

Influence of Plating Parameter and Surface Morphology on Mild Steel

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Abstract

The plating parameter effect of zinc deposition on mild steel substrates was investigated. The results showed an improved surface finished and homogeneous layer. The distance between the anode and the cathode on voltage, plating time and coating thickness were considered. The mild steel was deposited into solution of zinc bath for varying voltage between 0.5 v and 1.0v. It was discovered that the sample plated at 0.8v for 15 minutes gives the best plating deposition and appearance. The surface morphology of the plated sample was analyzed by Focused ion beam scanning electron microscopy (FIB-SEM), AFM and X-ray diffraction.

Key Words: Substrate, zinc deposition, plating parameter.

Introduction

Electroplated zinc coatings are considered as one of the main methods used for the corrosion protection of steel (1). The usage in industrial sectors as a protective coating for large quantities of products and other fabricated ferrous metal parts have lead to the development of alloys. Zinc deposits offer good protection and decorative appeal at low cost (1-7). Since zinc is anodic to steel, it protects the base metal even if the deposit is porous. An acid zinc bath is used where it is desirable to have a high plating rate with maximum current efficiency. Considering pollution hazards and high industrial effluent

treatment costs, non-cyanide zinc baths have been introduced in place of cyanide solutions (4-5).

Zinc coatings are obtained either from cyanide, non-cyanide alkaline or acid solutions. Good deposition depends mainly on the nature of bath constituents, the substrate surface, and time of plating. However, there is increasing fear that someday coating of metals will be subdued by these interacting stresses (6-7). In the present work, an attempt has been made to study the influence of plating parameter of zinc deposition on mild steel and morphology of this substrate. SEM, AFM and XRD were employed for this surface characterization.

Experimental Method

The Mild steel substrate of dimension 1.0 x 3.0 x 0.2 cm was used. The analysis by spectrometer leading

to the chemical composition (in Mass %) is gathered in the following Table:

Element	% Content	Element	% Content	Element	% Content	Element	% Content
P	0.0066	Fe	99.4	A	1 0.125	B	0.0009
Zn	0.022	Co	0.0057	Si	0.028	S	0.018
As	0.0059	Ti	0.001	Mn	0.397	Nb	0.0046
Zr	0.0016	Pb	< 0.0020	Ni	0.025	V	0.0075
La	0.0018	Mg	0.002	Mo	< 0.0020	Bi	0.0024
Cr	0.0075	W	< 0.010	Ce	< 0.0040	Ca	0.017
C	0.131	Cu	0.035	Sn	< 0.001		

The chemicals used were of AR grade and easily soluble in water. For preparation of the solutions, distilled water was used. Surface preparation was done on the polishing machine with different grades of emery paper in order of 60um-1000um grades, followed by polishing. The pickling of the samples was done in diluted H₂SO₄ acid solution; this was to remove all organic contaminants and oxides, followed by electrolytic degreasing with alkaline solution by passing current into the solution for about 5 minutes and subsequent cleaning in water, to remove all grease or oily contaminants.

Electrolytically degreased metal substrate was immersed in a solution containing dissolved zinc salts and made the cathode by connecting it to the negative terminal of the rectifier of the electroplating bath. The anode was also immersed and connected to the positive terminal of the rectifier. The anode was made of pure Zinc rod

about 99.98%. The following plating parameters were varied, the voltage was varied between the ranges of (0.5 -1.0V), the substrates were plated at time variation of 10 to 35 minutes and the plating distance from the anode to the cathode also varied between 10cm to 30cm respectively. Finally, the samples were rinsed before transferring the plated sample to the passivation tank which was done with blue passivation as to increase the resistance of zinc against corrosion in two minutes, then water rinsed and later air dried.

Results and Discussion

The effects of varying parameter in the zinc plated bath on mild steel have been illustrated from figure 1-8, evaluating the performance of zinc deposition.

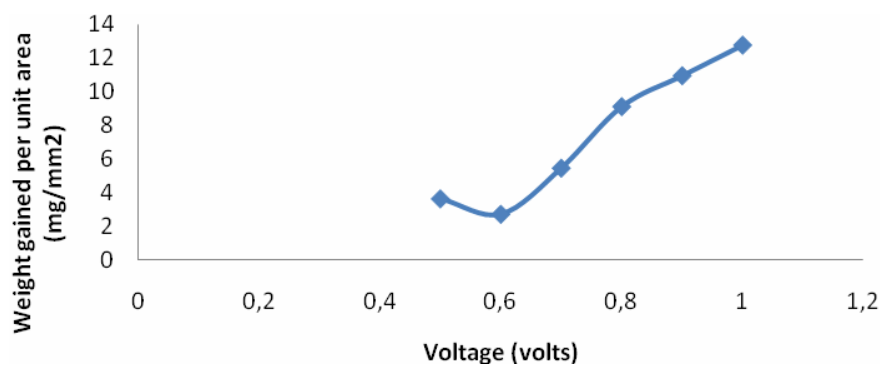


Fig. 1: Plot showing weight (mg/mm²) of zinc electrodeposited on low carbon steel against voltage (volts) at 10 min. and distance 10cm from the anode

