Experimental study and effect of particulate interference on the microhardness, wear and microstructural properties of ternary doped coating

O. S. I. Fayomi, A. P. I. Popoola, O. O. Joseph, A. O. Inegbenebor, and D. O. Olukanni

Citation: AIP Conference Proceedings **1758**, 020017 (2016); doi: 10.1063/1.4959393
View online: http://dx.doi.org/10.1063/1.4959393
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1758?ver=pdfcov
Published by the AIP Publishing

Experimental Study and Effect of Particulate Interference on the Microhardness, Wear and Microstructural Properties of Ternary Doped Coating

O. S. I. Fayomi[1, 2*], A. P .I. Popoola[1], O. O. Joseph[2],
A.O Inegbenebor[2] D.O. Olukanni [3]

[1]*Department of Chemical, Metallurgical & Materials Engineering, Tshwane University of Technology, Pretoria, South Africa*
[2]*Department of Mechanical Engineering, Covenant University, P.M.B. 1023, Canaanland, Ota, Nigeria*
[3]Department of Civil Engineering, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria

* ojosundayfayomi3@gmail.com

Abstract. This paper studies effects of the composite particle infringement of ZnO/Cr_2O_3 on zinc rich ternary based coating.The corrosion-degradation property in 3.5% NaCl was investigatedusing polarization technique. The structural characteristics of the multilayer produce coatings were evaluated by scanning electron microscope (SEM) equipped with an energy dispersive spectrometer (EDS). The mechanical response of the coated samples was studied using a diamond base Dura –Scan) micro-hardness tester and a MTR-300 dry abrasive wear tester. The combined effect of the coatings gave highly-improved performance on microhardness, corrosion and wear damage. This also implies that protection of wind-energy structures in marine environments can be achieved by composite strengthening capacity.

INTRODUCTION

The challenge of component during service as a result of mechanical degradation and chemical deterioration is no news a concern to materials expert, in such a way that it affects both the domestic, industrial and national development [1]. Corrosion scientists and engineers are continually seeking for techniques and methods to effectively combat corrosion by learning the phenomenon and its control with the aim of finding better ways of using engineering materials.The failure of this materials are majorly in application like construction, aerospace, automobile, solar cells, ship building, and energy conservative. With the increasing way to oppose this catastrophic, promising methods of mitigation had been employed ranging from vapour deposition, laser coating, cold spray coating and so on. Surface enhancement of engineering materials is necessary for preventing service failures and corrosion attack in industry [1, 2].Electrodeposition technique had been proved to give superior advantages due to cost effectiveness, processing and nature of characteristics. Zinc coatings add corrosion resistance to steel in several ways [4]. As a barrier layer, a continuous zinc coating separates the steel from the corrosive environment. The sacrificial properties of zinc can be seen in a galvanic series where the potential of zinc is less noble than steel in most environments at ambient temperatures. Zinc, like all metals, corrodes when exposed to the atmosphere. Infringement of particulate into bath rich such as zinc-composite had been seen as a promising way of getting better performance in term of corrosion protection, wear resistance and other metallurgical properties [5-7]. Hence, this paper focuses on the effects of Cr_2O_3 particulates on the morphology of the composite coatings. The hardness and corrosion resistance of the $Zn\text{-}ZnO\text{-}Cr_2O_3$ coatings are also evaluated.

Technologies and Materials for Renewable Energy, Environment and Sustainability
AIP Conf. Proc. 1758, 020017-1–020017-6; doi: 10.1063/1.4959393
Published by AIP Publishing. 978-0-7354-1416-7/$30.00

EXPERIMENTAL SECTION

Preparation of substrate

Flat steel specimens of dimension (30 mm x 20 mm x 1 mm) sheet were used as the substrate and zinc sheets of (40 mm x 30 mm x 2 mm) were prepared as the anodes. The initial surface preparation was performed using progressively finer grades of emery paper, as described in our earlier publications [3, 4]. The samples were properly cleaned with sodium carbonate, pickled and activated with 5% HCl at ambient temperature for 10 seconds, followed by instant rinsing in deionized water. The specimens were obtained from Metal Sample site, Nigeria. The chemical composition of the sectioned samples analyzed on a spectrometer were C 0.15%, Mn 0.45%, Si 0.18%, P 0.01%, S 0.031%, Al 0.005%, Ni 0.008%, Fe Balance.

