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Experimental Study of the Interaction of Solanum Tuberosum Fluid as Additive in Electrodeposition Bath in the Presence of Zn-Tio_2 on Mild Steel

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Abstract

Enhancing mild steel properties is necessary to meet global competiveness and performance during application. In this study, we report the effect of Solanum tuberosum as additive to Zn-TiO_2 sulphate bath coating by electrodeposition method on low carbon steel. The interfacial and structural characteristics of the produced coating were examined by means of scanning electron microscopy equipped with energy dispersive spectroscopy (SEM/EDS). The corrosion resistance properties of the deposited coatings were assessed in 3.65% NaCl using linear polarization method and characterized by optical microscope (OPM). Diamond based microhardness tester was used to measure hardness of the composites. From the results, it is evident that Zn-TiO_2-solanum coating resulted in improved performance as compared to Zn-TiO_2 coating; both in hardness properties and corrosion resistance properties propagation as a result of its embedded structural build up.

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Keywords: Zn-TiO2, Solanum, Electrodeposition, Structural Properties

1. Introduction

Low carbon steel remains the most used material for both domestic and industrial applications owing to its unique properties and importance as an engineering material [1, 2]. On the other hand, mild steel is globally used due to its low cost and good mechanical strength. But then again, one of the major weaknesses of mild steel is its

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poor corrosion and wear behaviour [2]. Due to these shortcomings, mild steel protection techniques have been investigated to improve the lifespan of steel against deterioration. Intentions for electroplating are that it results in improved resistance to corrosion and wear [1-3].

Electrodeposition of metals has become commonly used in many industries, with distinct advantages compared to most other coating technologies, this is one of the technique used for steel protection and improvement of properties [4]. Taking into account all these considerations, zinc coatings and zinc-based coatings are used broadly to protect steel [5-6]. Investigation of zinc deposition on mild steel is quite unending because of the unique properties and the very low cost it offers [1-5].

Several researchers [7-10] reported that adding additives in plating bath tend to better the morphology, reduce porosity and helps with good performance in corrosion resistance properties. Glycerin, Thiourea, SiC and others are reported as examples of additional inorganic and metallic ingredients that perform such role of improving properties of coatings. However, research is developing more into the use of nontoxic, cheap organic juice extraction as alternative of toxic and expensive additives [11, 12].

In this study, the surface morphology, corrosion resistance and hardness properties of a $Zn–TiO_2$ and $Zn-TiO_2$-Solanum tuberosum coatings were studied and related having taken into consideration the chemical constituents of Solanum as an additive.

2. Experimental Procedure.

2.1. Material preparation

Small low carbon steel samples of 60 mm 40 mm 1 mm dimension with the chemical composition presented in Table 1 were used as substrate and 99 % zinc sheets were used as anodes. Analar grade chemicals were used. Deionized water was used for preparation of the electroplating bath solution. From then on, 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 2M HCl solution at room temperature for 15 seconds followed by rinsing in distilled water.

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

2.2. Solanum Tuberosum fluid extraction

Potato tubers of equivalent weight (2.5kg) were selected and cut into smaller pieces and squeezed to remove the fluid. The extracted juice was stored in clean airtight bottles and refrigerated. Figure shows the Solanum tuberosum molecular structure.

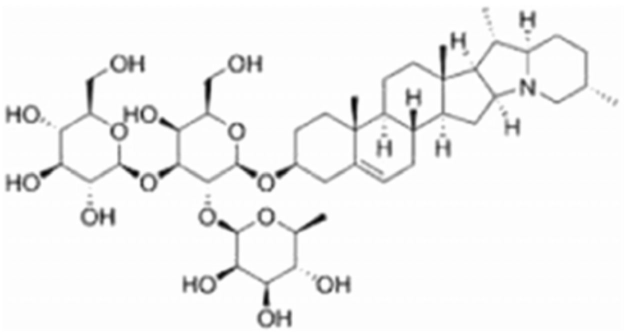

Figure 1: Solanum tuberosum molecular structure

2.3. Preparation of coating formation

The prepared sample was dipped in a solution containing dissolved bath constituents which was heated for 1hour and simultaneously stirred at 350rpm 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 V for 20 min. With the depth of dipping and distance from cathode to anode 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.

Table 2: Bath Composition of Zn-TiO_2/Solanum and Operating Condition.

Composition	Mass Concentration (g/L)
$ZnSO_4$	70
TiO_2	15
Solanum tuberosum	10(ml)
Boric Acid	10
$NaSO_4$	20
Glycine	10
Thiourea	10
pH	4.2
Voltage	3 V
Time	20 min.
Temp.	40ºC

2.4. Surface characterization

The surface morphology of the electrodeposits was observed using SEM. Micro-hardness studies were carried out using a Diamond pyramid indenter EMCO Test at a load of 10g for a period of 10s. Additionally, Positector was also used to determine surface profile of the coatings.

