Characterization of electroplating by using Zn-nano sized Al_2O_3 as composite coatings

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Abstract

Nano sized alumina (Al_2O_3) ceramic particles (80 nm) were co-deposited with zinc (Zn) using electrodeposition technique to develop composite coatings. The coatings were produced in acid chloride solution. Mechanical properties such as wear resistance is studied.
The morphology of the coatings was characterized by scanning electron microscopy X-ray. It was found that, co-deposition of nano sized Al_2O_3 particles and Zn metal was successfully achieved by using electrodeposition method without any chemical interaction between the ceramic particles and the electrolyte . The microstructures of the coatings were examined by scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques.

Key word: electroplating ,mechanical properties ,nanoAl_2O_3,SEM,XRD

Introduction

Nowadays, application of steel in product manufacturing has gained much interest because of its unique properties such as low cost, recyclability and excellent mechanical characteristics. However, low corrosion resistance of this material is the most important problem. One of the most common approaches to overcome this problem is the application of protective coatings to enhance the life span of this material. In this regard various materials have been used as coating such as zinc, cadmium, synthetic and/or extracted organic compounds, modified polymers, resins and alloys [1].

Electrodeposited (electroplated) coatings are one method widely utilized to confer protection to metallic surfaces. These coatings can consist of single metals, but also many binary and even ternary alloys can be deposited, producing in many cases, enhanced corrosion protection. A wide variety of metals can be successfully deposited in this manner

ranging from noble metals such as gold and silver through to more base metals such as zinc and cadmium [2].

Anti-corrosion coatings, especially zinc have been widely studied with this technique. When compared to other metals, zinc is anodic to iron and steel and therefore offers better protection if applied as

thin films than similar thicknesses of nickel and other cathodic coatings. It is relatively less expensive than other metals and readily applied in barrel, tank or continuous plating facilities [3].

pure zinc coatings suffer from poor mechanical properties and the incorporation of a second hard phase during the electrodeposition process (e.g. ceramic nanoparticles) would normally permit to enhance them[4].

Electrodeposition of composite Coatings (Co-deposition) is process of incorporating fine particles of metallic, non-metallic compounds, or polymers from an electrolytic or an electroless bath in the electroplated layer to improve material properties such as hardness, wear resistance, corrosion resistance, lubrication, yield, tensile, and fracture strength [5].

Co-electrodeposition is a simple and low cost technique to produce metal matrix composite coatings which have been widely used in automotive and aerospace [6].

Metal – matrix composites are materials in which the properties of metallic host material are modified with the addition of a second phase (ceramic). Electro-deposition of composite coating, based on second phase hard particles dispersed in a metallic matrix. The second phase can be hard oxide (Al2O3, TiO2& SiO2) or carbide particles (SiC & WC) [7].

Composite coatings based on Zn are finding increased interest in surface technology and corrosion protection. Potential fields of application are improved corrosion and wear resistance of Zn composite layers with extended lifetime [8].

Nowadays, the ability to produce new composite materials with good properties by using micro and nano particles is leading technological interests. This improvement depends mainly on the size and the percentage of the particles codeposition, as well as on the distribution of these particles in the metallic matrix.[9]

Nanostructured coatings offer great potential for various applications due to their superior characteristics that are not typically found in conventional coatings. Because of the novel properties and various potential applications, nano composite materials, with typical

grain sizes <10 nm, are attracting increasing attention from researchers all over the world. Because of the small grain size of these materials and consequently the large volume fraction of atoms in or near the grain boundaries, these materials exhibit properties that are often superior and sometimes completely new, in comparison with those of conventional coarse-grained materials [10].

Experimental

Mild steel plates, with a nominal composition of 0.13% C, 0.54 Mn, 0.06 Cr and the remainder Fe. Were cut with dimensions of (100, 80, 20) mm length, width and thickness respectively. The test specimens were immerse for 2 minutes with an alkaline degreasing chemical, and then removed from the solution, rinsed in distilled water, immersed in methanol, and air-dried. The specimens were, in turns, etched for 2 minutes in 10% HCl, rinsed in distilled water, immersed in methanol, air dried and stored in a desiccator for further experimental process . For the preparation of solutions, distilled water was used. Plating bath composion shown in (Table 1). Electrodeposition of zinc on steel was performed by partially immersing the steel specimen and the zinc electrodes in the plating solution through the rectangular hole made on prepared Perspex cover for the 250ml beaker used as the plating bath. The pH of the bath solution was adjusted with 10% hydrochloric acid or sodium carbonate solution. Zinc plate of 99.99% purity was added as anode. The anode was activated each time by immersing in 10% HCl followed by water wash. The deposits were obtained at a constant current density from the optimized solution.