Formation of deposited coating

The prepared Zn-ZnO-Cr_2O_3 composite bath was heated for 2hrs and stirred intermittently to obtain a clear solution before it was prepared for electrolytic deposition on the steel. The prepared cathode and anodes were connected to the D.C. power supply through a rectifier as described by [3, 4]. Deposition was carried out at varying applied current density around 1.0A/cm^2 for 15 minutes. The distance between the anode and the cathode and the immersion depth were kept constant. Thereafter, the samples were rinsed in water and then dried. The formulated design plan for the coating is described in Table 1.

TABLE 1: Formulated designed bath composition ofZn-ZnO-Cr_2O_3

Sample order	Matrix Sample	Time of deposition (min)	Current density(A/cm^2)
1	Zn-**8**ZnO	15	1.0
2	Zn-8ZnO-**16**Cr_2O_3	15	1.0

Structural characterization of the coatings

The structural studies and elemental analysis of the fabricated alloy samples were verified using a high-tech TESCAN scanning electron microscope with an attached energy dispersive spectrometer (SEM/EDS).

RESULTS AND DISCUSSION

Surfacemorphology

Figure 1a and b shows the structural properties of Zn-8ZnO and Zn-8ZnO-16gCr2O3 composite coating respectively. The EDS pattern of the composite coating confirms the crystalline phase of the film as identified in Figure 2. The nano particulates were found to be agglomerated when analyzed by scanning electron microscopy (Figure 1a) studies. This is due to the high surface energy of the particles. In general it can be seen that the coating on the mild steel plate resulted into a good appearance, better plating and good adhesion. The nature of the surface morphology and orientation in Figure 1b revealed the non- homogeneous appearance but good dispatches as expected. There are no pores and cracks at the interface, which shows that the interface bonding is firm. But the observed improvement may not be far from the possibility that the deposition behaviour and the adhesion strength of any particular plating often based on the current density, potential, plating time and strengthening effect of the grain present in the matrix [5] Figure 2 revealed the morphology of the coating, indicate fine grain size, uniform arrangementandcrystalgrowthfortheZn-8ZnO-16gCr_2O_3 coating.UnliketheZn-8ZnO depositionwheregood surfacedeposition was achieved but irregularor inhomogeneous dispersion of deposit wasobserved.

