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Full Length Research Paper

Environmental failure of 2 M acid strength on zinc electroplated mild steel in the presence of *Nicotiana Tobacum*

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The corrosion inhibition efficiency of *Nicotiana tobacum* (tobacco leaves) on the corrosion performance of zinc electrodeposited mild steel in 2 M HCl was studied using weight loss and gasometrical principle. The zinc electroplated mild steel coupon of 45 mm by 20 mm was immersed in HCl, in the presence of *N. tobacum* of varying extract concentration of 25, 55, 75 and 100 cm^3 at 50°C elevated temperature in 56 min. Increasing rate of hydrogen gas during the chemical reaction was examined. Inhibition feasibility was explained by formation of insoluble complex absorbing adhesion on the surface metal. However, results obtained indicate that, percentage of extract concentration increase as the number of H_2 gas generated. Extract in acid medium retard corrosion degradation of the deposited mild steel and forcefully reduce corrosion rate. Micro structural examination through OPM, AFM and XRD revealed the morphology and evaluation performance of *N. tobacum.*

Key words: Environmental failure, Inhibitor, electroplated mild steel, *Nicotiana tobacum,* gasometric.

INTRODUCTION

Corrosion is a serious engineering problem in this modern age of technological advancement which accounts for economic losses and irreversible structural damage. Efforts have been made to restrain the destructive effects of corrosion using several preventive measures (Loto et al., 1990; Ashassi-Sorkhabi et al., 2008; Abiola et al., 2007; Popoola et al., 2011)

Organic, inorganic, or a mixture of both inhibitors can inhibit corrosion by either chemisorption on the metal surface or reacting with metal ions and forming a barrier-type precipitate on its surface. (Al-Sehaibani, 2000; Abdel-Gabar et al., 2008; Satapathy et al., 2009). Toxic nature and high cost of some chemicals currently in use as inhibitors strengthen development of environmentally acceptable and inexpensive inhibitors. Extracts from different parts of plants such as Henna, *Lawsonia inermis* (Al-Sehaibani, 2000), *Rosmarinous officinalis* (Kliškić et al., 2000). *Carica papaya* (Okafor et al., 2007), *Cordia latifolia* and curcumin (Farooqi et al., 2009) date palm, *phoenix dactylifera,* henna, *lawsonia inermis,* corn, *Zea mays* (Rehan, 2003) and many more, have been found to be good corrosion inhibitors for metals and alloys. The anticorrosion activity of onion, garlic, and bitter gourd for mild steel in HCl media showed good results studied from literatures, James et al., (2009). Oil extracts of ginger, jojoba, eugenol, acetyl-eugenol, artemisia oil, and pennyroyal (*Mentha pulegium*) are used for corrosion inhibition of steel in acid media. The extract of datura was used as corrosion inhibitor for mild steel in acid medium. Quinine has been studied for its anticorrosive effect of carbon steel in 1 M HCl. The inhibitory effect of Winged prickly ash (*Zenthoxylum alatum*) extract on the corrosion of mild steel in aqueous phosphoric acid enhance corrosion prevention performance on steel and alloys (Singh et al., 2010).

Hence, the aim of this work is to study the surface morphology and the effect of *N. tobacum* extract

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Table 1. Chemical composition of mild steel sample.

Element	% Content	Element	% Content	Element	% Content	Element	% Content
P	0.0067	Fe	99.2	A	l 0.125	B	0.0009
Zn	0.0230	Co	0.0057	Si	0.029	S	0.018
As	0.0059	Ti	<0.0010	Mn	0.397	Nb	0.0046
Zr	0.0016	Pb	< 0.0020	Ni	0.025	V	0.0010
La	0.0019	Mg	0.002	Mo	< 0.0020	Bi	0.0025
Cr	0.0076	W	< 0.010	Ce	< 0.0040	Ca	>0.017
C	0.130	Cu	0.036	Sn	< 0.001		

concentration on 2.0 M HCl. The result of this investigation is focus to economically derive extract to mitigate the problem of corrosion.

MATERIALS AND METHODS

Preparation of *Nicotiana tobacum* leaves extract

Fresh *N. tobacum* leaves were dried and grinded into powder. Dried (8 g) powder was soaked in distilled water of 250 ml and refluxed for 3 h. The aqueous solution was filtered; concentration of 120 ml was estimated to study the corrosion inhibition properties. Corrosion tests were performed on zinc plated mild steel for the initial percentage metal composition is shown in Table 1. After immersion the sample were washed thoroughly in distilled water and finally degreased with acetone and dried at room temperature.

Weight loss method

Weight loss measurements was performed on the zinc plated mild steel samples, by immersing test specimen into 2 M HCl for 24 days at 50°C with and without addition of varying extract concentrations. This was further cleaned by distilled water, rinsed with acetone and the sample re-weighed again to calculate the corrosion rate (C_R) and inhibition efficiency (E %). The surface coverage (θ) and inhibition efficiency (I.E %) were determined by using the following equations:

$$\text{I-E (\%)} = \frac{w-wo}{w} \times 100 \quad (1)$$

Where w_o and w are the weight loss values in presence and absence of inhibitor respectively. Hence, the corrosion rate (C_R) of zinc electrodeposited mild steel was calculated using the relation:

$$C_R = 87.6 \times r/ ATD \quad (2)$$

Where r is corrosion weight loss of zinc electrodeposited mild steel (mg), A the area of the coupon (cm^2), T is the exposure time (h), and D is the density of mild steel in g/cm^3.