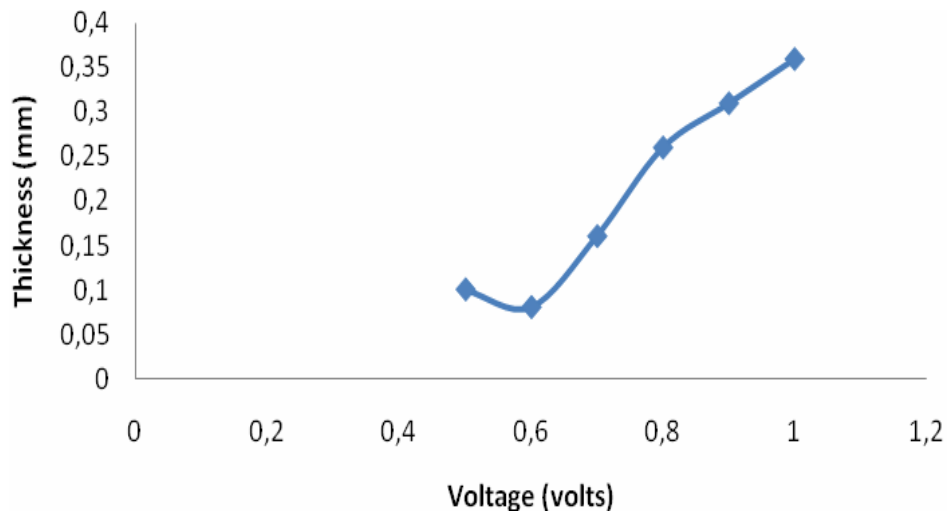


Fig. 2: Plot showing the thickness (mm) of zinc electrodeposited on low carbon steel against voltage (volts) at 10 min. and distance 10cm from the anode

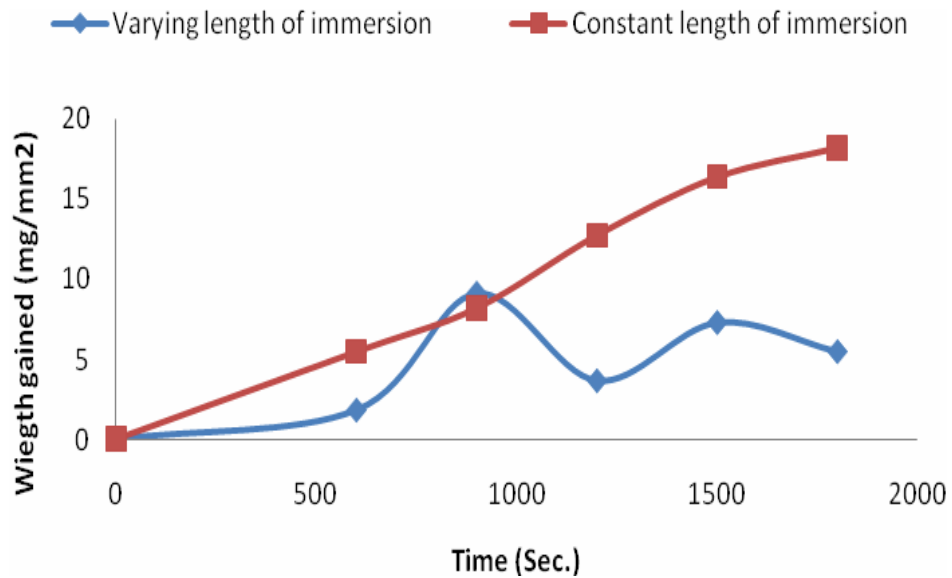


Fig. 3: Plot showing the weight (mg/mm²) of zinc plated on carbon steel gained per time (sec.) at cathode to anode distance of 10 cm

