

Al-NANOSTRUCTURED FILM COATING ON MILD STEEL SURFACE FOR CORROSION PROTECTION

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ABSTRACT

Nanostructured coating is a great and important for surface coating industries, especially in oil and gas, and automotive. This type of coating is expected to improve three times longer than a normal coating in corrosion protection. The nanostructured coating will fill up the uneven surface substrate at the size of nanometer compared to the normal coating which only cover the substrate surface. The void between the substrate and coating material initiate corrosion activities. In this work Aluminum nanostructures coating was deposited on mild steel surface by an electron beam thermal evaporator. The parameters used to optimize the coating is power and time exposure. The formation of nanostructures coating was measured by AFM, FESEM and EDX. The deposition of Al-nanostructured on mild steel substrate was carried out by applying deposition time of 2 min and 5 min with various current deposition such as 60A and 70A. The results show the formation of nanostructures film coated on mild steel in certain parameter.

Keywords: Al-nanostructures; Film Coating; Thermal Evaporation; Mild steel

INTRODUCTION

Corrosion protection of actively corroding metals such as mild steel using such methods remains relatively less explored. Mild steel is low carbon steel that inexpensive and widely used as a structural material in various engineering applications [1]. It's known as good ductility but with poor wear resistance [2]. One of the main areas of modern science of materials is to create nanostructured materials with surface layers. Nanostructured materials represent a promising class of protective coatings will super-diffused properly into the substrate surface, thus less void between an evident gap in the mechanism of the coating protects against corrosion [3]. Therefore, in order to extend its service life time, several processes to improve surface protection with formation of Al nanostructured coating layer by Electron Beam Thermal Evaporation technique.

EXPERIMENTAL

Surface pre-treatment of mild steel

The material used was mild steel specimen with $2\text{cm} \times 2\text{cm}$ dimension. The surface of mild steel was mechanically polished initially with rough silicon carbide (SiC) paper (400cW) and followed with fine Sic paper (800cW) in order to get clean and smooth surface without impurities and oxide layer. After that, the polished mild steel specimen was rinsed with ultra-pure water and degreased using ultrasonic bath in acetone for 15 minutes and left standing to dry using nitrogen gas before further deposition process.

Coating deposition

Aluminium nanostructures coated on mild steel substrate using Electron Beam Thermal Evaporation method. Al nanostructured coating were deposited on mild steel coupons by electron beam thermal evaporation of a 99.999 % pure Al wire target in the VPC-1100 physical model vacuum deposition system. The deposition chamber was pumped down to 1×10^{-4} Torr by using the vacuum evaporation pump. The film thickness was monitored by the deposition time (2 min, 5 min). The deposition beam current was 60 A and 70 A. The distance between source and substrate is kept constant at 16 cm.

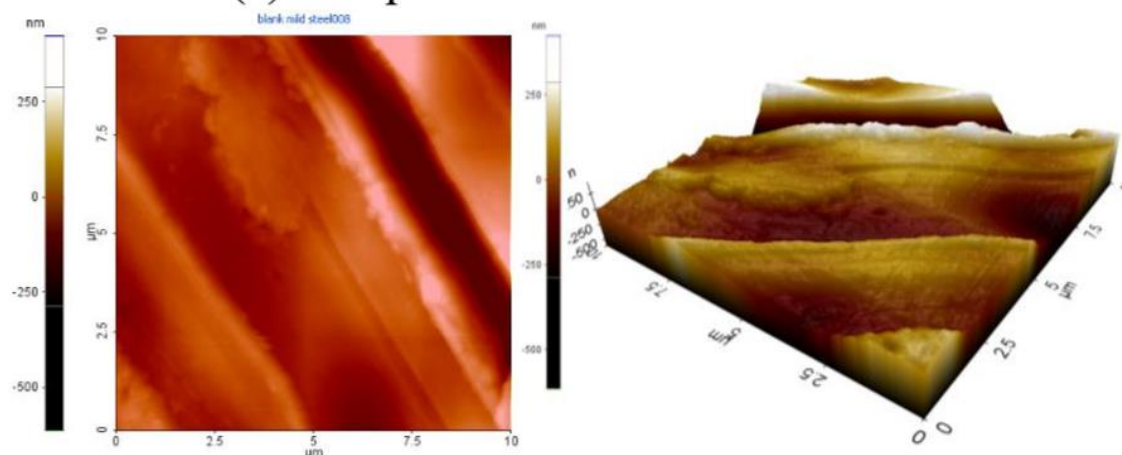
Characterization.