Gasometrical technique

Gasometeric measurements set up in Figure 1 were performed on cell containing 100 cm^3 test solutions at 50°C. The rates of hydrogen gas evolved in 56 min by a calibrated channel of downward displacement water flow were observed. Time and volume relationship was also established.

The efficiency of the inhibitor in gasometrical method was also determined by Tafel method with regard to volume of hydrogen gas evolved with or without inhibitor.

$$(\%)\ \text{I.E} = \frac{vo-v1}{vo} \times 100 \quad (3)$$

Where vo is the volume of hydrogen gas without Inhibitor and v1 is the volume with extracts.

RESULTS AND DISCUSSION

Figure 2 shows inhibitor concentration-time curve of zinc electrodeposited mild steel in 2 M of hydrochloric acid in the absence and presence of *N. tobacum.* This results indicate that the presence of extract at all percentage composition to time exposure retard corrosion occurrence compare to control medium that exceed twice above the inhibitory substrate indicating excess corrosion rate visibility and metal degradation.

Careful look at Table 2, corrosion rate increases with decreases in % IE. However, rising temperature decreases the inhibitory process at 50°C optimum level. Below and above the optimum range, the inhibitory efficiency retard and corrosion rate will be altered to accelerate. Further work may need to be done on extracts bark in different test environments under varied conditions in order to bring out the best.

Weight loss and gasometric studies

Effect of inhibitor concentration

Inhibitory concentration influence in 2 M HCl was shown in Figure 2. The extract showed maximum inhibition efficiency at 100% in the presence of HCl, followed by 75, 55 and 25% compare to the control substrate. Thus, indicate that the inhibition effect of this extract increases as the rate of corrosion decreases.

Gasometric analysis results from Table 2 reviled that the percentage inhibitor for the 100% extract addition performance evaluation was effective than other. This implies that with higher corrosion inhibitor, less corrosion rate was generate and lower the volume of H gas evolved as shown in Figure 3, 4 and 5. it can also be noted that

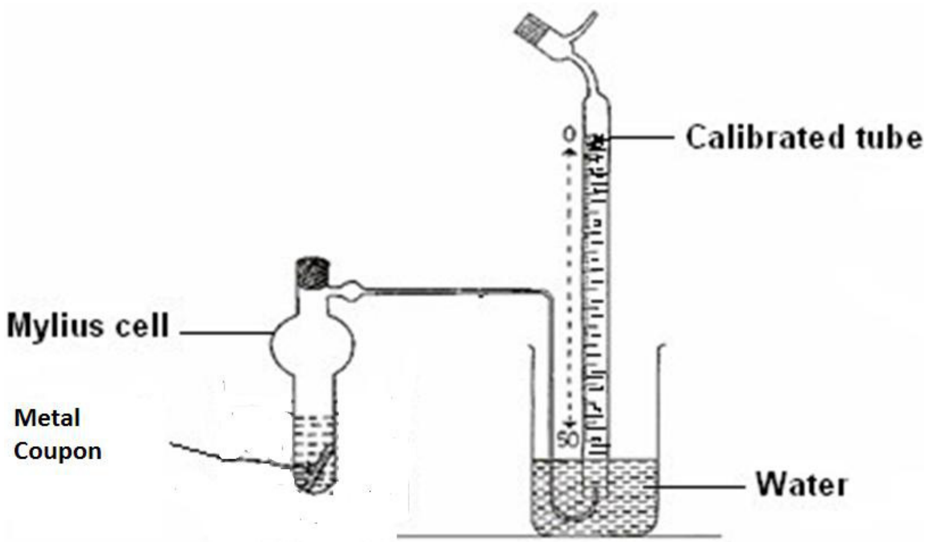

Figure 1. Schematic diagram of the system used in chemical measurements.

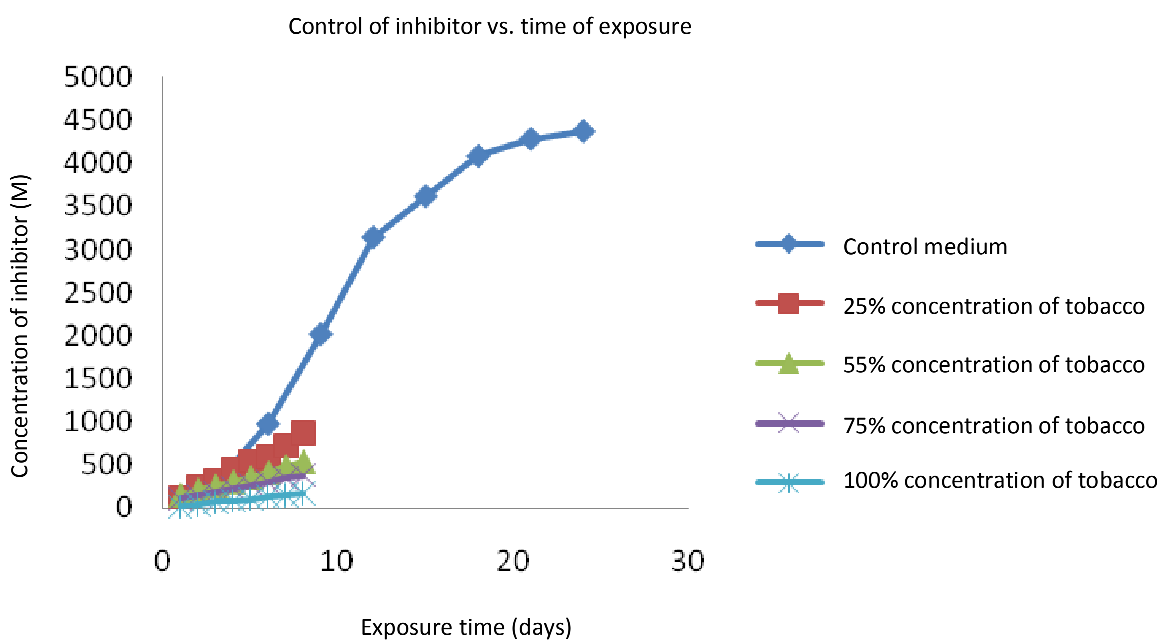

Figure 2. Concentration of inhibitor-time curve for Z-E steel in 2 M HCl in the presence and absence of inhibitor.