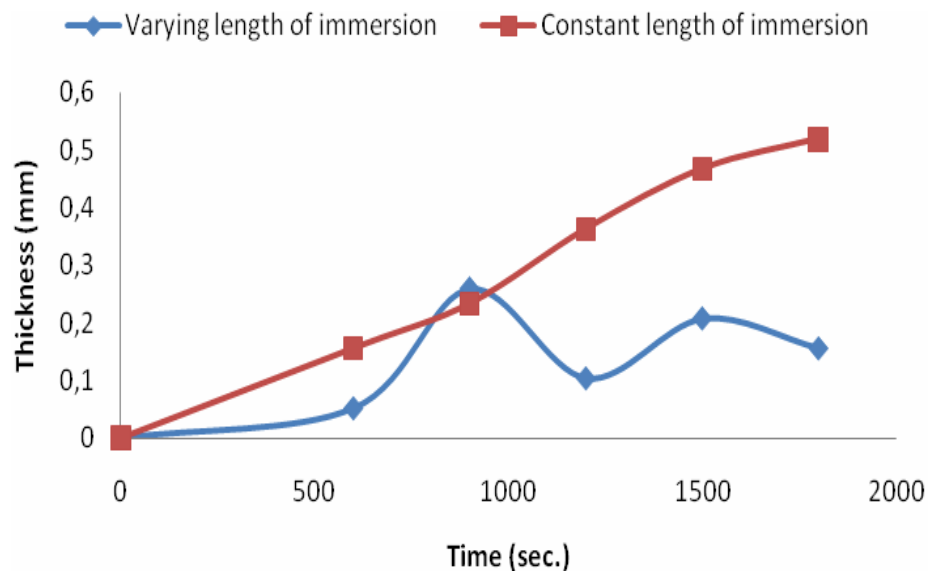


Fig. 4: Plot showing the thickness (mm) of zinc plated on carbon steel per time (sec.) at cathode to anode distance of 10 cm

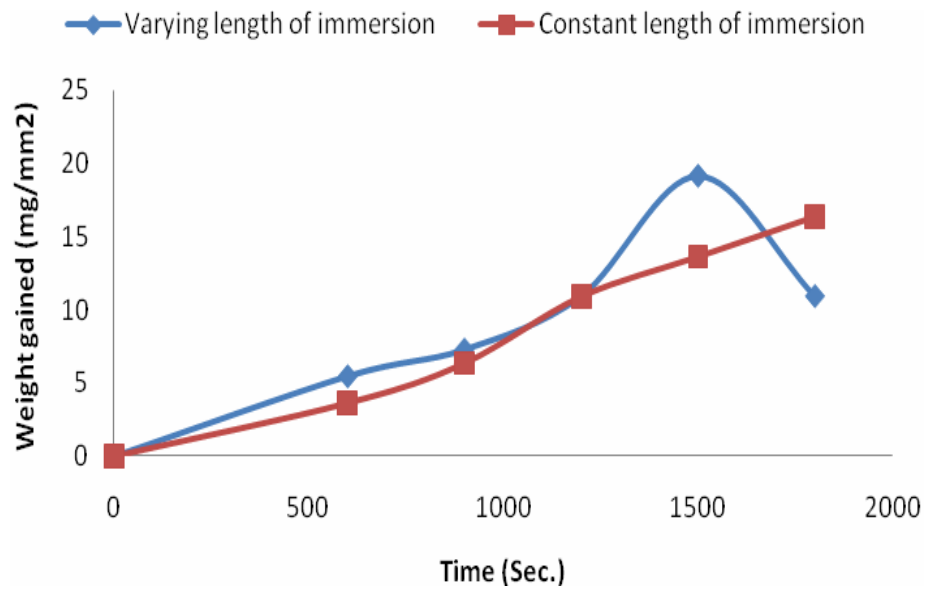


Fig. 5: Plot showing the weight (mg/mm²) of zinc plated on carbon steel gained per time (sec.) at cathode to anode distance of 20 cm

