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Evaluation of Responses from Electrolytic Multilayer Hybrid Coating for Extended Application

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Abstract

This paper examines the electro-mechanical responses of electrodeposited Zn-ZnO-MgO composite coating from sulphates bath with emphasis on its hardness and wear characteristics. The ZnO/MgO modified Zn series co-deposition was obtained from ordinary sulphate-based bath consisting of 16g/l MgO and 30g/l ZnO particulate. The particles were dispersed by mechanical agitation at 200 rpm. The presence of the MgO and ZnO were confirmed by high magnification optical microscope (OPM). The hardness and wear propagation were examined by diamond based microhardness tester and MTR 300 Abrasive wear tester. The results indicate that the inclusion of the nano-sized particulate leads to excellent tribological behavior and increase hardness behavior. The thermal stability characteristic was also sustained over time.

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Keywords: Nano sized, microhardness, wear, mechanical responses

1. Introduction

Environment that actually affects a metal are often characterized by micro environmental conditions and macro-mechanical properties [1-3]. It is indeed the reactivity of this local environment that determines the real hardness and tribological damage [4] while the basic mechanical challenge, the structural and protective coating, influences the nature of prevention [5]. Protective coatings are perhaps the most extensively used system mechanical damage control. They are used to provide long-term protection under a broad range of hardness and anti-wear environments,

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ranging from atmospheric contact to the most demanding counter body [6-7]. Simple oxides such as Al_2O_3, TiO_2, ZrO_2, CeO_2 and SiO_2 are commonly used due to their ease of availability. These oxides can be incorporated into plain Zn matrix or Zn alloy [8]. ZnO nanoparticles were found to improve abrasive nature of Zn-Al when they were incorporated within the optimal concentrations. It was established that these particles have significant effect on the surface morphology of the coatings [9]. MgO was found to aid improved hardness when incorporated at reasonable conditions. Research has shown that incorporation of ZnO into a metal matrix often guarantee positive results on the mechanical behavior [10-11]. There is no sufficient fact in the available literature that provides insight about incorporation of ZnO and MgO nanoparticles into Zn matrix and their special properties. Therefore, this research aims to fabricate Zn-ZnO-MgO nanocomposite coatings for industrial application.

2. Experimental Procedure

Carbon steel samples of 40 mm x 40 mm x 2 mm dimension with the chemical composition presented in Table 1 were used as substrate and 99.99 % zinc sheets were used as anodes. Analar grade chemicals were used all through this experiments. The surface preparation of the mild steel sample was prepared with different grades of emery paper in the order of 60 µm, 120 µm, 400 µm, 800 µm and 1,600 µm to render free of defects. Samples were activated by dipping in 1M HCl solution at room temperature for 5 seconds followed by rinsing in distilled water. The prepared sample was dipped in a solution containing dissolved bath constituents which was heated for 1hour and simultaneously stirred at 200 rpm to obtain homogenous solution. Cathode and anodes were connected to the D.C. power supply through a rectifier. Electrodeposition was carried out with applied voltage of 3 volts for 20 minutes, while the depth of dipping and the distance of the cathode from the anode were kept constant. Immediately after the plating, rinsing was done in distilled water and samples were air-dried. The bath composition and process parameters are shown in Table 2 while the summarized data of Zn-ZnO-MgO plated samples for constant plating time at various current is shown in Table 3. The surface morphology of the electrodeposits was observed using optical microscope (OPM) at 100µm. Micro-hardness studies were carried out using a Diamond pyramid indenter EMCO Test at a load of 200 g for a period of 5s.