The 3D surface topography and roughness of the prepared samples were recorded by an Atomic Force Microscopy (AFM, XE-100) at a scan rate of 1.00 Hz and scan size $1.0\text{ }\mu\text{m}$. AFM measurements were performed under ambient conditions using standard topography AC air (tapping mode in air). The thickness of the coatings was measured at least three random areas by Surface profiler (P-6). The surface morphology of the treated specimens were visualized and imaged using Field Emission Scanning Electron Microscope (FESEM, Carl Zeiss SMT Supra 40 VP) while the chemical composition of samples were analyzed by energy dispersive X-Ray spectroscopy (EDX) controlled by a software (the Oxford INCA X-max 51-xmx 0021).

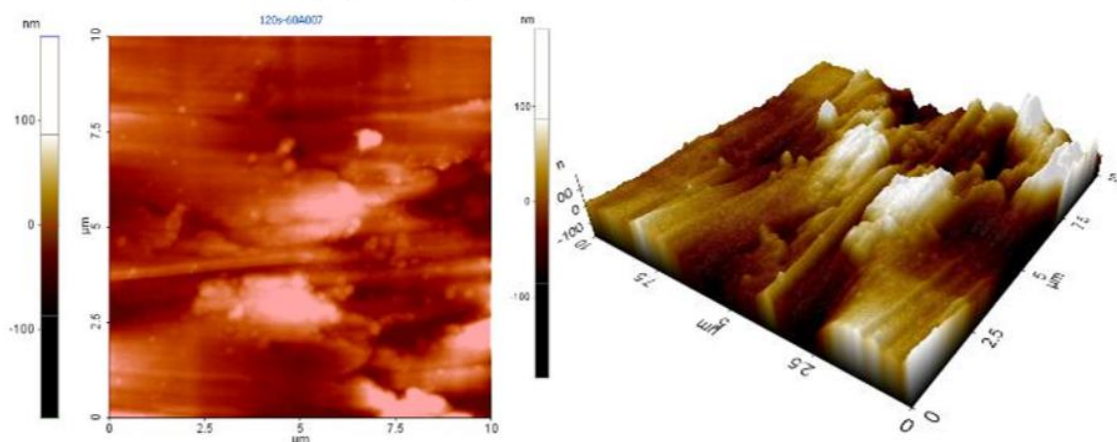
RESULTS AND DISCUSSION

AFM measurements were performed to extend information about the surface topography and roughness of the samples. The AFM images of the samples were taken and are shown in Figure1. It presents the comparison of the AFM surface topography images and AFM three-dimensional map of aluminium nanostructured coatings which different time exposed and current deposition.

