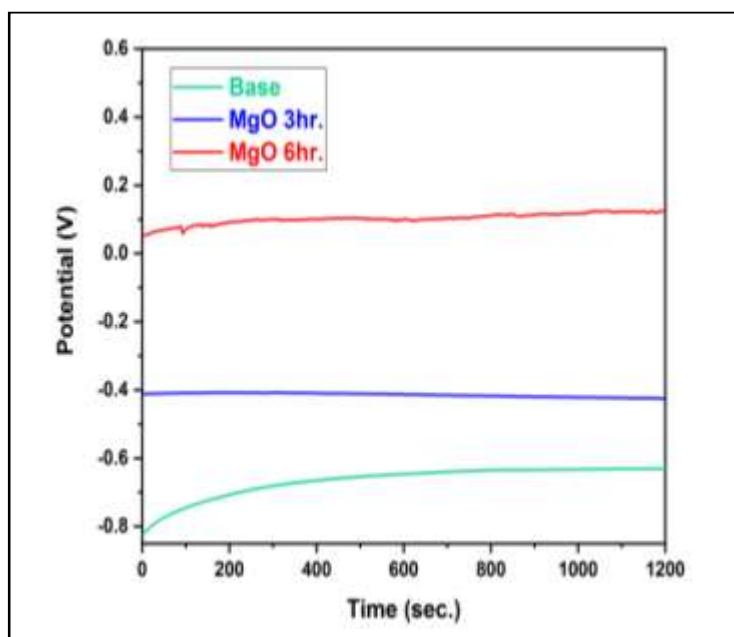


Figure 10. The Open circuit potential test for samples coated by MgO.

Table 7. Corrosion characteristics for all samples.

ITEM	E _{corr.} (volt)	I _{corr.} (Amp)	Corr. Rate (mmpy)	OCP (volt)
Base	-0.155	1.689×10^{-6}	1.470×10^{-2}	-0.631
MgO 3hr.	-0.565	2.141×10^{-7}	1.863×10^{-3}	-0.425
MgO 6hr.	-0.277	5.211×10^{-8}	4.535×10^{-4}	0.123

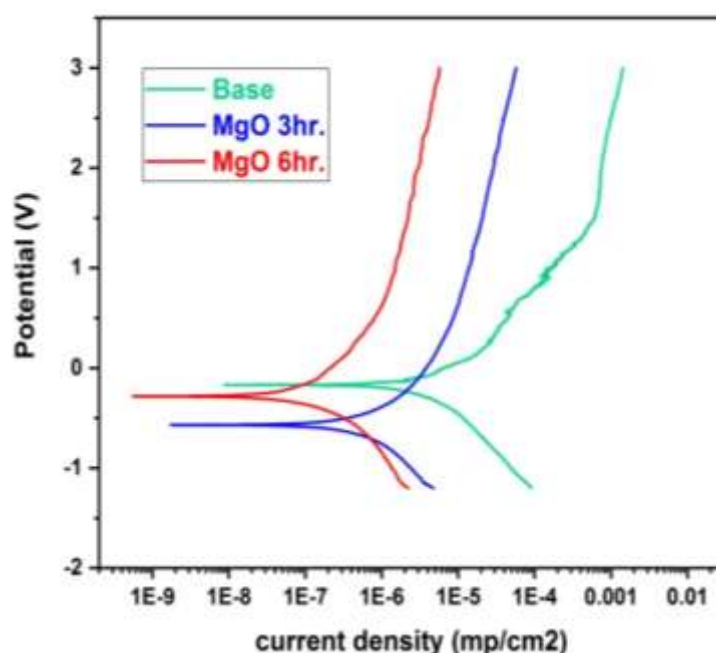


Figure 11. The Polarization curves (tafel) for all samples

The (R_p) resistance polarization can be funded from the slopes of the anodic and cathodic curves (bc and ba) from eq. (1) to calculate the coating's impede corrosion, as shown in table 8.

$$R_p = \frac{\Delta E}{\Delta i} = \frac{bc \times ba}{2.303 \times i_{cor} \times (bc + ba)} \quad \dots (1)$$

From table 9 we see the polarization resistance increased from (887.252 $k\Omega \cdot cm^2$) for sample coated at 6 h compared with (41.110 $k\Omega \cdot cm^2$) to uncoated sample. The protection efficiency can determine from equation (2) below [27]:

$$PE = \frac{i_{cor.(uncoated)} - i_{cor.(coated)}}{i_{cor.(uncoated)}} \times 100 \quad \dots (2)$$

From table 9, which represent the protection efficiency for the coated samples we see that the sample coated with at 6 hour achieved. The better protection efficiency reaches up to 96.91%, as good indicator for an excellent coating performance. The Nyquist plot for samples coated with MgO layer shows a semicircle shape for non-porous layer, as shown in fig. 12.

The comparison reveals a significant disparity in the Nyquist curve between the coated and untreated samples, indicating a substantial variance in resistance between the two samples. Where i_{corr} uncoated represents the corrosion current for the Ti6Al4V alloy, only current of corrosion sample and i_{corr} coated represents the corrosion for the coated sample [20-21]. Table 9 calculated polarization resistance for different coated sample.