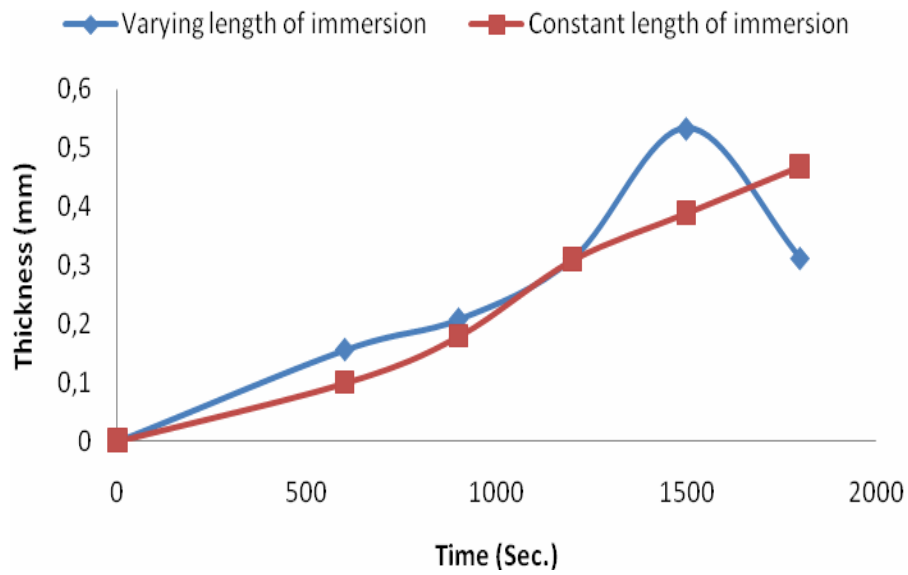


Fig. 6: Plot showing the thickness (mm) of zinc plated on carbon steel per time (sec.) at cathode to anode distance of 20 cm

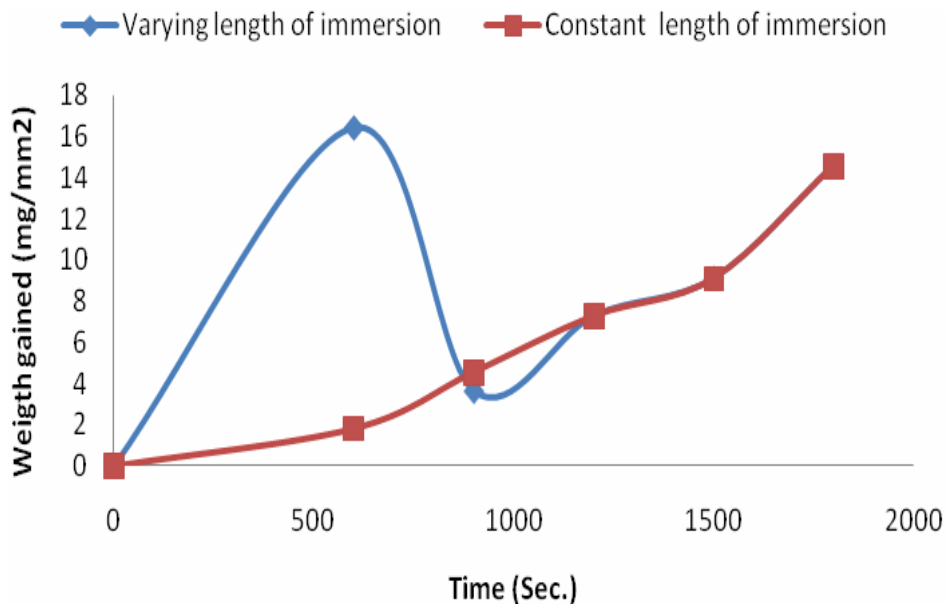


Fig. 7: Plot showing the weight (mg/mm^2) of zinc plated on carbon steel gained per time (sec.) at cathode to anode distance of 30 cm

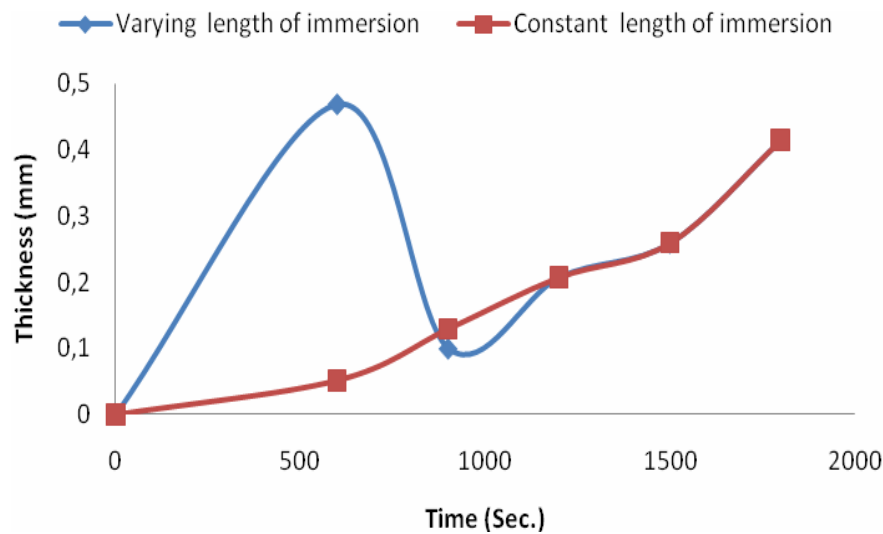


Fig. 8: Plot showing the thickness (mm) of zinc plated on carbon steel per time (sec.) at cathode to anode distance of 30 cm

Influence of voltage variation on weight gained

Critical look at figure 1-3 shows general increase in weight gained as the voltage increases. For the voltage range between 0.5V and 0.6V full surface adhesion was not obtained which was due to low voltage applied. The 0.8V was chosen at the best plating voltage, this is due to the fact that the 0.8V presents the best physical properties and good surface homogeneity. The appearance of the substrate became dull and deposition poor due to patchy films of coat on the surface of the steel sample at 0.9 and 1.0V respectively.