2.5. Corrosion testing

AUTOLAB Pontentiostat was used to study the corrosion behavior of as-received sample and the coatings in 3.65 % NaCl environment. The polarization measurements were carried from a start potential of −1.5 to an end potential of +1.5 V at a scanning rate of 0.01 V/s. KCl was used as a reference electrode and graphite served as a counter electrode. Working electrode was the sample, and the whole body of the specimen was exposed to the corrosion environment. From the Tafel corrosion analysis, the corrosion rate and linear polarization resistance were obtained.

3. Results and Discussion

Experimental results obtained for Zn-TiO_2/Solanum electro-deposition are shown in Table 3. The deposition voltage was kept constant. Following the Zn-TiO_2/Solanum deposition, a good surface coating was achieved from Zn-TiO_2-Solanum composite.

Table 3: Summarized data of Zn-TiO_2/Solanum plated samples for constant plating time at various current

Sample order	Time of deposition (min)	Potential (V)	Current density (A/cm^2)
As received	-	-	-
Zn-TiO_2	20	3	3.5
Zn-TiO_2- Solanum	20	3	3.5

3.1. SEM/EDS Surface characterisation of electrodeposited samples.

The morphologies of the deposits formed were studied using SEM/EDS. Micrographs of Zn-TiO_2/Solanum coatings at 3.5 A/cm^2 for 20min are presented in Figure 2a and b. The EDS results confirmed the presence of Ti on the coating. The surface morphology and orientation of Zn-TiO_2-Solanum showed uniform grains and compact crystalline structure as compared to Zn-TiO_2. The morphological change is due to the presence of Solanum Tuberosum as additive. The Zn-TiO_2 coating does not contain any cracks and the addition of Solanum resulted in improved uniformity of the Zn-TiO_2 sample.

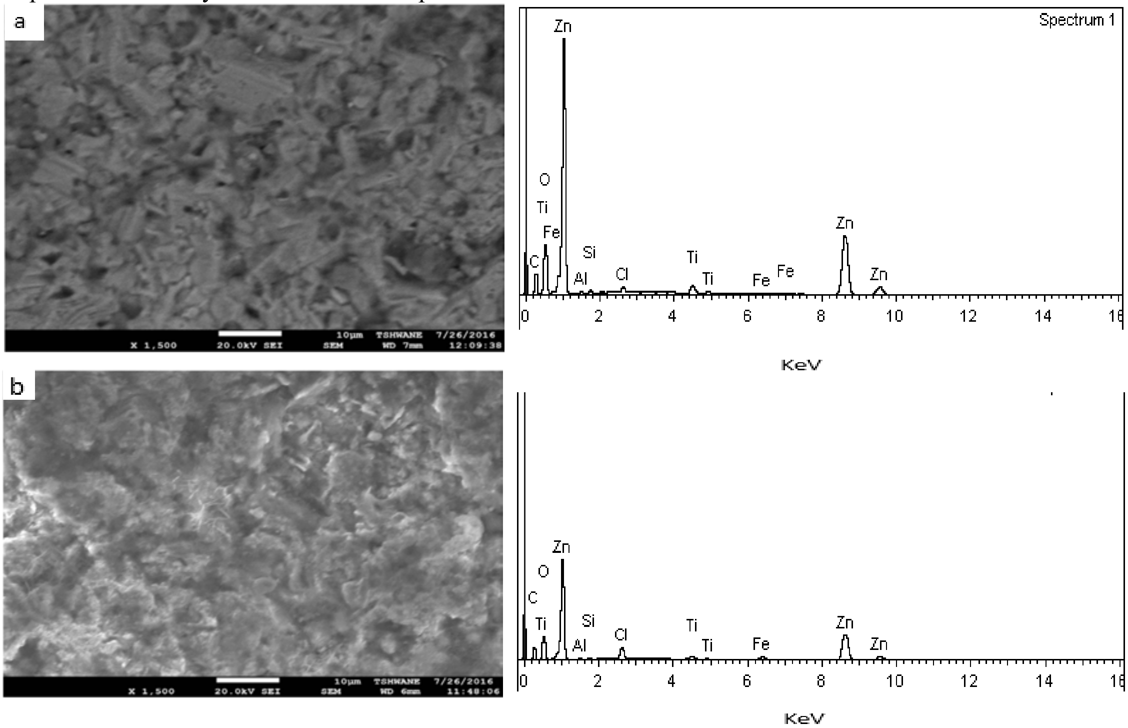

Figure 2: SEM/EDS Micrographs a) Zn-TiO_2 b) Zn-TiO_2-Solanum

The microhardness properties was examined and the average microhardness values for all the samples were calculated. Zn-TiO_2-Solanum has the highest value of hardness (Figure 3). This was due to the influence of natural additive which was added to the plating bath. This improvement in hardness of deposited Zn-TiO_2/Solanum samples (about twice over the microhardness of as received) especially with Solanum Tuberosum fluid is in line with [7] that additives tends to increase the hardness of the coating developed due to the fine-grained structure of the deposit.