Table 8. Calculated polarization resistance for different coated sample

ITEM	I _{corr.} (Amp)	bc	ba	R _p (Kohm)/cm ²
Base Ti6Al4V.	1.689×10 ⁻⁶	0.289	0.358	41.110
MgO/ Ti6Al4V 3hr.	2.141×10 ⁻⁷	0.242	0.257	252.776
MgO/ Ti6Al4V 6hr.	5.211×10 ⁻⁸	0.178	0.265	887.252

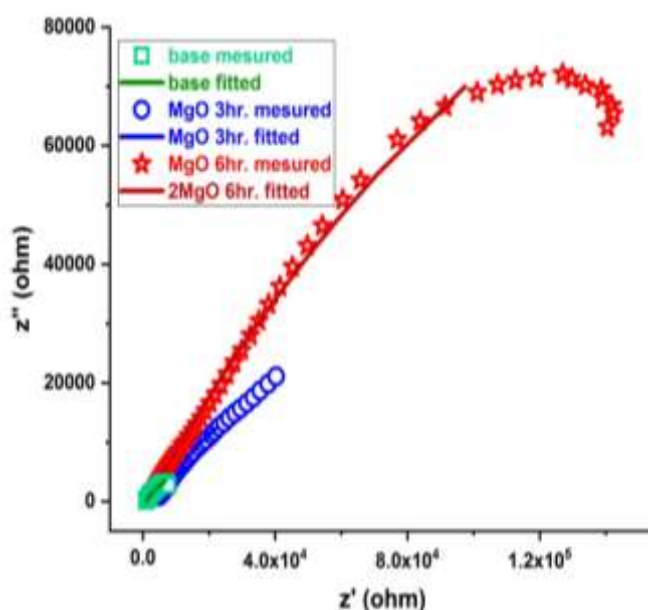
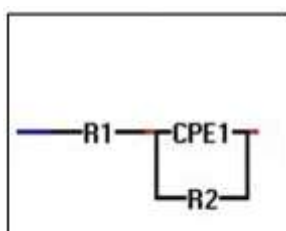


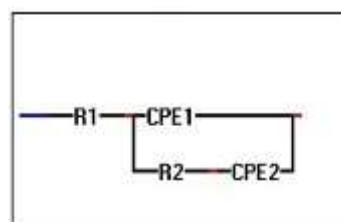
Figure 12. The Nyquist plot for samples coated with MgO/ Ti6Al4V

The fitted equivalent circuit for uncoated samples shows typically the Randle circuit model, as shown in fig. (13.a), while the coated shows different fitted equivalent circuit model refers to the non-porous layer as show in fig. (13-b) where we used a Constant Phase Element (CPE) instead of a capacitor (C) due to the not ideal capacitance behavior, we also used

R1 as the resistance of the solution and R2 as the charge transfer resistance. Table 10 presents the fitted calculated values for the equivalent circuits, showing that the resistance for the sample coated for 6 hour was 419.6 kΩ cm², compared with 1 kΩ cm² for the double layer resistance of the uncoated sample, best results compared with result [13].



(a)



(b)

Figure 1. The fitted equivalent circuit models for (a) uncoated and (b) coated samples

Table 9. Calculated protection efficiency of coated samples

ITEM	<i>i</i> _{cor.} (Amp)	PE (%)
Base .Ti6Al4V	1.689×10 ⁻⁶	-----
MgO / Ti6Al4V 3hour.	2.141×10 ⁻⁷	87.32
MgO/ Ti6Al4V 6hour.	5.211×10 ⁻⁸	96.91

Table 10. The calculated fitted corrosion values from equivalent circuit models.

ITEM	R1 (ohm)	R2 (Kohm.cm ²)	CPE1 (F)	n1	CPE2 (F)	n2
base Ti6Al4V	1000.3	-----	-----	---	6.7095E-05	0.536
MgO/ Ti6Al4V 3hour	3187.5	197.3	2.6461E-06	0.660	1.3030E-04	0.143
MgO/ Ti6Al4V 6hour	3465.1	419.6	2.6649E-06	0.532	4.6062E-04	0.256

4. Conclusions

The following is concluded:

1. RF sputtering was successfully for Coated Ti6Al4V Alloy with (MgO) thin layer for 3 hour and 6-hour time deposition respectively.
2. OPT and SEM gives images of microstructural information of uncoated and coated varieties. The OPT images revealed a clear effect of etching as pitting on the surface to improve bond strength in MgO/Ti systems. Thus, increasing the adhesion between the implant and tissue.
3. Crystal structure of the coated surface of the Ti6Al4V alloy was determined by XRD for 3 and 6 hours respectively. The crystalline size (27.91 and 29.56 nm). XRD analysis showed the elemental components of the surface materials in Ti6Al4V alloys/MgO, also the concentration of Al is low and disappear V element in the alloy compared to Ti. Therefore the peak intensity is lower for these elements.
4. SEM with said view cross section determine the thicknesses (2.43 μm for 3 hour and 3.36 μm for 6 hour) time deposition respectively. EDS give the weight percentages for elements. (SEM-EDS image program was determine grain size (177.5 and 264 nm).
5. The roughness of samples was determined by AFM the value reduce after coated from (1.02 μm) uncoated to (12.23 and 36.54 nm) for the coated samples and the average size of particle coating (84.4 and 93.4 nm) for 3 hour and 6 hour) time deposition respectively.
6. The average size of particle coating with nano size determines by different techniques. However the differences in values are due to the method of analysis used by each technique; EDS-SEM uses scan image, AFM use probe, and XRD use diffraction method.
7. Potential dynamic polarization and open circuit potential (OCP) and Electrochemical Impedance Statistical Measurements (EIS) measurements in simulated body fluid (SBF); The OCP shows increase in potential with increasing coating times, which means an increased in passivation with increasing thickness of coating layer.

8. The polarization resistance increased with increasing coating time and reduce for (887.252 kΩ cm²), which is the sample coated at a 6-hour period, compared to (41.110 kΩ cm²) for the uncoated sample. Also, the protection efficiency reaches 96.91% for the sample coated at the 6-hour period.

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