little hydrogen gas were given off during kinetics reaction between HCl and deposited metal unlike the control specimen. However, rate of corrosion reaction can be traceable to the function of hydrogen gas evolved with time. Therefore this deduction was derived.

Rate of corrosion $\propto$ Volume of H gas evolved $\times$Time

R = KVT

Where R is the rate of corrosion, K is the kinetic constant, V is the volume of H gas evolved and T is the time.

Effect of immersion time

For feasibility study of inhibitive behavior and passivation of the extract on substrate, weight loss analysis were performed on the substrate for 24 day with 4 days time interval at 2 M HCl in absence and presence of the extract varying concentration at 50°C. The time influence on inhibitive efficiency and hydrogen gas evolution was

Table 2. The value of corrosion parameter for the corrosion of Zn electrodeposition mild steel in 2 M HCl in the presence and absence of inhibitor concentration.

Days	Control	25%concentration	55%concentration	75%concentration	100%concentration
3	273.6	125.9	150.5	107.8	16.1
6	974.9	254.7	210.5	146.3	42.6
9	2017.3	322.4	256.8	183.9	71.3
12	3143.5	443.5	302.8	222.7	85.4
15	3620	547.4	353.1	270.7	106.3
18	4086.4	597.9	410.5	303.1	129.4
21	4285.8	719.3	479.5	348.1	148.5
24	4374.9	876.1	534	382.5	170.9

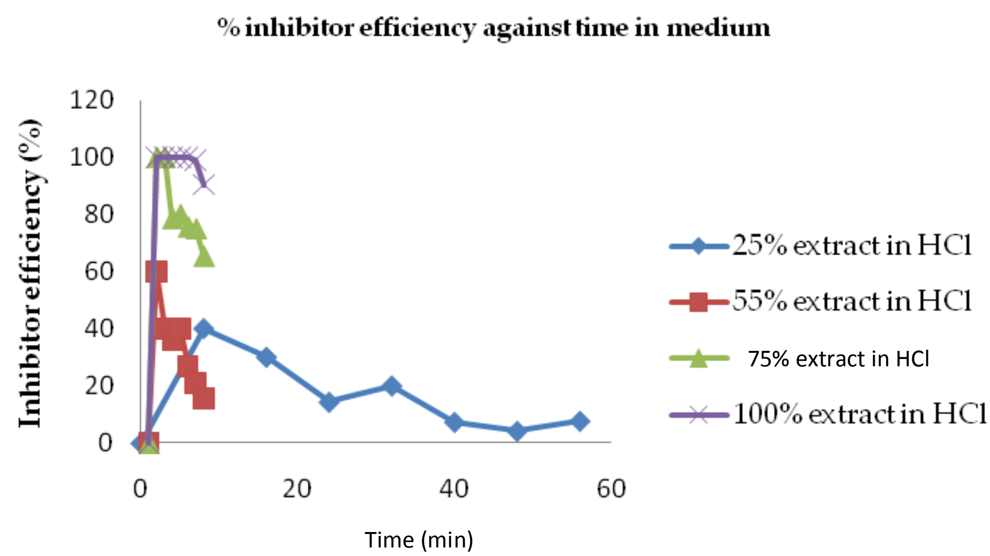

Figure 3. Inhibitor efficiency-time curve for the Z.E- steel in 2 M HCl in absence and presence of inhibitor.

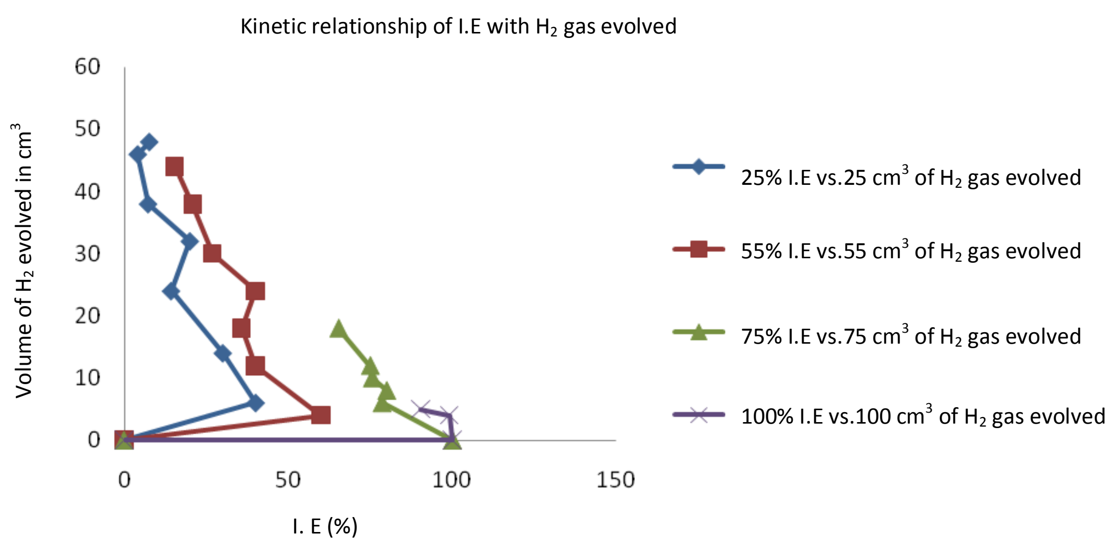

Figure 4. Volume of H_2 gas - I.E for the Z.E- mild steel in 2 M in absence and presence of different concentration of inhibitor.