The steel specimen was connected to the negative side of a DC supplier while the zinc electrodes were also connected with a wire to the positive side, Fig. 1. The plating solutions were put in turns into the beaker . After plating experiment, the plates were subjected to bright dip in 1% nitric acid for 2 s followed by water washes The specimens were stored in a desiccator for further analysis. Polarization curves were measured in tap water,3.5% NaCl and 3% HCl at room temperature. The coatings were examined for the identification of the crystalline phase. The phase composion of coating were identified with X-ray generator with copper Kα radiation ($\lambda = 1.5406\ A^0$) and a nickel filter. The diffractometer scanning speed was adjusted to 6^0 per minute and the range of the

diffraction angle ($2\theta^0$) was (20^0-80^0) and step time 0.6 sec. the image plate XRD system worked with (target: Cu) radiation operating at 40.0 KV and 30mA. The morphology of surface deposits were observed by a scanning electron microscopy model (Inspect S50 FEI Company).

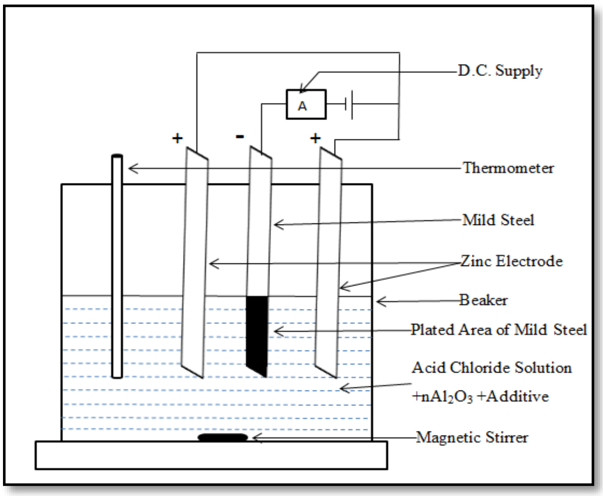

Fig. (1): Schematic diagram of experimental set-up.

Table (1) Basic bath composition and operating conditions.

Bath composition	Concentration	Operating conditions
$ZnCl_2$ NH_4Cl H_3BO_3 Al_2O_3	30 g/l 150 g/l 20 g/l 30 g/l	Cell current: 1 A Plating time: 10 min pH: 4.5 Temperature: 25^0C Anode:Zinc metal(99.99) Cathode: Mild steel Cell constant in Ampere:1A

Results and discussions

Morphological study

Composite (Zn- nano Al_2O_3) coatings produced by electroplating method were examined by EDX and XRD, as presented in Figs. 2 and 3. Microstructural analyses of the coatings confirmed the possibility of (Zn- nano Al_2O_3) deposition by DC . XRD and EDX analyses showed that the alumina particles did not react with the zinc and no aluminum or zinc complex formed during deposition. Figs. (4 a and b shows the SEM surface morphology of DC plated coatings, with and without nano Al_2O_3 particles. The effect of nano Al_2O_3 particles on the coating grain size was considerable.

