Morphology and Properties of Zn-Al-TiO_2 Composite on Mild Steel

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Abstract

The influence of TiO_2 composite and dispersed pure Al particle on zinc alloy electrodeposited on mild steel was studied from chloride bath solution.Microstructural and mechanical properties of the alloy were investigated. The structure, surface morphology, and surface topography of the deposited alloys were characterized by scanning electron microscopy (SEM) and atomic force microscope (AFM).In addition, hardness of the coated alloys was measured. It was found that the obtained Zn-Al-TiO_2 alloyexhibited more preferred surface morphology and mechanical strength compared tothe substrate. The result shows the existence of interaction between TiO_2 compounds and zinc alloy particulate. It also exhibited well bright dominate zinc coating on steel surface.

Keywords: *Morphology, Additive, TiO_2, Atomic force microscopy (AFM).*

1. Introduction

Deposited zinc coating is widely used method considered for corrosion resistance of steel [Shivakumara et al., 2009, Popoola et al., 2012]. However, the corrosion prevention and hardness properties are minimal compare to the huge expectation. Efforts have been directed toward improving the properties of zinc electrodeposition with other metal such as cadmium and nickel. Hence, some alloy formation such as Zn-Cd, Zn-Ni and Zn-Fe have gained successful access to the zinc industries as direct replacement for ordinary zinc coating [Praveen and Venkatesha, 2011, Popoola et al., 2012 and Basavanna and arthoba, 2009]

Recently focus is now shifting toward possessing a better hardness material and preferred corrosion resistance properties through the use of composite material [Rahman et al., 2009, Volinsky et al., 2001 and Fayomi et al., 2011]. In this paper Zn-Al-TiO_2 deposition on steel was prepared. The solution contains zinc, aluminum salt with TiO_2dispersed within the bath formation. The investigation also examined the mechanical property of composite.

2. Experimental

The deposition of Zn-Al-TiO_2 alloy was performed in an electrochemical cell of two electrodes in which mild steel (50mm x 25mm x 1mm) sheet was used as substrate and zinc sheets of mild steel size were used as anodes. Before electro-deposition thesubstrate was polished with successively finer grades of emery paper, cleaned with Na_2CO_3solution, pickled and activatedin 10% HCl solution at room temperature for 15 seconds and immediately followed by rinsing in distilled water. The working electrodes were connected to the rectifier. The baths were prepared by dissolving amounts of 150g/l ZnO, 35g/l Al, 9g/l TiO_2, 100g/l KCl and 10g/l H_3BO_3. Deposition was carried out at constant potential of 0.3Vat 0.8A/cm^2 with the bath pH of 4.5. All the depositions were performed in 20 minutes.
Surface morphology of the Zn-Al-TiO_2coatingwas investigated using Scanning Electron Microscope (SEM) and Atomic force microscope(AFM). Microhardness (VHN) of the coatings deposited was measured by using a Dura scanmicrohardness tester under an application of 100 g load.

3. Results and Discussion

Substrate Characterization

Chemical composition of mild steel substrate can be seen in Table1. The SEM spectrum in Figure 1 shows the morphology of mild steel. EDSanalysis established the essential elemental composition with Fe being the major constituent.

Table 1:Chemical composition of as-received mild steel

Elements	Composition (wt%)
Carbon	0.150
Silicon	0.180
Sulphur	0.031
Phosphorus	0.010
Iron	Balance

SEM photomicrograph studies

Scanning electron microscope SEM, combined with energy dispersive spectroscopy, EDS, was used to investigate the surface morphology of the deposited coating. SEM photomicrograph of the deposited obtained from the ternary bath shows more finely grained and homogeneous surface appearance compare to the previous studies by (Fayomi et al., 2011) which has some porous and nonhomogeneous composition.