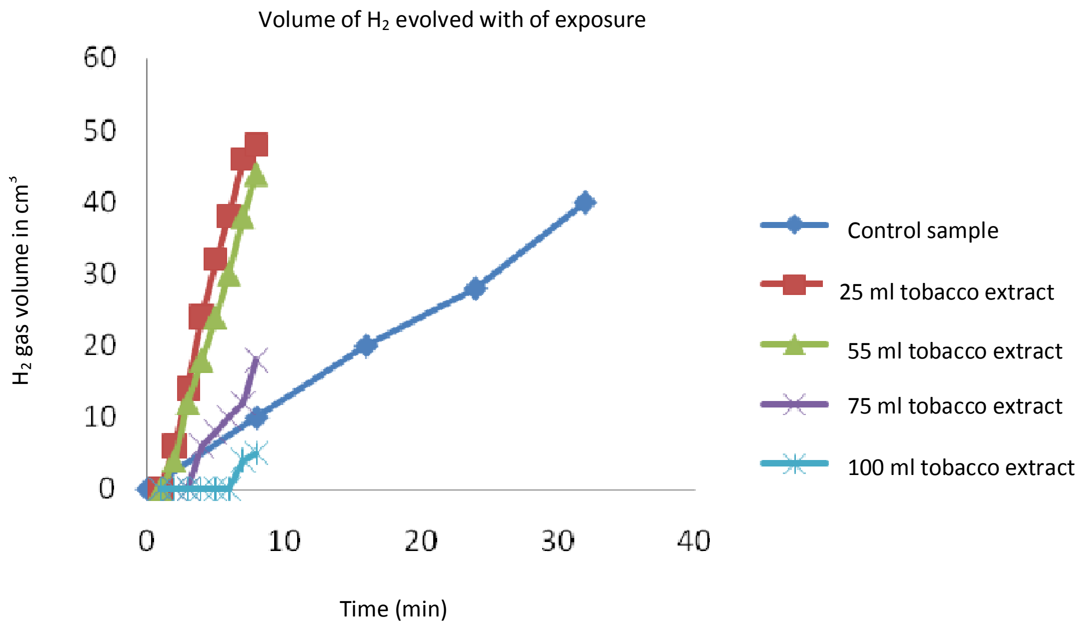

Figure 5. Volume of hydrogen gas evolved- time of exposure in the presence of *Nicotiana tobacum* at varying concentration.

Table 3. Inhibition efficiency of *N. tobaccum* for Zn electrodeposition mild steel in 2 M HCl using gasometrical technique.

		Volume of H_2 gas evolved					%I.E			
S/N	Time (h)	Control	25	55	75	100	I.E% 25	I.E% 55	I.E% 75	I.E% 100
1	0	0	0	0	0	0	0	0	0	0
2	8	10	6	4	0	0	40	60	100	100
3	16	20	14	12	0	0	30	40	100	100
4	24	28	24	18	6	0	14	35	78	100
5	32	40	32	24	8	0	20	40	80	100
6	40	41	38	30	10	0	7	26	75	100
7	48	48	46	38	12	4	4	20	75	99
8	56	52	48	44	18	5	7	15	65	90

shown in Figures 3 and 5, establishing the fact that inhibition efficiency of the extract increased with increasing immersion time. This increase in inhibition efficiency per time reflects the strong adsorption of kinetic constituents present in the extract on the plated steel surface, forming a more fusion protective layer. However, increase in time of immersion with an increase in the concentration of extract results into suitability of the corrosion inhibitor efficiency.

Effect of acid concentration and H gas evolved

From Table 3, it is noted that hydrogen gas evolved increases as inhibitive effect depreciated with time. This decrease in %IE can be attributed to decrease in aggressiveness of acid concentration in the presence of the extract as shown in Figure 6. It was also observed that at 8 min all extract in the acid test dissolution attain the maximum inhibitory efficiency as the acid strength failed drastically.

Mechanism of inhibition

The kinetic behavior of *N. tobaccum* leaves extract towards the corrosion of Z-plated steel in 2 M of hydrochloric acid depend on several influence such as surface adhesions, structure, the molecular particles and reactivity to hasten complex formation. The inhibition mechanism of *N. tobaccum* under this study is examined to be function of complex adsorbing formation between