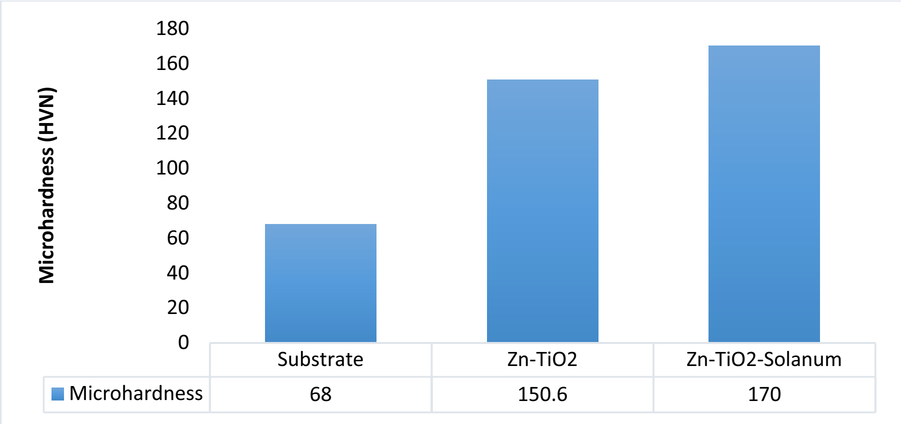

Figure 3: Comparism of Microhardness of Zn-TiO_2/Solanum coating with as received

3.2. Potentiodynamic polarization studies

Figure 4 represent the linear polarization curves of coated and control sample performance in 3.65% NaCl environment. Table 4 of polarization data results supports outcomes from Figure 4 looking at the corrosion rates of the electrodeposited samples and as received. From Figure 4, the significant positive change in potential of the Zn-TiO_2 when Solanum is added as ingredient to the bath. The addition of Solanum fluid in the presence of Zn-TiO_2 in electrodeposition bath increases the corrosion resistance properties of mild steel. Zn-TiO_2-Solanum coatings indicated better corrosion potential of 0.21047 V. This specifies that Zn-TiO_2/Solanum coatings matrixes are favourable for improving the substrate material.

Table 4: Electrochemical corrosion data obtained for mild steel in 3.65%NaCl concentration at 298K.

Sample	I_{corr} (A/cm^2)	R_P (Ω)	E_{corr} (V)	Corrosion rate (mm/yr)
As-received	0.0704	27.600	-1.5309	4.1001
Zn-TiO_2	0.000109	142.43	-1.821	1.18054
Zn-TiO_2-Solanum Tuberosum	1.55E-05	196.52	-0.28488	1.0181

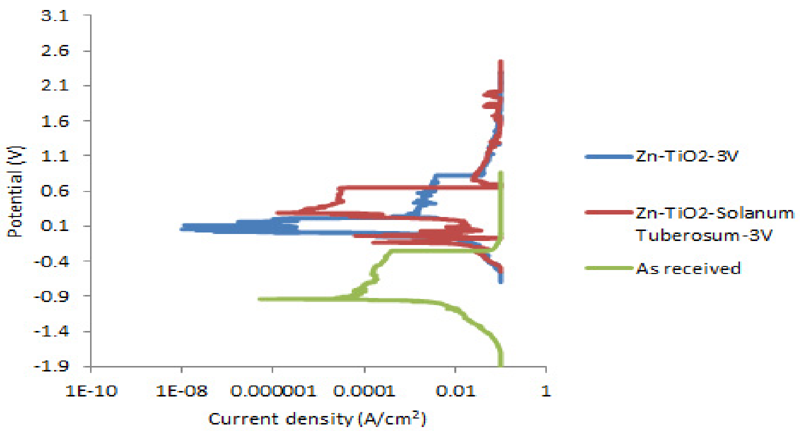

Figure 4: Potentiodynamic polarization curves for Zn-TiO_2/Solanum Tuberosum coatings matrix.

4. Conclusion

Zn-TiO_2/Solanum was successfully deposited on mild steel. Addition of Solanum Tuberosum fluid as additive to electroplating bath in the presence of Zn-TiO_2 resulted to improvement of corrosion resistance and increased hardness. EDS analysis affirmed the presence of Zn, Ti, and other chemical agents from solanum tuberosum responsible for the improvement of mild steel.

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