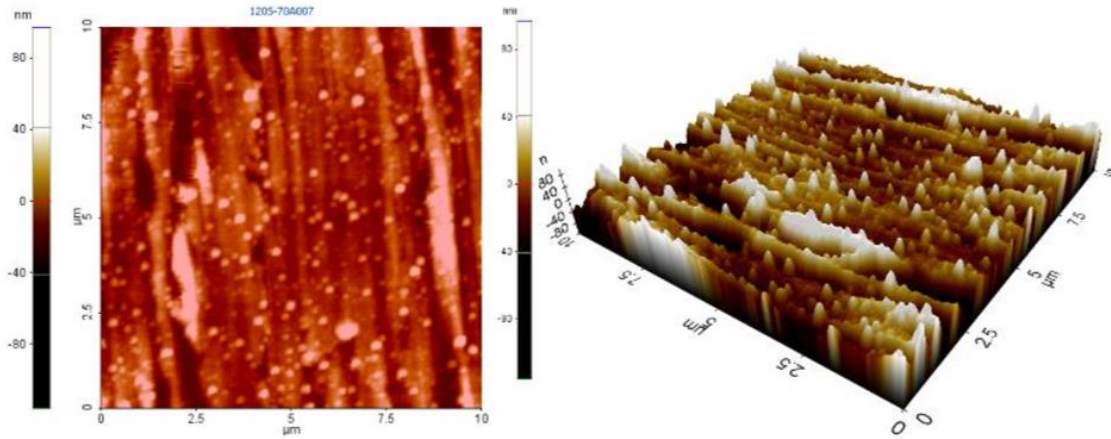
(a) Sample A: uncoated mild steel



(b) Sample B: 2 min /60 A



(c) Sample C: 2 min /70 A



(d) Sample D: 5 min /60 A

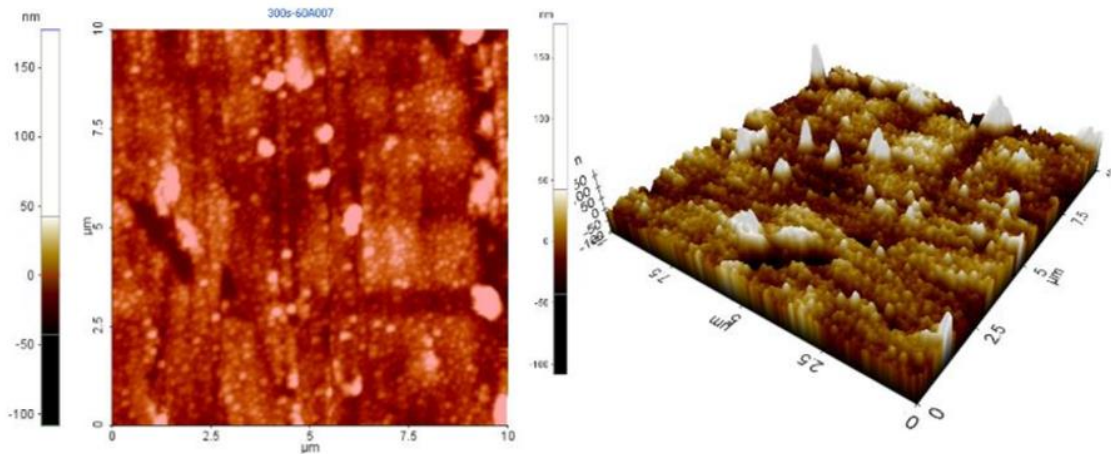


Figure 1: AFM surface topography images and AFM three-dimensional map (10 μm × 10 μm) of Al- nanostructured coated on mild steel at different time exposed and current deposition which (a) uncoated mild steel (b) 2 min/60 A (c) 2min/70 A and (d) 5 min/60 A

In the case of uncoated mild steel surfaces obtained flat structure with crack due to the polishing effect. The average surface roughness is 108.067 nm for uncoated mild steel. It can be seen that, uncoated mild steel was rougher compared to Al coated on mild steel. In contrast, for Al- nanostructured coating samples, numerous topography images were recognized on the mild steel surface depending on deposition conditions. All Al coatings, unlike (2 min/60 A) sample, indicated rather similarly grain structure with different average surface roughness, as shown in Table 1.

The roughness of samples was decreased from 33.296 nm to 15.587 nm, when the current deposition were increased from 60 A to 70 A at the constant time exposure 2

min. The significant increment of roughness average of 2 min sample may due to high grain size surface which can be observed from the FESEM image. According to G. Tailong (2013), the increase of the sputtering power and the kinetic energy of the sputtered particles also, increase with forming a continuous surface migration energy. So there are more particles reach the substrate crystal on surfaces and larger of particles is formed. The current deposition is large when the high power adsorbed atomic migration mechanism Al-nanoparticle to a large. It is possible to diffuse from the grain boundary to the layer coating interface lower in energy, space or gap position, so the roughness of the layer coating decreased [4].