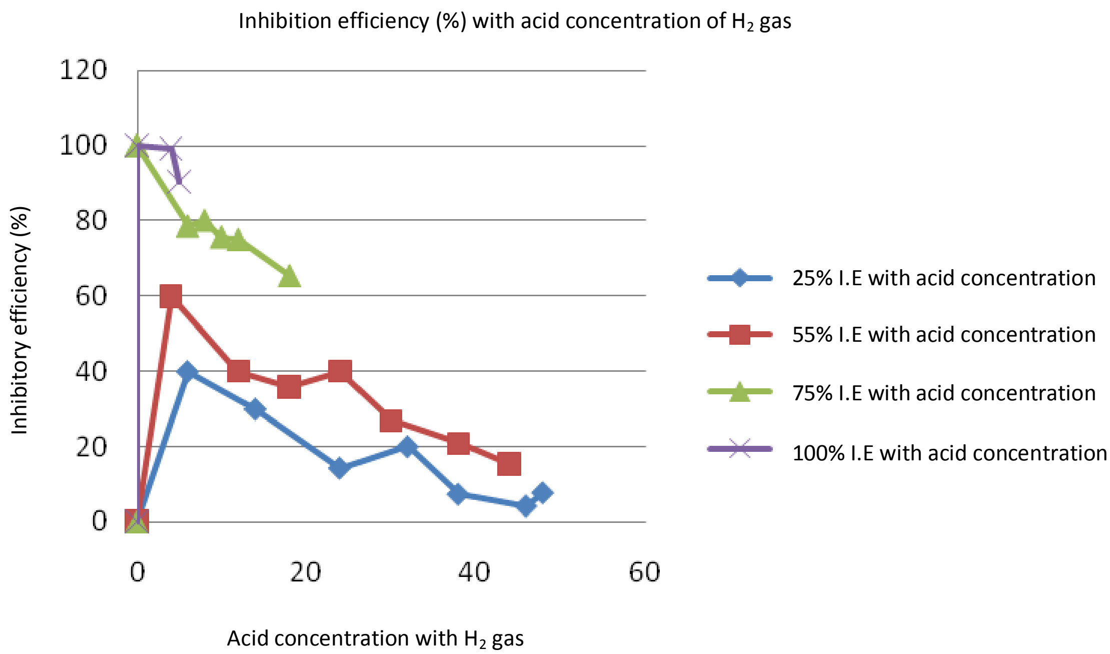

Figure 6. Inhibitor efficiency of varying concentration with acid concentration with gas evolved.

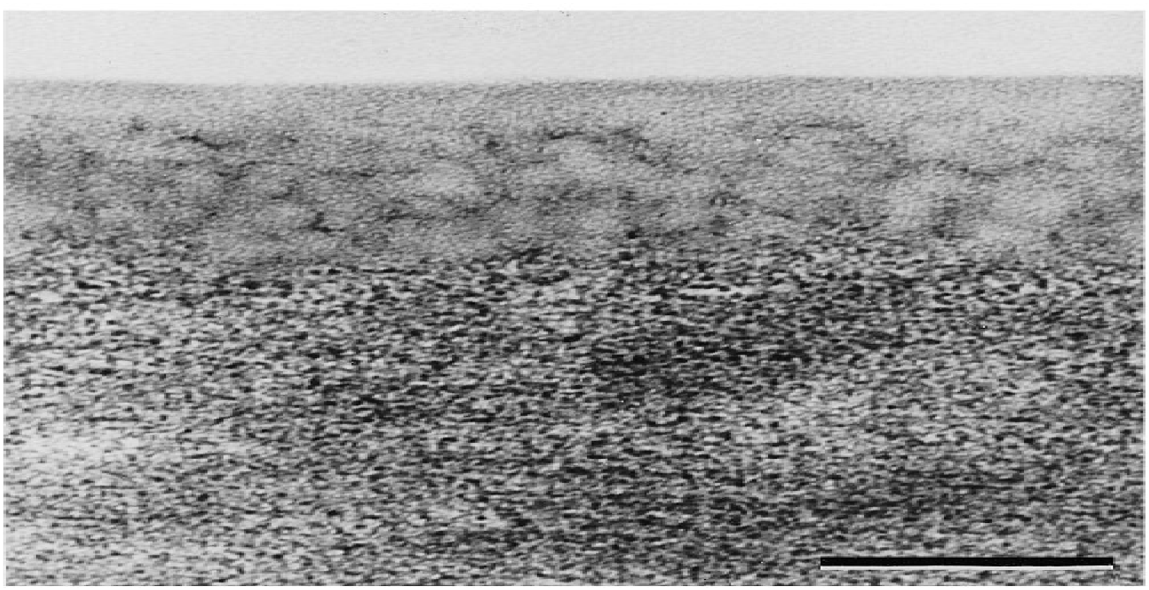

Figure 7. Electron opaque structure of *Nicotiana tobacum.*

the investigated plated steel and extract used. However, this hastens multiple bonds through which they get adsorbed on the metal surface. The high performance of *N. tobaccum* leaves extract could be due to large size of constituent's molecule (Figure 7), which covers wide areas on the metal surface and thus retarding high corrosion occurrences. It is understood that compound containing electron denoting group are more efficient than compounds containing electron withdrawing groups. The electron donated group enhances adsorption and increase the surface covered by the compound (Popoola et al., 2011; Abdullahi et al., 2008). This assumption could be further confirmed by gasometrical principle results that *N. tobaccum* leaves extract could adsorb onto steel surface to form a dense and more tightly protective film covering both cathodic and anodic reaction sites thus,