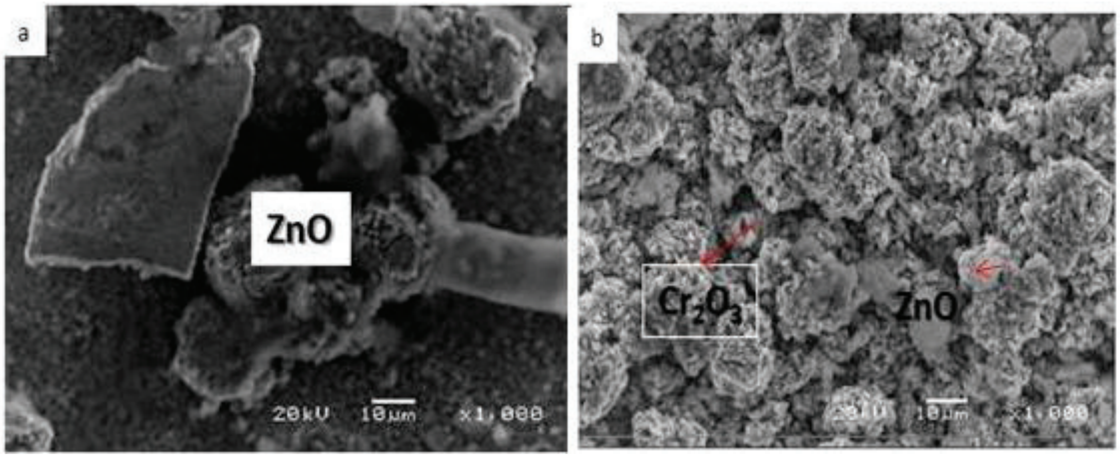


FIGURE1.SEM images of the a) Zn-8ZnO and b) Zn-8ZnO-16gCr_2O_3 composite coating

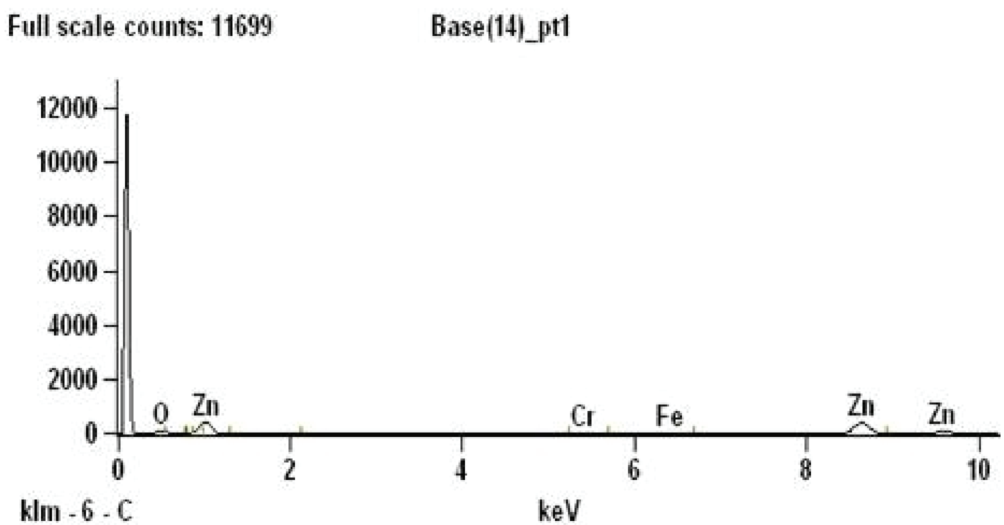


FIGURE 2. Energy Dispersive Spectral Zn-8ZnO-16gCr_2O_3 hybrid

Wear and Microhardness property

Figure4showsthewearlossofZn -ZnO coating andZn-ZnO-Cr_2O_3composite coatings with differentCr_2O_3 contents.Itis obvioustthat the wearresistance ofthe compositecoatings is morethanthatof Zn -ZnO coating. Thoughthe wearresistance of the compositecoatings did not increasewith increase inthe Cr_2O_3 particlescontent, as it can be seen that Zn-ZnO-8Cr_2O_3 displayed the optimum wear resistance, but the addition of Cr_2O_3 in the matrix has immensely contributed to the wear resistance. The thermal deformations were observed in 250^{o}C for 4hrs and mechanical responses of the coated samples were investigated. A goodincrease inthemicro hardnessvaluewasobservedintheZn-ZnO-Cr_2O_3composite coating even before heat-treatment asshowninFigure3.The microhardness valuefor theZn -ZnOmaterialwas134.0 HVN and almost doubled for the value ofZn-8ZnO-8Cr_2O_3compositecoating (which was the optimal performance) with344HVN. Figure 4 illustrates the wear analysis of the coatings. The improved wear resistance canbeattributedtothe strengtheningeffect. The hardness process parameterand microstructural behaviourare theparameterswhichaffectthewear resistance as indicated by [6]. The wear resistance increases with increasinghardnessof the matrix. The tendency of Zn-ZnO-Cr_2O_3composite coatings for plastic deformationislessthan Zn - ZnO coating. The resultssuggestthatthewearresistancewas improvedby the addition of Cr_2O_3 particles. According to [7], the embeddedCr_2O_3 particles cansignificantlyimprove thetribological performanceof Zn-ZnO-Cr_2O_3composite coatings.

Figure 3 show the Microhardness variation of the nano-composite coating before heat treatment. The increase inhardnessof the Zn-ZnO-Cr_2O_3composite coated specimens was dueto thepresenceof theCr_2O_3as reinforcement additive, despite the fact that the increase in the quantity has limit.

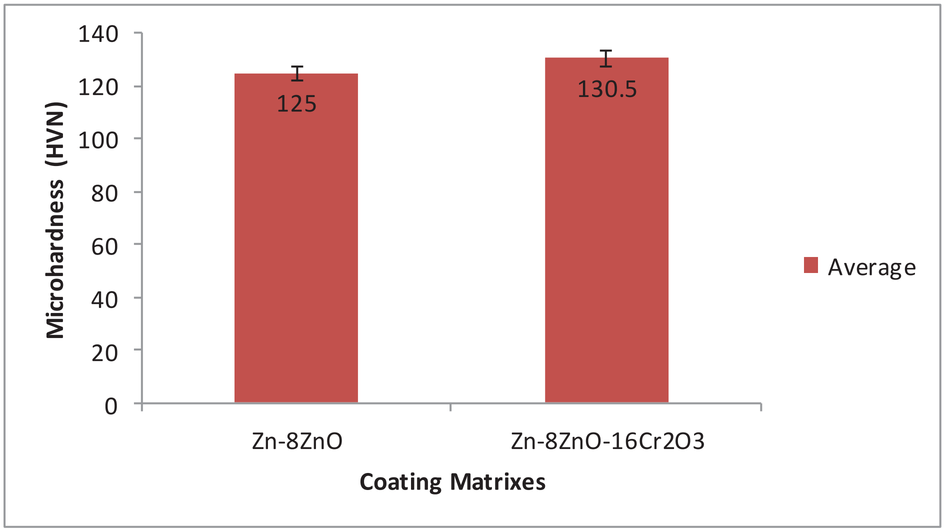


FIGURE 3. Variation ofhardness propertywith coating matrix.