Influence of plating time on weight gained

Figures 3, 4 and 5 show the relationship between the weights gained, thickness and voltage on time of plating for 10cm, 20cm, and 30cm, distance of object from the anode. For constant depth of immersion and varying distance values, weight gained increases as the plating time increase. Figures 6, 7 and 8 also show the same phenomenon for the thickness of coat film.

XRD Analysis

XRD diffraction patterns obtained on the electrodeposits in 0.6V and 8V are given in Fig. 9a and 9b. At 6V and 8V Zinc phase was seen at different peak level.

Morphological study

SEM/AFM

Focused ion beam-Scanning electron microscopy, FIB-SEM and AFM, was used to investigate the surface morphology and topography of zinc deposited galvanostatically at different current densities. The zinc deposited at 0.6A and 10A are shown in figure 10. Increasing the current density caused the zinc element in the alloy to increase till 8A and decrease above that.

Figures 10 to 11 show the structural details of zinc deposit obtained. Homogeneous structure is observed with perfect crystal and uniform arrangement on the deposit. The zinc morphology consists of regular fine grain size. The area of zinc deposited from the bath at 0.6V, has a fine grained micro structure with some cracks as seen in Fig. 11a. The AFM picture shows dark- scattered deposit in some places indicating spherical crystalline deposition. Fig.11b indicates a perfect adhered and regular distributed of grains. The growths of spherical crystallites cover the entire surface, thereby giving it a uniform appearance, finer grained texture and dendrites free.