Table 1: Chemical composition of the low carbon steel

Element	C	Mn	Si	P	S	Al	Ni	Fe
Composition	0.15	0.45	0.18	0.01	0.031	0.005	0.008	Balance

Table 2: Bath Composition of Zn-ZnO-MgO coating

Composition	**Mass Concentration (g/L)**
$ZnSO_4$	75
ZnO	30
K_2SO_4	50
Boric Acid	10
MgO	8 -16
$NaSO_4$	75
Glycine	10
Thiourea	10
pH	4.8
Voltage	I Volt
Time	20 min.
Temp.	40^oC

3. Results and Discussion

The surface morphologies of Zn-30ZnO-8MgO and Zn-30ZnO-16MgO nanocomposite coatings are shown in Fig. 1 below. There is flake-like crystalline structure with coarser grains in Figure 1a. With the increase in MgO content to 16g/L, observed pores were noted but uniform and compact microstructures were seen (see Figure 1b). Incorporation of nanoparticles into a metal matrix induces grain refinement by impeding the growth of the crystals. Therefore, the modification of the morphological characteristics of the Zn-30ZnO-8MgO coatings can be attributed to the incorporation of ZnO and MgO nanoparticles into matrix to optimum capacity of 8g/L.

Figure 2 compares the hardness properties of the composite coatings with the as-received sample. The average micro hardness values for all the samples calculated indicates that, Zn-30ZnO-8MgO-1.0A nanocomposite coatings possessed the highest hardness value of 248.0 HVN, against all other processed coating samples in the series. The least improved coatings are found to be at 200.4 HVN with Zn-30ZnO-8MgO-0.5A. It can also be deduced that, the hardness after when the mass of MgO increases from 8 to 16g there was a decreases. The phenomenon of dispersion strengthening was observed to impact on the coating structure but not on the microhardness characteristics. Although change in process parameter often affect influence coating behavior given rise to robust significant improvement to coatings [8] however the loading capacity at 8g/L were seen to positively influence the hardness behavior especially at moderate current density of 1.0 A/dm^2.

Figure 3 shows the wear performance of as received sample and Zn-ZnO-MgO nanocomposites coating series which were tested at a constant normal load of 5 N under dry wear conditions. The average wear mass values of the samples are presented in the series chat with all coating posed improved significantly wear resistance as against the as-received. These results imply that the incorporated nanoparticles provide resisting characteristics to Zn matrix with ZnO and MgO particles possess better self-resisting properties at Zn-30ZnO-8MgO-1.0A. Higher wear loss of as-received was noted with as-received a result not far fetch from assumption by [4] that coating are prone to severe deformation as a results of nature of preservation and wear process parameter. The wear loss of the most improved coating was attained at 0.01g/min while the as-received sample possesses 0.12g/L

Table 3: Summarized data of Zn-ZnO-MgO plated samples for constant plating time at various current

Sample Labels	Time (min)	Coating Thickness (µm)	Coating Texture (Inch)	Weight Gain (g)	Current Density (A/dm^2)	Additive Concentration (g)
As received						
Zn-30ZnO-8MgO	20	420.60	112.0	0.0519	1.0	8
Zn-30ZnO-8MgO	20	409.34	329.0	0.0924	0.5	8
Zn-30ZnO-16MgO	20	332.94	252.4	0.0630	1.0	16
Zn-30ZnO-16MgO	20	313.82	282.5	0.0813	0.5	16