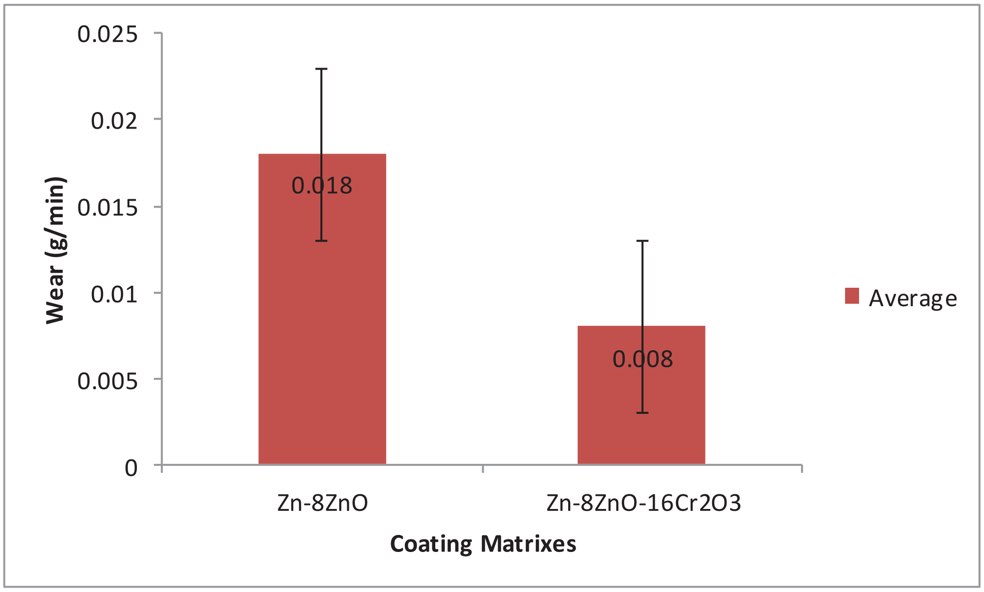
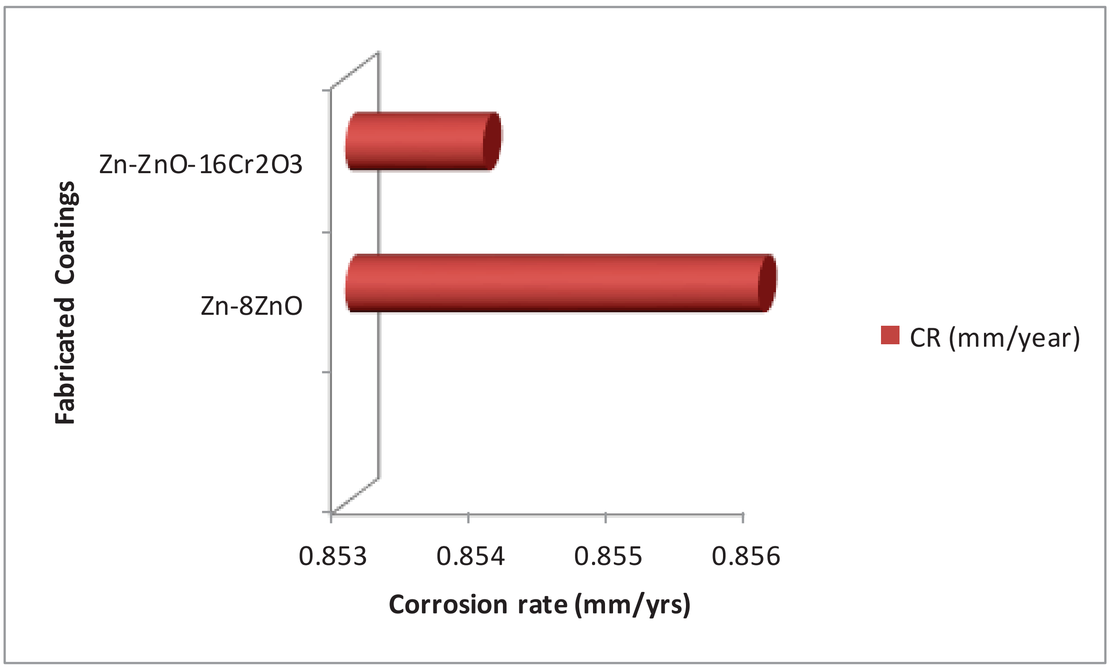


FIGURE 4. Variation ofwear rate with time.