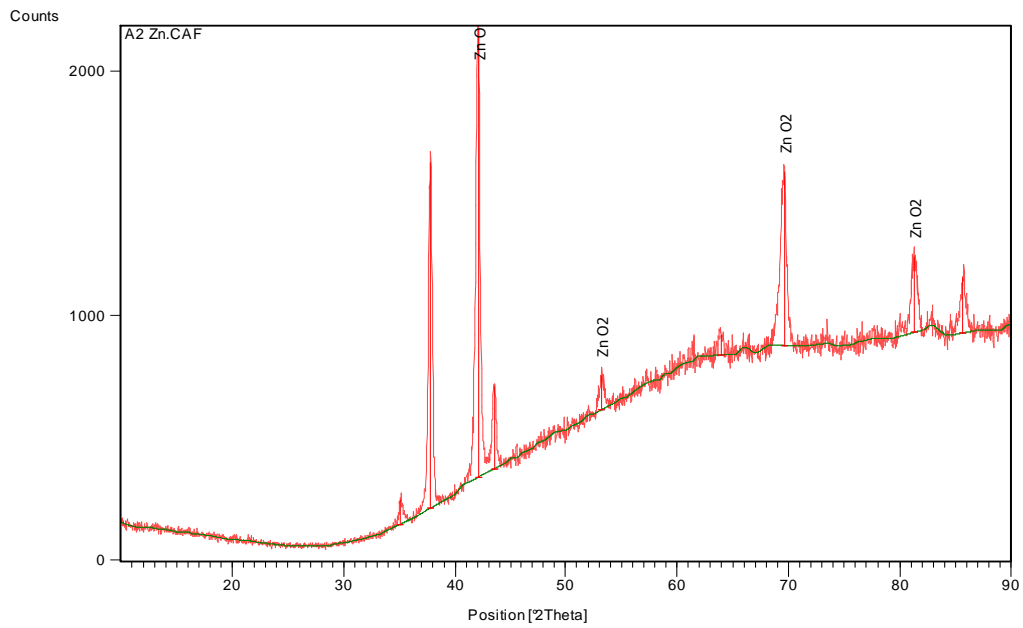


Figure 9. XRD patterns of the electrodeposits obtained from Zn at 0.6V plating

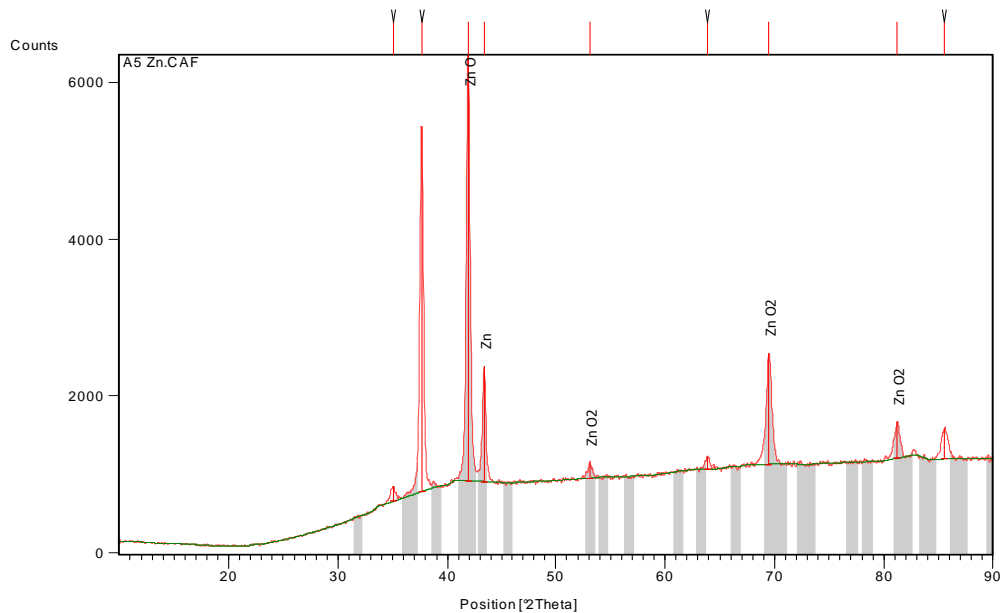


Figure 9b. XRD patterns of the electrodeposits obtained from Zn plating bath with 0.8 Volt

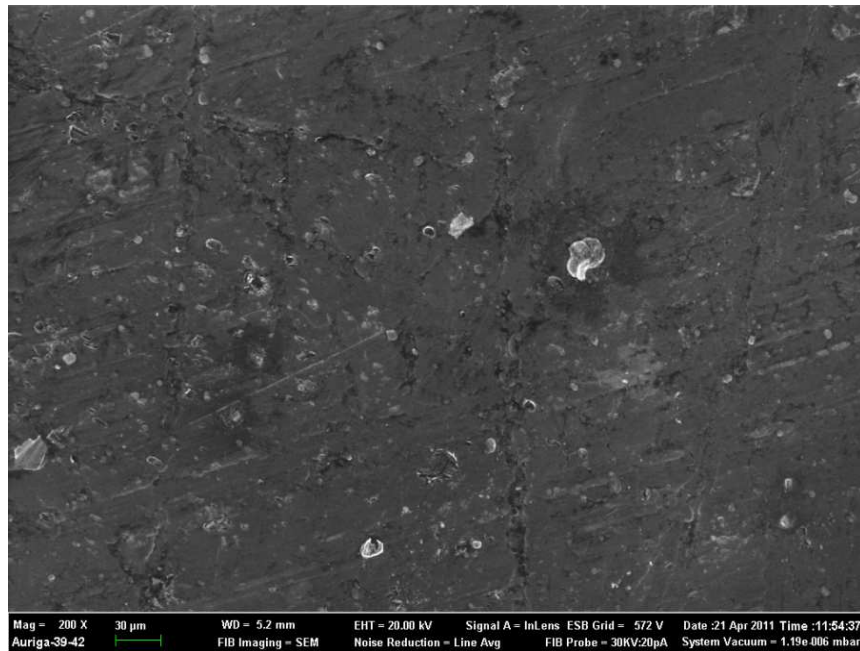


Figure 10a. SEM photograph of the deposit obtained from Zn plating bath with. $T=328$ K, $c.d.=0.6$ A/dm² time=15 minutes.