Table 1: Result of AFM surface roughness

Sample	D.C Power	Time Exposed	Ra (nm)
A	uncoated mild steel		108.067
B	60 A	2 min	33.296
C	70 A	2 min	15.587
D	60 A	5 min	15.410

The AFM image in figure 1 (b) and (d) shows the topography of surface roughness of the difference time exposure 2min and 5 min at the constant current 60 A. The surface roughness for sample (b) shows bigger value with 33.296 nm due to shorted deposition time. However, the surface roughness for sample (d) shows smallest value with 15.410 nm. The time exposures increases from 2 min to 5 min show the surface roughness is decreasing because the pillar start growth and the total number of pillar increase.

Lower surface roughness is observed for sample C and D, respectively: $Ra_C = 15.587$ nm and $Ra_D = 15.410$ nm. It is shows the number of agglomerates is smaller and agglomeration of aluminium particles is observed at certain regions of the coating and a surface morphology homogeneously covered with aluminium layer [5]. The formation of Al-nanostructured growth well at sample 5 min/60A. The pillar size is less than 100 nm for this sample.

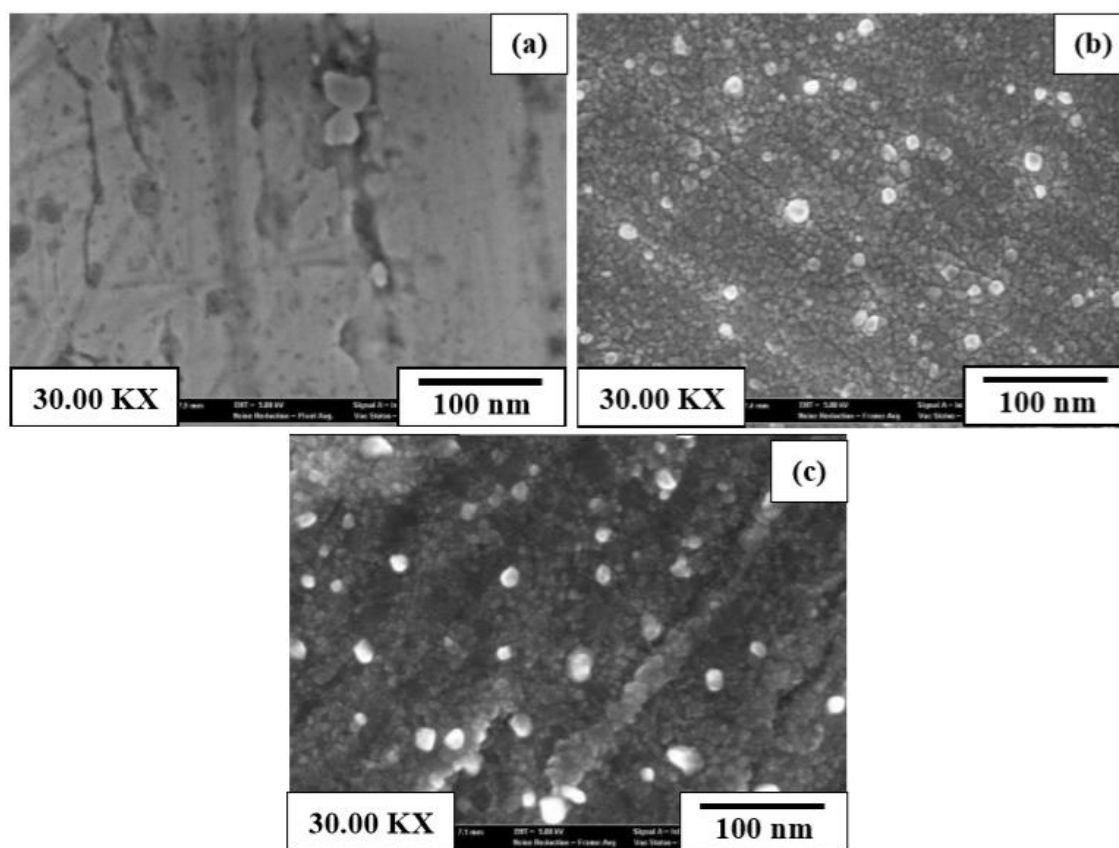


Figure 2: FESEM surface morphology of uncoated mild steel and Al-nanostructures coating (a) uncoated mild steel (b) 70A/2min and (c) 60A/5min

Figure 2 shows the morphologies of the uncoated mild steel (a) and Al nanostructured coating (b) surface as imaged by FESEM. Surface of the uncoated mild steel (Figure 2a) seems to be too rough with imperfections due to the contamination which can be extrinsic; composed of organic debris and mineral dust from the environment and also be intrinsic; such as a native oxide layer.