Polarization measurements

The values of $E_{corr,}$ j_{corr}, corrosion rate (CR) and polarization resistance (R_P) of the samples before heat-treatment are extrapolated from tafel slope as presented in Table 2. The results revealed the corrosion resistance behaviour of the coatings in 3.65% NaCl static solution. From the polarization curves of Zn-ZnO-Cr_2O_3 composite coating in Figure 5, it was found that the addition of Cr_2O_3 altered the shape of the polarization curve but causes a considerable increase in the value of the Ecorr. The features from the linear polarization test (Figure 5) indicate that an increase in additive concentration intensifies this process. However, the optimal value for the coating with least corrosion rate was Zn-8ZnO-8Cr_2O_3, which implies that addition of Cr_2O_3 gives better effect of corrosion resistant property. According to [9], this could be attributed to the nature and tenacity of the passive film produced by Zn-8ZnO-8Cr_2O_3 on the surface of the coated steel and the drop in the potential thereafter could be traced to slight passivity breakdown experienced when the concentration of Cr_2O_3 was further increased, which is in line with [8].



784

FIGURE 5. Potentiodynamic polarization curves o Zn-ZnO-Cr_2O_3 composite coating on mild steel in 3.65%NaCl solution.

TABLE2: Polarization data extrapolated from Tafel slope for matrix Zn-ZnO-Cr_2O_3 composite coating.

Samples No	**E_{corr},Obs (V)**	**j_{corr} (A/cm²)**	**CR (mm/year)**	**Rp (Ω)**
1. Zn-8ZnO	-1.3067	0.003029	0.854270	23.583
2.Zn-ZnO-16Cr_2O_3	-1.3706	0.003102	0.856890	20.390

CONCLUSIONS

The following conclusions were drawn from the study:

1. Composite coatings consisting of Zn-ZnO and Zn-ZnO-Cr_2O_3particles weresuccessfully prepared by means of an electro-depositiontechniqueonto carbon steel substrates.
2. The plating of Zn with incorporation ZnO and Cr_2O_3in the coating was confirmedby the EDS and XRD.
3. The co-deposition of nano-sized Cr_2O_3 particles in a metal deposit modified the surface morphology of the substrate.
4. The developed composite coating was mechanically and thermally stable.
5. The presence of Cr_2O_3 particles in the matrix of the coating system increased adhesion, corrosion resistance and micro-hardness of the surface, compared to that of plain carbon steel.

ACKNOWLEDGEMENT

This material is based upon work supported financially by the National Research Foundation. The authors acknowledge the support from Surface Engineering Research Centre, (SERC) Tshwane University of Technology Pretoria, South Africa**.**

REFERENCES

1. M. J. Rahman,S. R. Sen, M. Moniruzzaman and K. M. Shorowordi, J. Mech. Eng. **40**, 9-14 (2009).
2. B. M. Praveen, T. N. Venkatesha, Y. ArthobaNaik, and K. Prashantha, Surf. Coat. Tech. **201**, 5836-5842 (2007).
3. A. P. I. Popoola, O. S. I. Fayomi and O. M. Popoola, Int. J. Electrochem. Sci. **7**, 4898–4917 (2012).
4. O. S. I. Fayomi, V. R. Tau, A. P. I. Popoola, B. M. Durodola, O. O. Ajayi, C. A. Lotoand O. A. Inegbenebor, J. Mater. Environ. Sci.**3**, 271-280 (2011).
5. L. E. Umoru, I. A. Fawehinmiand A. Y. Fasasi, J. Appl. Sci. Res. **2**, 200-204 (2006).
6. E. A. Noor and A. H. Al-Moubaraki, Int. J. Electrochem. Sci. **3**, 806-818 (2008).
7. A. P. I.PopoolaandO. S. Fayomi, Int. J. of thePhy.Sci. **6**, 2447-2454 (2011).
8. O. S. I. Fayomi, A. P .I. Popoola, C. A. Loto and S. T. Adedokun, Protection of Metals and Physical Chemistry of Surfaces. **52**, 238–243 (2016).
9. J. Winiarski, A. Leśniewicz, P. Pohl and B. Szczygieł, Surface & Coatings Technology.**299**, 81–89 (2016).