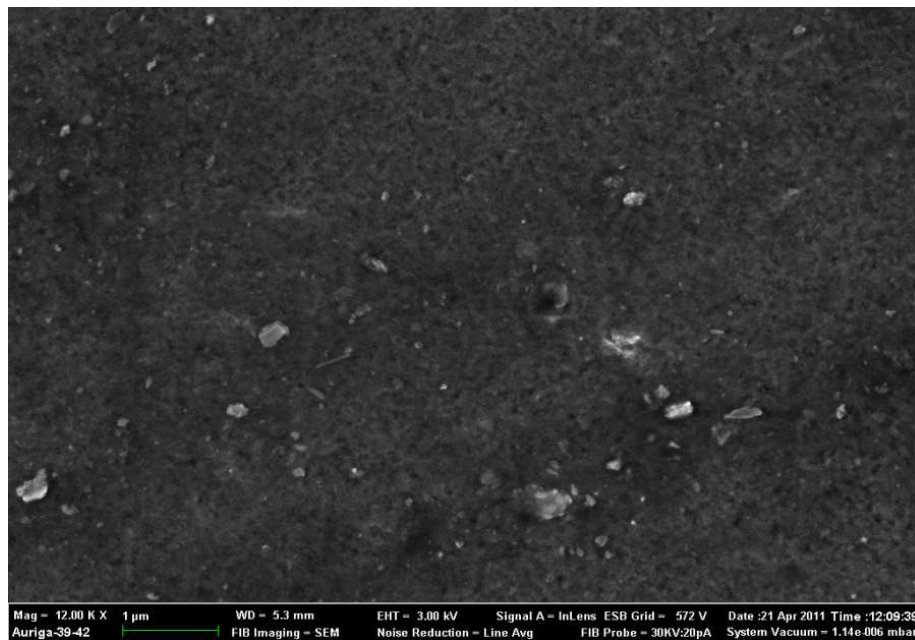


Figure 10b. SEM photograph of the deposit obtained from Zn plating $T=328$ K, $c.d.=0.8$ A/dm², time=15 minutes.

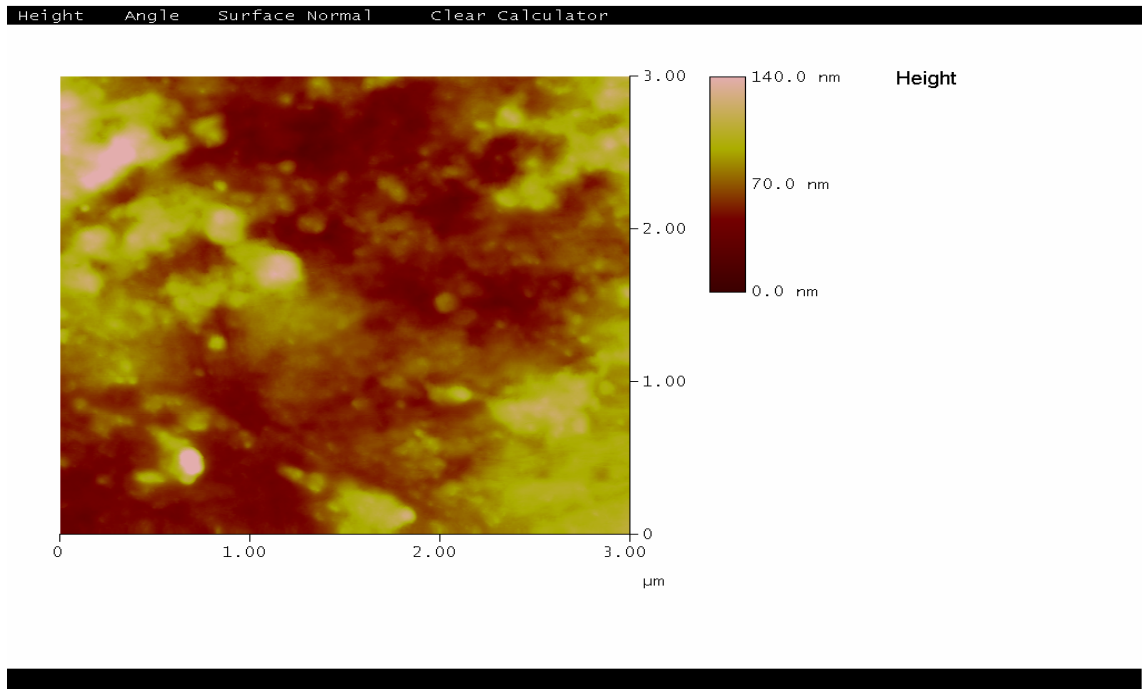


Figure 11a AFM photograph of the deposit obtained from Zn electrodeposition in 0.6V