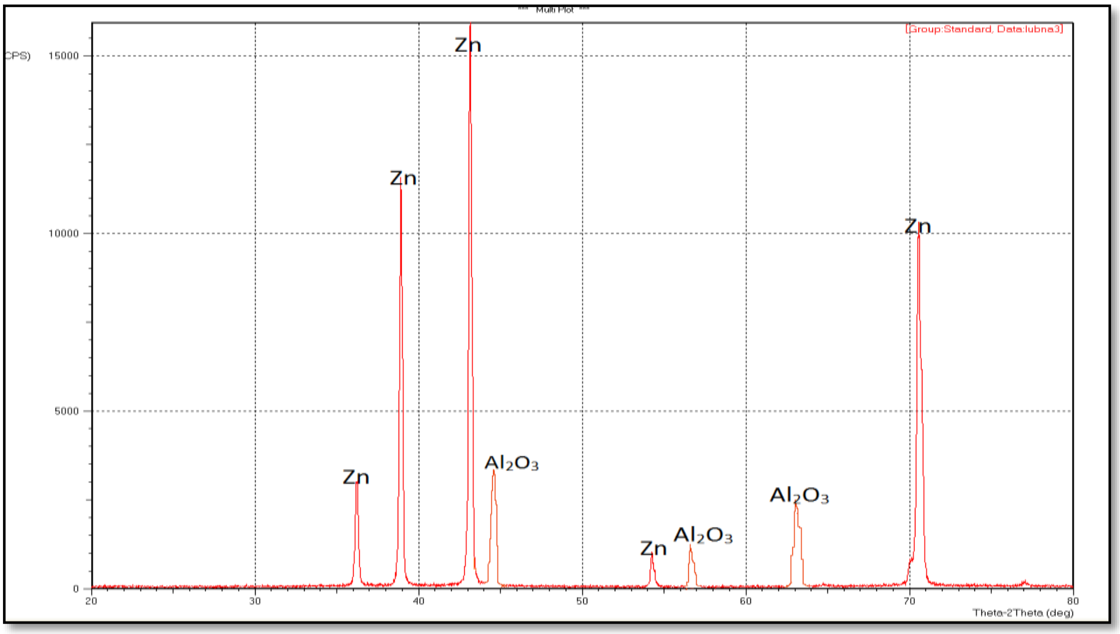

Fig.(2): XRD patterns of Al_2O_3 co-deposited samples.

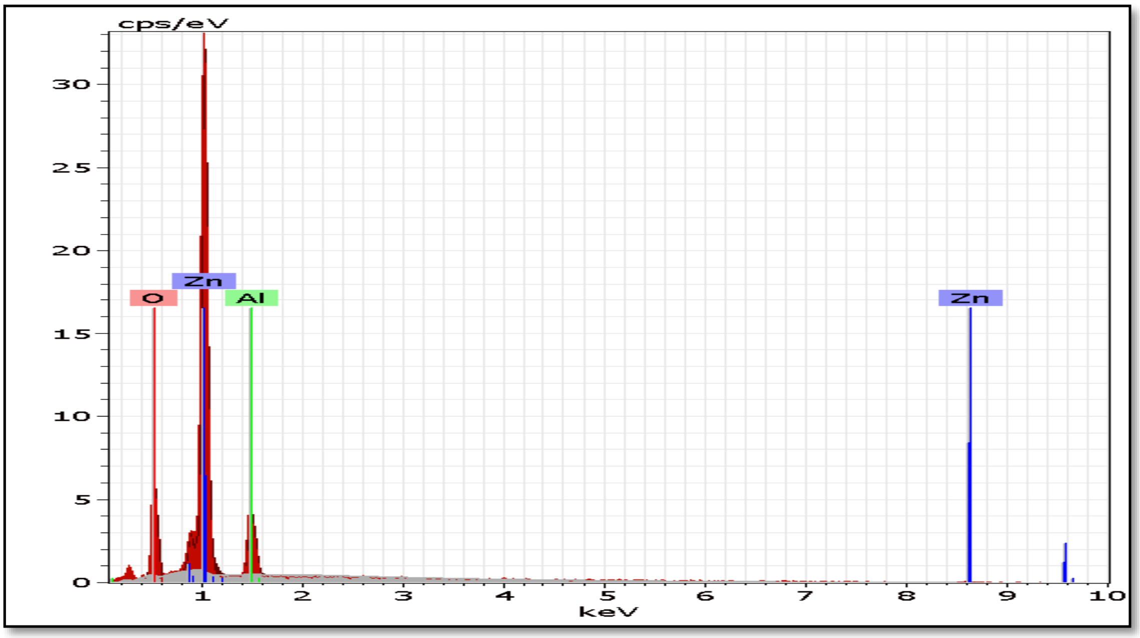

Fig. (3): EDX for Zn-Al_2O_3 composite coating.