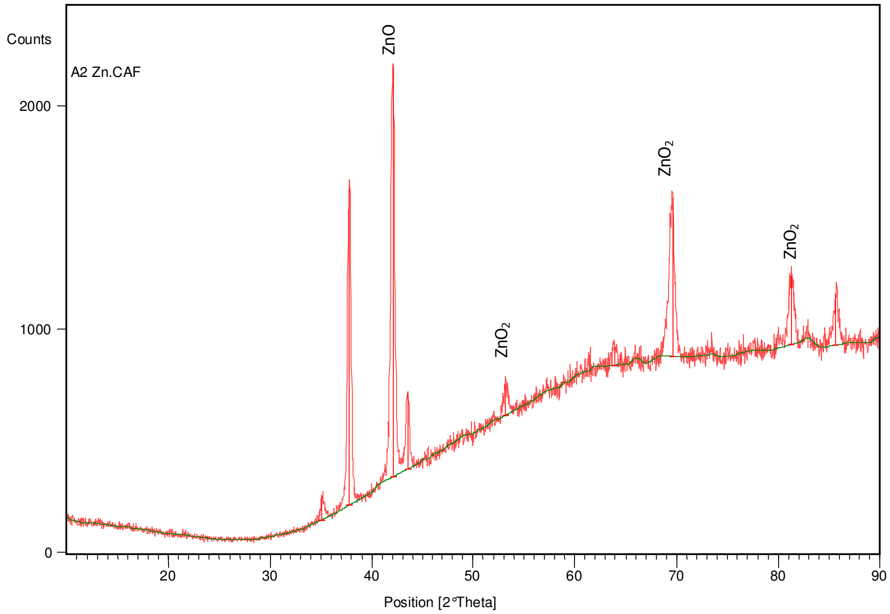

Figure 8. XRD patterns of the electrodeposits mild steel plating.

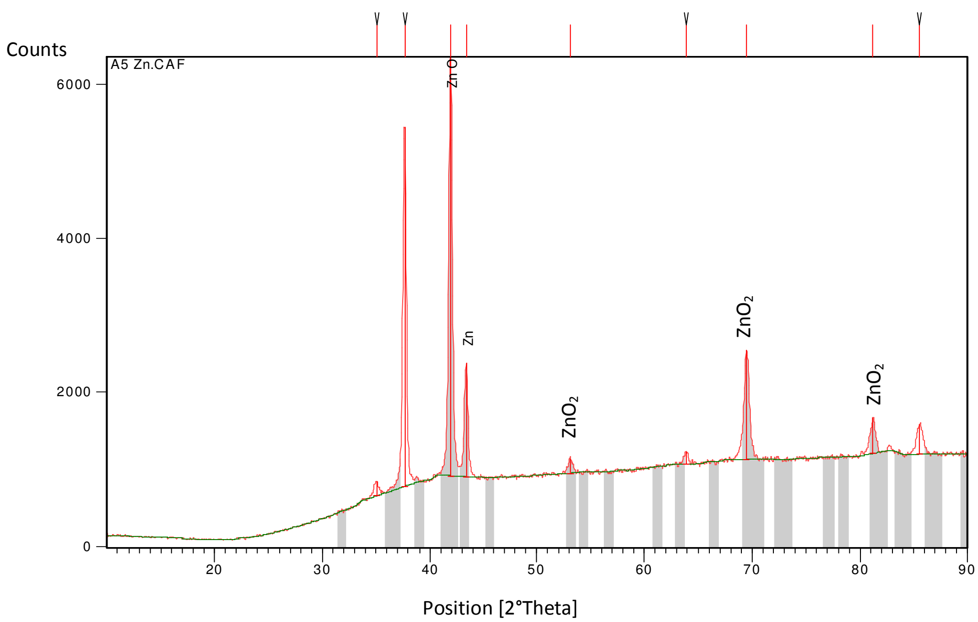

Figure 9. XRD patterns of the electrodeposits mild steel with inhibitor.

retarding corrosion phenomenon.

AFM, XRD and OPM morphological study

XRD analysis

XRD diffraction patterns obtained on the electrodeposited Substrate are given in Figures 8 and 9 showing the absent and present of inhibitory effect respectively.

AFM

From Figures 11 and 12, atomic force microscope AFM was used to investigate the surface morphology and topography of zinc deposited mild steel indicating the presence and absence of inhibitor. Homogeneous