(Figure 2b) illustrates the field emission SEM micrograph of Al-nanostructures coating with deposition time at 2 min/70 A. The morphology of the Al-nanostructured coating shows the compact uniform and produced agglomerates coatings covered the entire surface on the mild steel. The growth of the nanoparticles and have significant influence on microstructure of Al- nanostructured coating. (Figure 2c and d) shows the Sphere-like, light in reflections formations (“nanospheres”) of a diameter of (30 nm-110 nm). Since nucleation was accomplished instantly, the growth times ultimately controlled surface morphology of Al-nanostructures coating deposited on the mild steel. Growth times played important role determining the morphology of Al-nanostructures coating [6]. Since nucleation was accomplished instantly, the growth times ultimately controlled surface morphology of Al-nanostructures coating deposited on the mild steel. The average particles size is less than 100 nm it is easily avoid

the formation of void between coating materials and substrate surface. This formation are distributed rather homogeneous and attached on the surface of dense elevated parts of the studied coating.

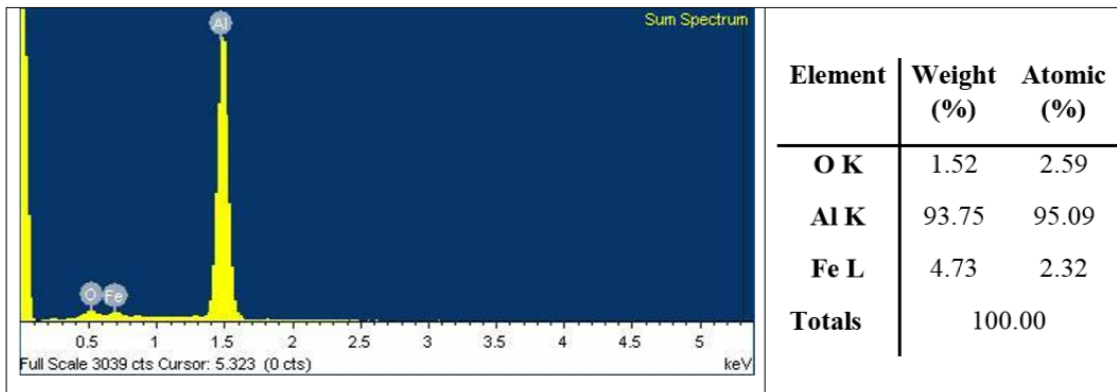


Figure 3: FESEM photomicrograph of Al- nanostructured coating with corresponding EDX spectrum

The investigation of elemental composition of Al-nanostructures coating deposited on the surface of mild steel substrates was performed using EDX analysis. Figure 3 shows the EDX analysis of the deposits obtained on the working with deposition beam current was 70A/2min. As expected, the deposits display a strong peak for Aluminium, slight peaks of the iron and oxygen. The Fe detected in the Al deposits may come from the substrate and the detected O may result from oxidation of Al of Fe. Table in figure 5 shows the components of the deposits clearly. The oxide presents in the coating will give advantages as aluminium oxide or alumina which refractory material, ceramic in nature and forms hard material which would increase coating hardness [7]. The EDX at various white spots on the surface of Al-nanostructures can grow uniformly in all directions, consequently forming spherical-like Al-nanoparticles.

CONCLUSION

In summary, the growth of Al-nanostructures deposited on mild steel substrates has been demonstrated with increasing current deposition and growth times exposure. The formation of Al- nanopaticles on mild steel surface shows the nanostructured Al-coating was formed as aspected. In this experiment Al-nanostructures were synthesized using aluminum wire target evaporation process that included the control of growth times and current deposition.

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