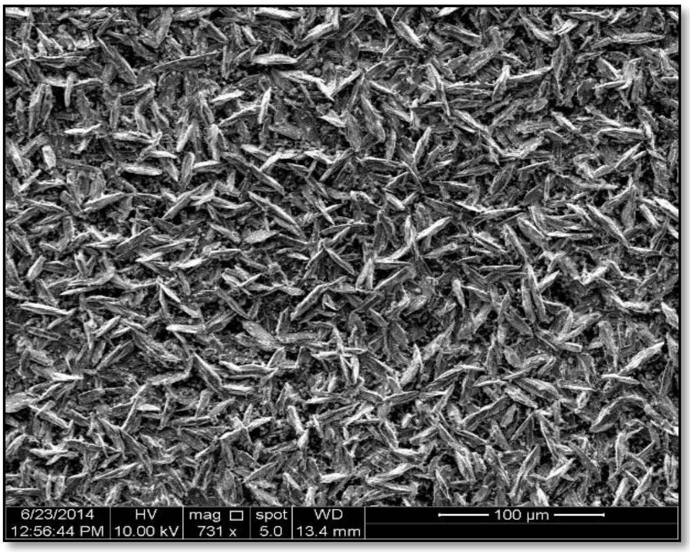

Fig.(4a):SEM photo micrographs of Zn-nano Al_2O_3 coating

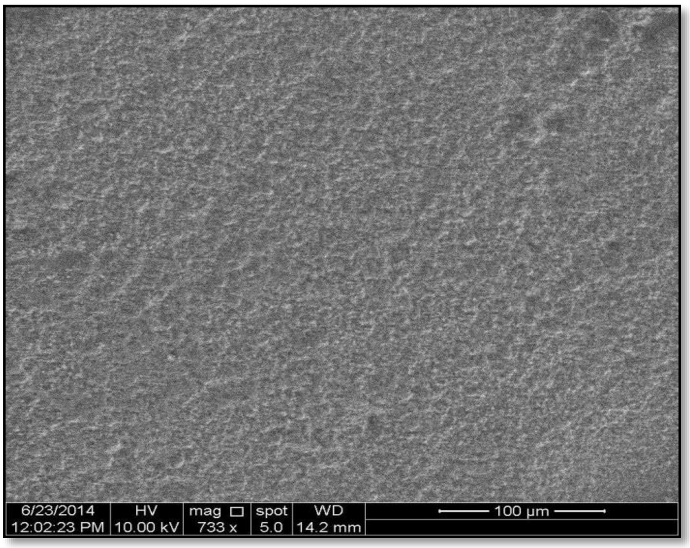

Fig.(4b) :SEM photo micrographs of Zn coating..

Mechanical properties

The weight loss rate obtained after pin-on disc test of composite and non-composite coatings as a function of applied load is shown in Fig. (5) .For the low carbon steel specimen, showed a continual losing in weight during the exposed period of friction surface, what causes a low resistance of wear for carbon steel, so we turn to a different ways to improve resistance. As for the steel specimen which coated with (Zn) layer, it is obvious from the figure that, there is an improvement occurred on the wear resistance of the steel sample, which resulting the hardness (Zn) layer component. Nevertheless, when adding nano alumina wear resistance is improve.

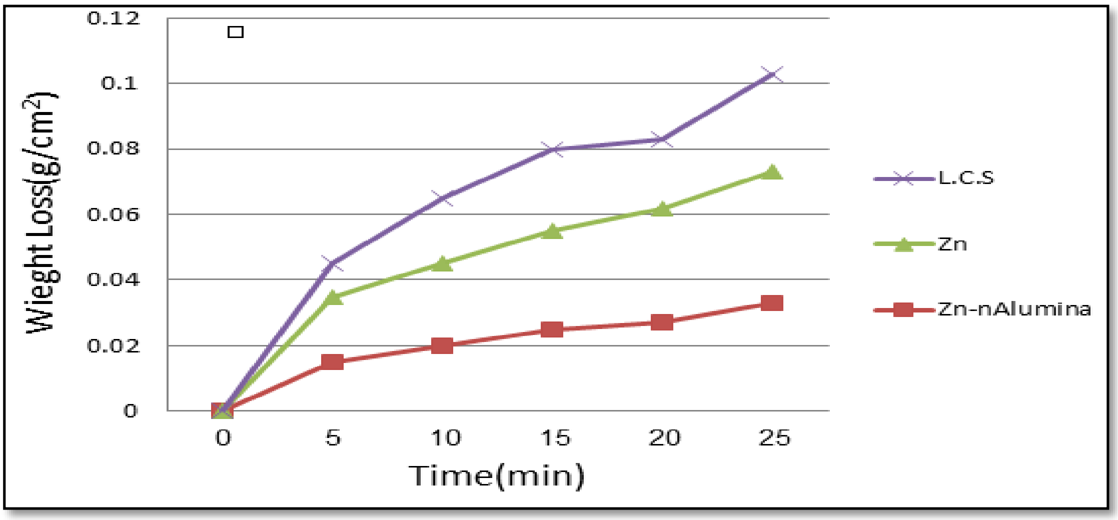

Fig. (5): Shows the time of exposure to the wear on the weight loss of specimens.

Conclusions

(1) The presence of nano-alumina particles affected the grain size and homogeneity of the coating morphology. It led to finer grain size in DC plated coatings.

(2) Zn-nAl_2O_3 coating carried out a good mechanical because of the alumina material is inactive chemical of highly hardness what reflect to achieve the best conclusion accustoms to the smallest

particles sized of making it integrated in a deep homogeneous way in the (Zn) plating. As well, the small close size to the spaces between particles in the crystalline feature makes it as supportive ones to this feature and isolate impurities from breaking through.

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