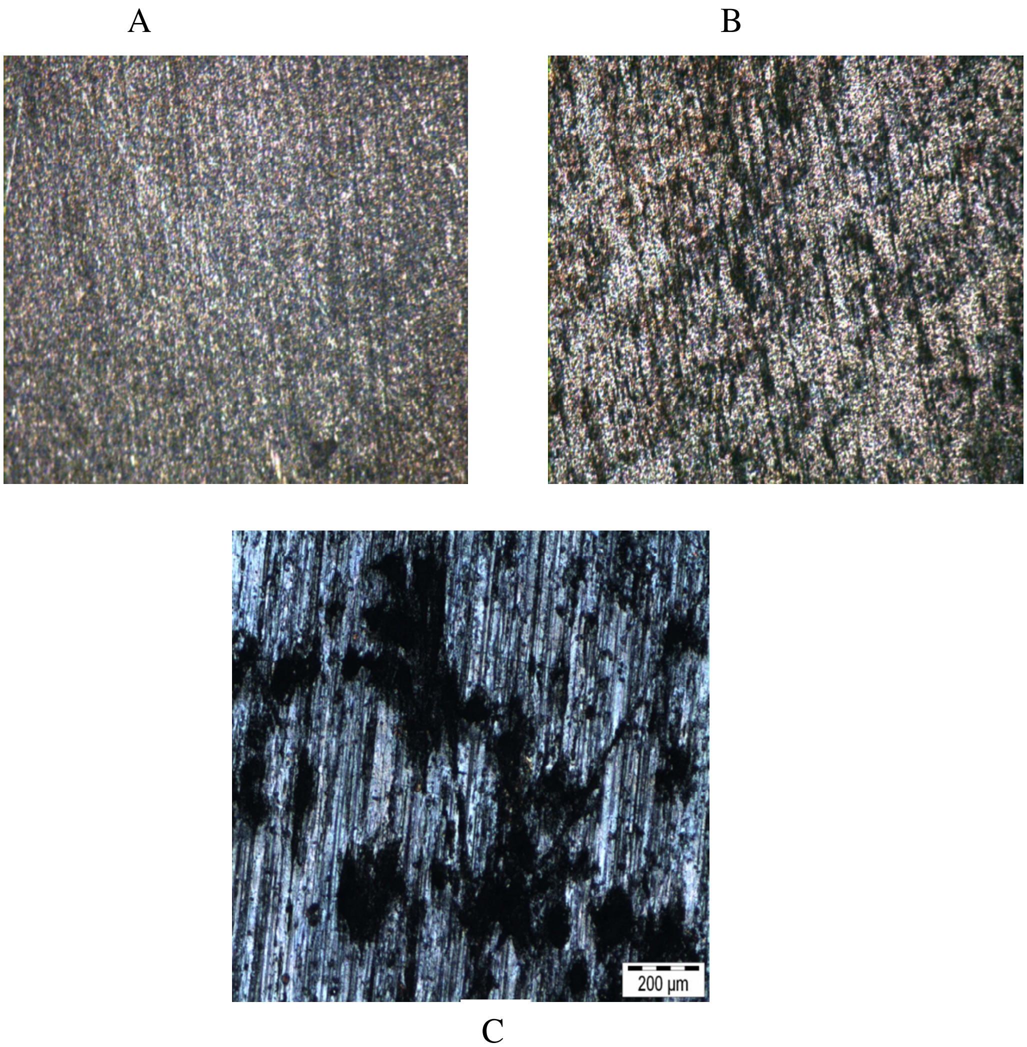

Figure 10. Metallographic micrographs for Z-plated mild steel sample under investigation. (A) Micrograph before plating, (B) plated sample (C) after immersion into 25 ml of the extract.

structure was observed with perfect crystal and uniform arrangement on the deposit. The zinc morphology consists of regular fine grain size and has a fine grained micro structure with some cracks as seen in Figure 11, indicating the presence of acid strength unlike Figure 12 with perfect adhered and regular distributed of grains due to inhibitory effect.

OPM

Micro structural studies for z-plated mild steel were investigated under optical microscopy (OP) before elctrodeposition and after experiment at each stage as illustrated in Figure 10. However, before exposure to the corrosive solution, parallel features on the clean polished of the substrate surface which are associated with polishing scratches were observed as shown in Figure 10(a). Examination of Figure 10(b) revealed that the corrosion attack (intergranular corrosion) occurs when the specimen is placed in 2 M HCl acid without any inhibitor. When immersed with *N. tobaccum* extracts in Figures 10 show how corrosion attack was reduced with 100 ml extract,

Conclusion

N. tobaccum inhibit the corrosion of plated steel under 2 M of hydrochloric. The inhibitory efficiency of this extract increased as the volume of gas evolved increases with the time of exposure. However, the kinetic and thermodynamics stability of this extract is traceable to the adsorption mechanism of insoluble complex on the metal surface. More so, the new deduction from the gasometrical formulation derived implies that increase in

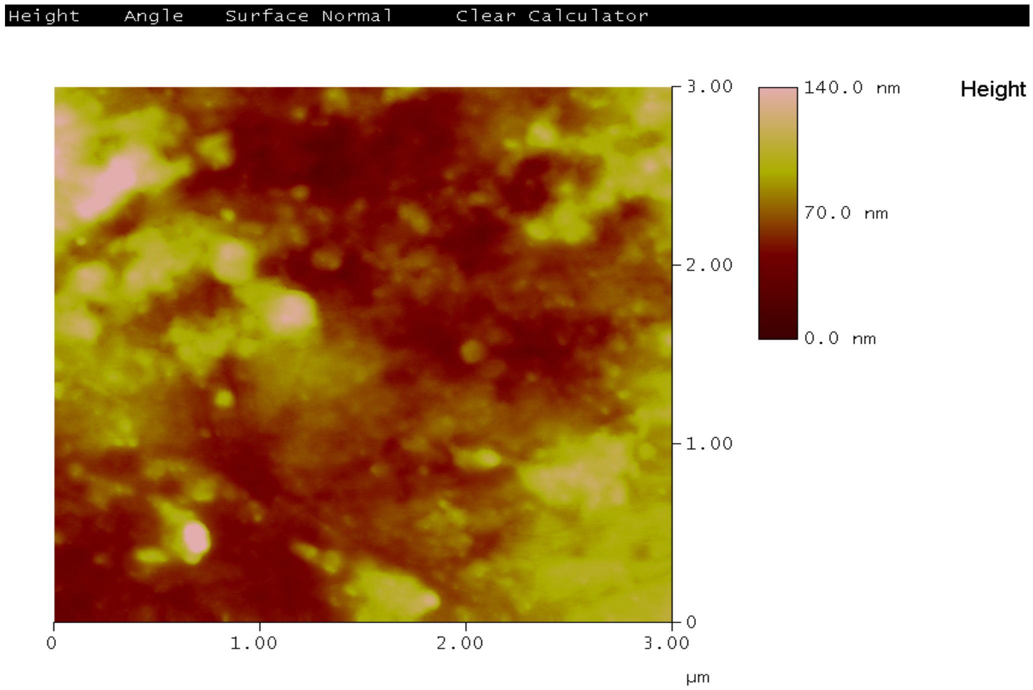

Figure 11. AFM photograph of the deposit obtained from Zn electrodeposition in 0.6 V.