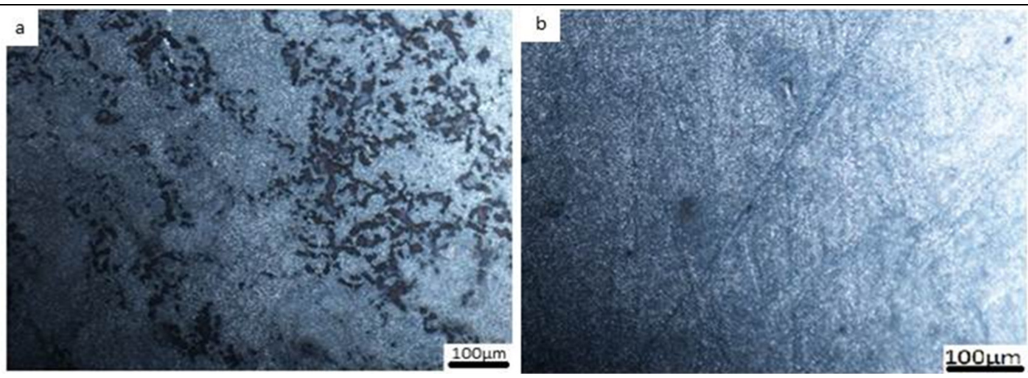

Figure 1: Micrographs of composite coating of Zn-ZnO-MgO coatings

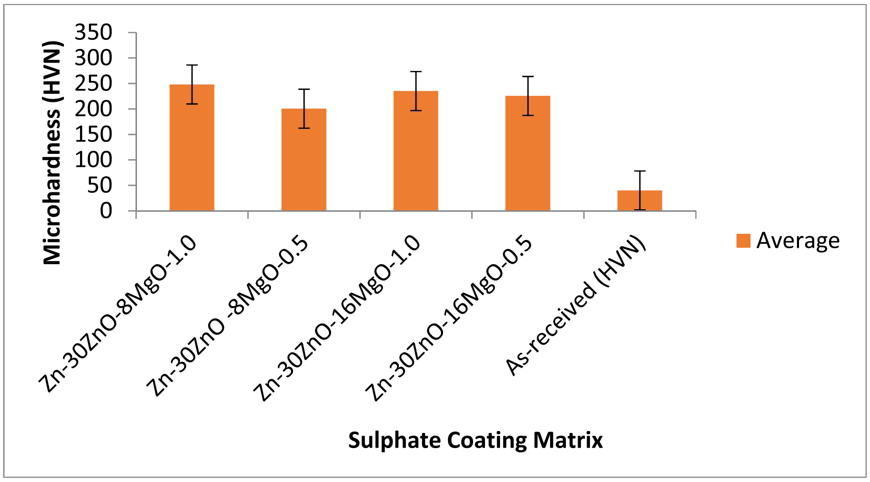

Figure 2: Micrographs of composite coating of Zn-ZnO-MgO coatings

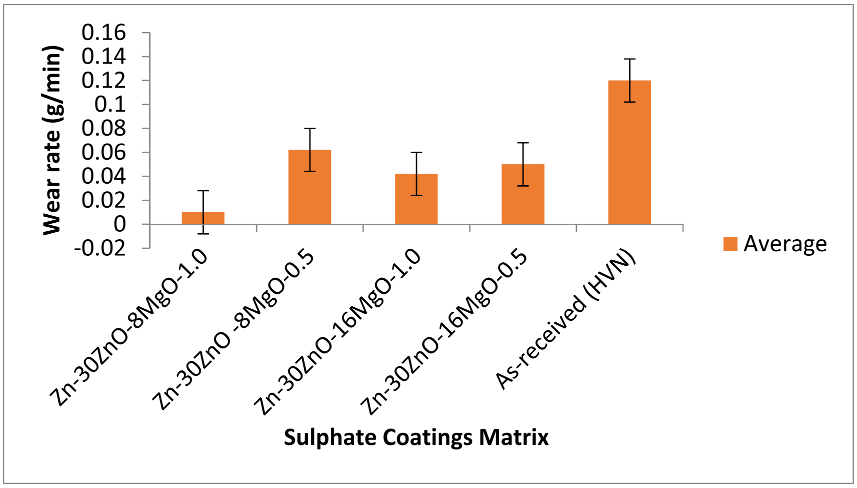

Figure 3: Micrographs of composite coating of Zn-ZnO-MgO coatings

4. Conclusion

Zn-ZnO-MgO nanocomposite coatings were successfully fabricated using co-deposition route. The effect of the incorporated nanoparticles on the surface morphology, microhardness, and wear properties were studied and compared. Zn-30ZnO-8MgO possessed better self-resistance plastic deformation properties as against the as-received mild steel. A good microhardness property was also attained with average property of 240HVN as against the 40HVN for control sample, a significant improvement of 100%. Therefore, it can be concluded that Zn-30ZnO-8MgO composites are suitable for wide industrial applications where the coatings are expected to work on mechanical principles.

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