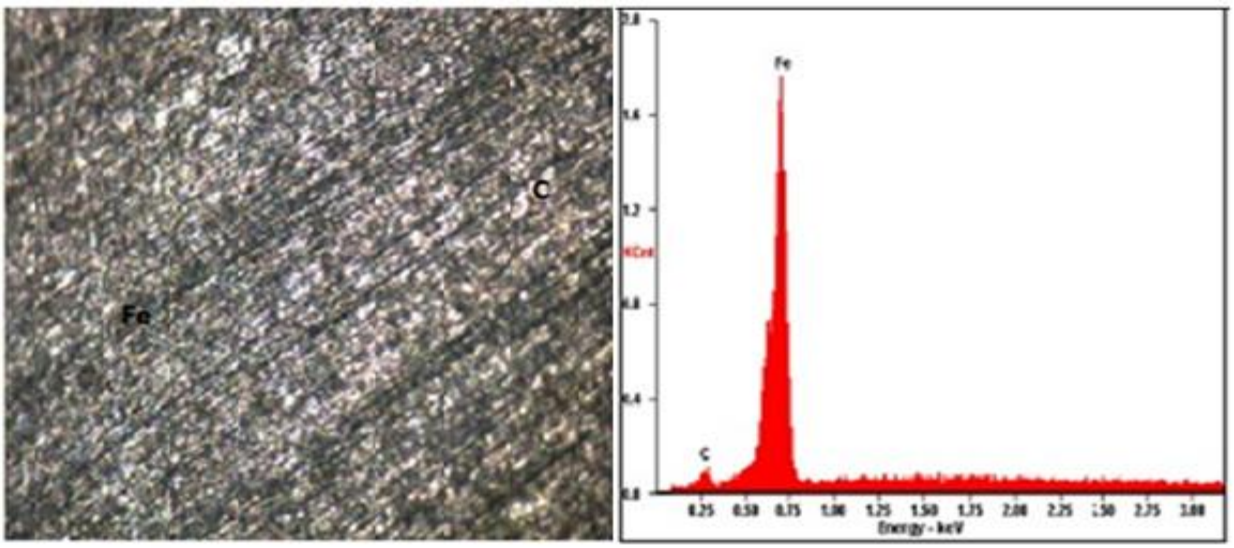

Figure 1:SEM/EDS spectra of as-received mild steel

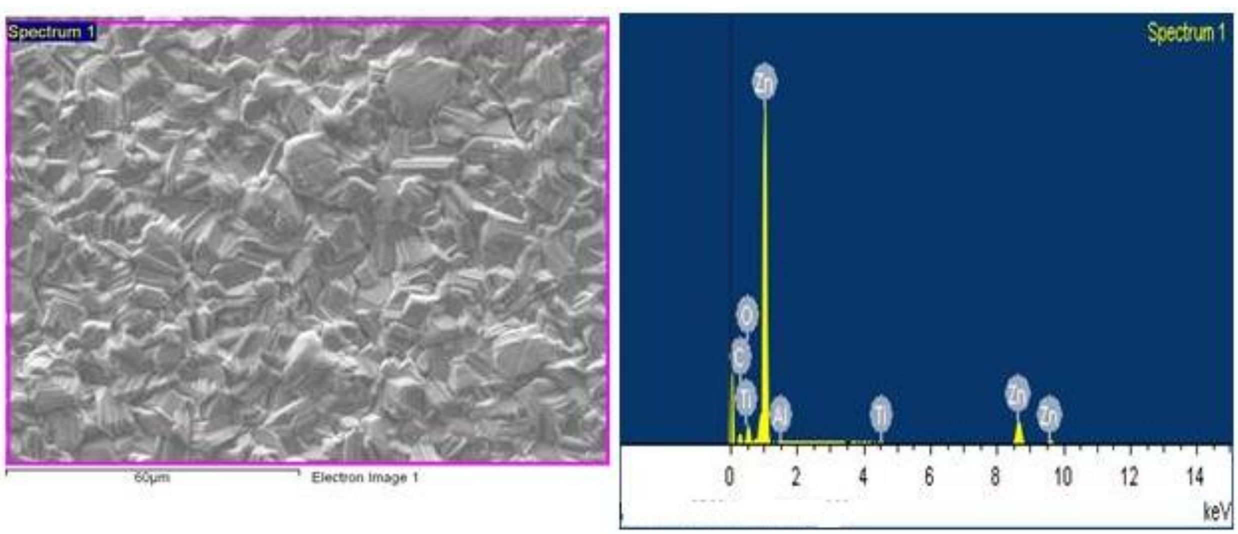

Figure 2.SEM/EDS spectra Zn-Al-TiO_2

It is ideal to say that the porous free nature of the coating and the visible smaller grain size as seen in (Fig 2) is a direct influence of the composite which lead to the change in the structural modification and the tendency of crystal growth. The change in morphology and the nature of crystal formation can be linked to a blocking influence of the titanium additive particulate which leads to an increased nuclei resulting into rapid nucleation surface formation, perfect crystal growth, and refinement in crystal size, bright deposit and arrangement of crystals.

AFM Studies

Scanning studies performed using AFM in Figure 3 also review the surface topography and the adhesion behavior of the coatings. In general, there are degrees of topography from the Zn-Al-TiO_2imaging indicating a homogeneous coating diffusion and perfect preferential sites.