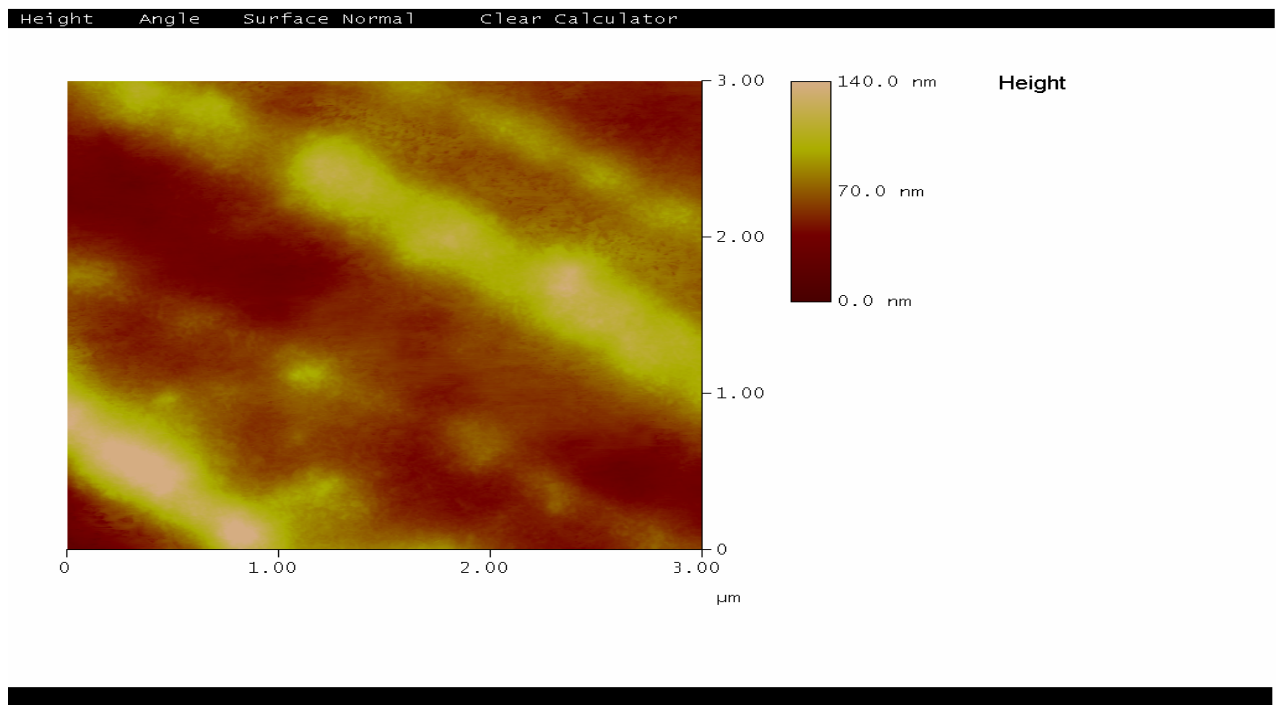


Figure 11b AFM photograph of the deposit obtained from Zn electrodeposition in 0.8V

Conclusion

After careful study of plating parameter on the plating bath, the conclusions below were drawn. Increase in applied voltage, plating time and decrease in distance of object (cathode) from the anode increases the weight gained and thickness of deposit. However, at 0.8V the best plating properties was obtained. The improved mechanical and physical properties obtained of the plating of zinc on mild steel at the above reference indicate that homogeneity of diffuse plating efficiency is achieved.

References

1. Abdullah, M., Fouda, A.S., Shama, S.A., and Afifi, E.A. Azodyes as corrosion inhibitors for dissolution of c- steel in hydrochloric acid solution. *Africa journal of pure and applied chemistry*, 2 (2008) 83.
2. Donald, R.A. The Science and Engineering of Materials, PWS publishing company, Washington, (1994) p.8.
3. Joo y. L., Joe W. K, Min-K. L., Hyun-T. K., Su-moon P. Effects of Organic Additives on Initial Stages of Zinc Electroplating on Iron. *Journal of the Electrochemical Society* 151 (2004) C25-C31.
4. Pedro de N, Adriana N, Correia, P. and Walney, S. A. Corrosion Study of Electrodeposited Zn and Zn-Co Coatings in Chloride Medium. *J. Braz. Chem. Soc.*, 18 (2007) 1164-1175.
5. Shivakumara, S., Manohar, U., Arthoba Naik, Y., Venkatesha, T. U. Influence of additives on electro-deposition of bright Zn-Ni alloy on mild steel from acid sulphate bath. *Bull. Mater. Sci.*, 30 (2007) 455-462. © Indian Academy of Sciences.
6. Popoola, A.P.I and Fayomi, O.S.I. Effect of Some Process Variables on Zinc Coated Low Carbon Steel Substrates'. *Scientific research and essays*. (2011)Accepted.
7. Hague, I.U, Ahmad, N and Akhan A. Zinc- Aluminum alloy deposition on mild steel. *J. Chem. Soc. Pak.* 27 (2005) 337-340.

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