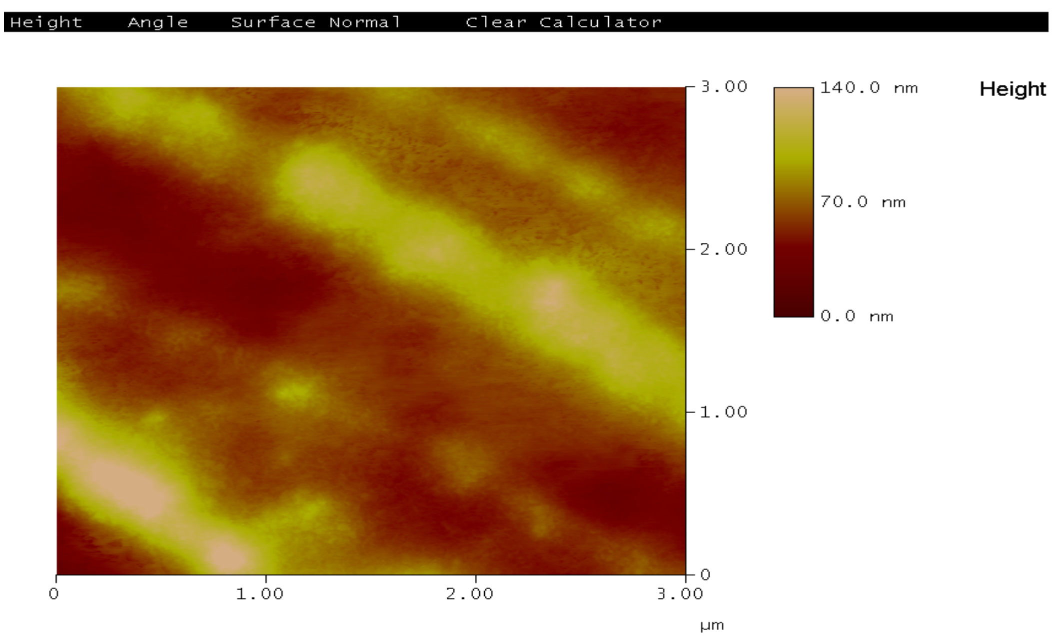

Figure 12. AFM photograph of the deposit obtained from Zn electrodeposition in 0.6 V.

extract concentration will reduce rate of corrosion. Morphological examination also establish the inhibitive evaluation performance of this extract indicate that the increasing extract concentration retard corrosion degradation on metal.

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REFERENCES

Abdel-Gaber AM, Khamis E, Abo-ElDahab H, Adeel S (2008). "Inhibition of aluminium corrosion in alkaline solutions using natural compound," Mater. Chem. Phys., 109(2-3): 297–305.

Abdullahi M, Fouda AS, Shama SA, Afifi EA (2008). Azodyes as corrosion inhibitors for dissolution of c- steel in hydrochloric acid solution. Afr. J. pure appl chem., 2(9): 083-091.

Abiola OK, Oforka NC, Ebenso EE, Nwinuka NM (2007)> "Eco-friendly corrosion inhibitors: the inhibitive action of Delonix Regia extract for the corrosion of aluminum in acidic media" Anti-Corrosion Methods Mater., 54(4): 219-224.

Al-Sehaibani H (2000). "Evaluation of extracts of Henna leaves as environmentally friendly corrosion inhibitors for metals," *Materialwissenschaft und Werkstofftechnik*, 31(12): 1060–1063.

Ashassi-Sorkhabi H, Seifzadeh D, Hosseini MG (2008). "EN, EIS and polarization studies to evaluate the inhibition effect of 3H-phenothiazin-3-one, 7-dimethylamin on mild steel corrosion in 1 M HCl solution," Corrosion Sci., 50(12): 3363–3370.

Farooqi IH, Hussain AM, Quraishi A, Saini PA (1999). "Study of low cost eco-friendly compounds as corrosion inhibitors for cooling systems," Anti-Corrosion Methods Mater., 46(5): 328–331.

James AO, Akaranta O (2009). Corrosion inhibition of aluminum in 2.0 M hydrochloric acid solution by the acetone extract of red onion skin, Afr. J. Pure Appl. Chem., 3(12): 262-268.

Kliškić MJ, Radošević S, Gudić KV (2000). "Aqueous extract of Rosmarinus officinalis L. as inhibitor of Al-Mg alloy corrosion in chloride solution," J. Appl. Electrochem., 30(7): 823–830.

Loto CA (1990). Corrosion inhibition of extracts on mild steel. Corrosion prevention and control, 37 (5): 131-136

Okafor PC, Ebenso EE (2007). "Inhibitive action of Carica papaya extracts on the corrosion of mild steel in acidic media and their adsorption characteristics," Pigment Resin Technol., 36(3): 134–140.

Popoola API, Fayomi OSI (2011). ZnO as corrosion inhibitor for dissolution of zinc electrodeposited mild steel in varying HCl concentration dissolution Int. J. Phys. Sci., 6: 8.

Rehan HH (2003). "Corrosion control by water-soluble extracts from leaves of economic plants," *Materialwissenschaft und Werkstofftechnik*, 34(2): 232–237.

Satapathy AK, Gunasekaran G, Sahoo SC, Amit K, Rodrigues PV (2009). "Corrosion inhibition by Justicia gendarussa plant extract in hydrochloric acid solution, Corrosion Sci., 51: 2848.

Singh A, Singh VK, Quraishi MA (2010). Quraishi Aqueous Extract of Kalmegh (*Andrographis paniculata*) leaves as Green Inhibitor for Mild Steel in Hydrochloric Acid Solution. Int. J. Corrosion, 10: 1155- 1162.