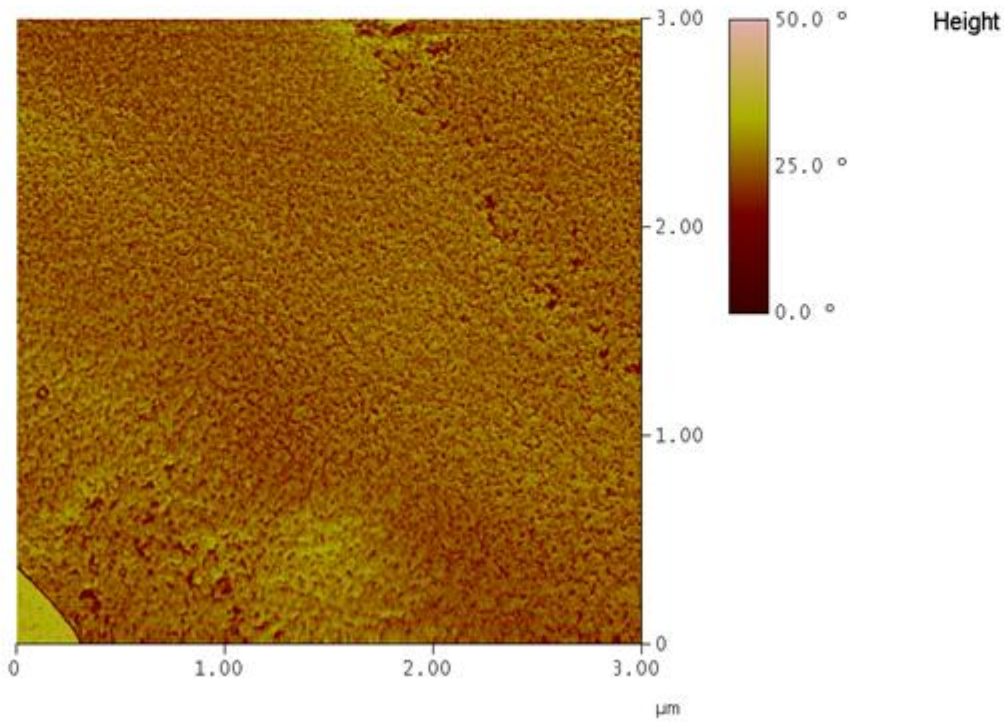

Figure 3: AFM Photograph of electrodeposited Zn-Al-TiO_2

The additive has a noticeable influence on the surface morphological topography of the coated sample with fine crystals around the surface which possesses fine grain size and good surface morphologies. Moreso, it has been reported that addition of composite to a bath resulted in microstructural changes leading to formation of complex intermetallic compounds [Praven and Venkatesha, 2011].

Microhardness Studies:

The microhardness value of Zn-Al-$TiO_2$and the substrate were measured. Figure 4 shows the influence of co-deposition of Zn-Al-$TiO_2$and the operating parameter on the hardness properties. Microhardness value for the coated sample and the substrate were 152 and 61 HVN, respectively.

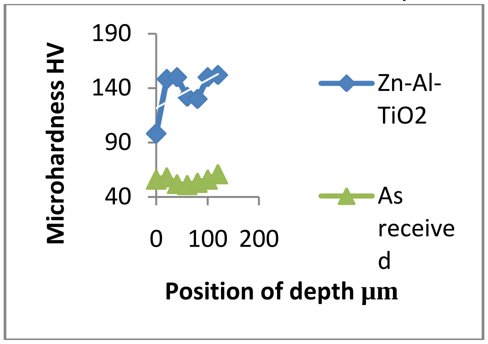

Figure 4. The microhardness/depth profile for mild steel and Zn-Al-TiO_2 coatings

This shows that a better grain size formation on the surface of the coated substrate occurs. It is obvious that there is resistance to dislocation as a result of the resultant bath formation matrix and the refinement of the grain size. Hence, the effect of Al andTiO_2can be said to significantly influence the tendency of highermicrohardness value which is in accordance to investigation by [Shivakumara et al, 2007Sundararaja et al., 2003, Rahman et al., 2009and Popoola et al., 2012]that fine-grained structure of the deposit or alloys and the dispersed particles in the fine-grained matrix may obstruct the easy movement of dislocations, to give a higher hardness value of deposited sample.Furthermore, it can also be noted by [Popoola et al., 2012] thatthe hardenability of the coating is determined to a large extent by the additive and the process parameter employed.

4. Conclusions

- ❖ A successful ternary co-deposition was achieved.
- ❖ Surface modification through the influence of Al andTiO_2 deposition has significantly enhanced surface adhesion property and improved the stability of mild steel.
- ❖ The hardness value increased 100% over the mild steel

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References

1. Basavanna,S. andArthobaNaik,Y. *J. of Appl. Electrochem*., 39 (2009) 1975
2. Fayomi,O.S. Tau,V.R. Popoola,A.P.I. Durodola,B.M. Ajayi,O.O. Loto,C.A. andInegbenebor,O.A. *J. of Mat. andEnv. Sci.,* 3, (2011) 271
3. Popoola,A.P.IFayomi,O.S. andPopoola,O.M *Int. J. of Electrochem. Sci.*, 6, (2012) 4860
4. Praveen,M and Venkatesha,T.V. *Int J. of Electrochem*, 261, (2011) 407
5. Popoola,A.P.IFayomi,O.S. andPopoola,O.M.*Int. J. of Electrochem. Sci.*, 6, (2012)4898
6. Rahman,M.J. Sen,S.R. Moniruzzaman,M. andShorowordi,K.M. *J. of Mech. Eng, Tran.*, 40, (2009) 9.
7. Shivakumara,S. Manohar,U. ArthobaNaik,Y. andVenkatesha,T. U. *Bull. Mat. Sci.* 30 (2007) 455
8. Sundararajan,G. andRama Krishna,L. *Surf. and Coat. Tech*, 167, (2003) 269.
9. Volinsky,A.A. Vella,J. Adhihetty,I.S. Sarihan,V.L. Mercado,L. Yeung,B.H. andGerberich,W.W. 2001. *Mat. Res. Soc.,* 649, 1-6