

TMS 2018

147th Annual Meeting & Exhibition

SUPPLEMENTAL PROCEEDINGS



TMS

 Springer

The Minerals, Metals & Materials Series

The Minerals, Metals & Materials Society
Editor

TMS 2018
147th Annual Meeting &
Exhibition Supplemental
Proceedings

TMS

 Springer

Editor
The Minerals, Metals & Materials Society
Pittsburgh, PA
USA

ISSN 2367-1181 ISSN 2367-1696 (electronic)
The Minerals, Metals & Materials Series
ISBN 978-3-319-72525-3 ISBN 978-3-319-72526-0 (eBook)
<https://doi.org/10.1007/978-3-319-72526-0>

Library of Congress Control Number: 2017963376

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The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

The TMS 2018 Annual Meeting Supplemental Proceedings is a collection of papers from the TMS 2018 Annual Meeting & Exhibition, held March 11–15 in Phoenix, Arizona, USA. The papers in this volume represent 37 symposia from the meeting. This volume, along with the other proceedings volumes published for the meeting, and TMS archival journals, represents the available written record of the 92 symposia held at TMS 2018.

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Experimental Investigation of the Effect of ZnO-*Citrus sinensis* Nano-additive on the Electrokinetic Deposition of Zinc on Mild Steel in Acid Chloride

Oluseyi O. Ajayi, Olasubomi F. Omowa, Olugbenga A. Omotosho, Oluwabunmi P. Abioye, Esther T. Akinlabi, Stephen A. Akinlabi, Abiodun A. Abioye, Felicia T. Owoeye and Sunday A. Afolalu

Abstract This work investigated the effect of ZnO-*Citrus sinensis* nano-additive on the electrokinetic deposition of Zinc on mild steel in acid chloride. Fifty-four plates of (100 × 10 × 3) mm³ mild steel samples were cut, cleaned with dilute H₂SO₄ solution, rinsed in water and dried. The nano-additive was produced by infusing 30 ml Orange Juice extract in Zinc Oxide solution. The acid chloride electrolyte consisting of 71 g ZnCl, 207 g KCl and 35 g H₃BO₃ in 1 l of distilled water was divided into six portions. The nano-additive with different molar concentrations 0(0.2)1.0 was added to each portion of the acid chloride. Nine plates of mild steel samples were electroplated with zinc as the anode in each of the six prepared electrolyte solution and plated at different times (three plates each at 10, 15 and 20 min). The effects of electroplating on the average weights were measured and the results from the experiment showed the optimal nano-additive concentration and electroplating time.

Keywords Nano-additive • Nanotechnology • Corrosion protection
Deposition • Mild steel

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Introduction

Steel has found various applications in the industries because of their excellent properties. It is reasonable in cost, longer life, and variability in strength levels and also very adaptable to corrective rework [1]. These properties made steel to meet the ever increasing stringent engineering needs in the industries. Steel is a major material in automotive and other sectors majorly because of corrosion resistance with zinc coatings, ease of joining, recyclability and good crash energy absorption [2–4].

In most manufacturing sectors and industries chloride solutions are used as cleaning agents and other function but steel being widely used in such industries are affected by the action of chloride solutions [5]. Electrodeposited steel can be made to withstand and reduce aggrieved strength of chloride as a medium [6, 7]. Different methods have been employed for corrosion protection but zinc coating is the major method used in industrial sectors as protective coating for large quantities of products and other fabricated ferrous metal parts [5, 8–13]. The addition of agents to aqueous electroplating baths plays an important role because of the important effects they produce on the growth, structure and glossiness of deposits [12, 13]. Additives have different benefits which include reduction in grain size and tendency to tree, improve mechanical and physical properties, reduces stress and pitting, increase current density range and promote levelling and brightening of deposit. In this investigation, the effect of orange nanoparticle additive on the surface morphology of the substrate performance was studied to determine the optimal nano-additive concentration and electroplating time.

Experimental Method

Samples of mild steel plates were cut into various pieces with the dimension $100 \times 10 \times 3$ mm. Surface preparation was done using polishing machine with different grades of emery papers. The pickling of the mild steel was done for 15 min using dilute H_2SO_4 of 120 ml of H_2SO_4 in 1 litre of water. The samples were rinsed, dried and stored in a desiccator. The percentage chemical composition of the mild steel substrate was analysed using Optical Emission Spectrometer as showed in Table 1.

Orange nanoparticle supernatant was used for this experiment. The additive was prepared by infusion of 30 ml of orange juice in zinc oxide solution of varying concentrations 0.2, 0.4, 0.6, 0.8 and 1 M. The mixtures were left to react for 48 h. The reacted mixture were centrifuged at 4500 rpm for 15 min. The supernatant were then, decanted from the mixture. The nano particle suspension was transferred to watch glass, after which it was air dried and stored in sample bottles at room temperature. The acid chloride bath for this experiment contained zinc chloride, boric acid and potassium chloride. The acid chloride solution was prepared by

Table 1 Chemical composition of the mild steel substrate

Elements	% Composition
Si	0.131
Mn	0.3042
Ni	0.0071
Mo	0.0007
C	0.057
Sn	0.005
Co	0.0013
Al	0.0257
Cu	0.0029
P	0.0144
Fe	Bal

Table 2 The additives concentration and electroplating time

Additive	Concentration (M)	Time (Min)
Control	0	10, 15, 20
ZnO-Citrus sinensis nano-additives	0.2	10, 15, 20
	0.4	10, 15, 20
	0.6	10, 15, 20
	0.8	10, 15, 20
	1	10, 15, 20

dissolving 71 g of zinc chloride, 207 g of potassium chloride and 35 g of boric acid in 1 l of distilled water. This solution was filtered to remove any form of impurity.

The mild steel to be electroplated (cathode) and two zinc anodes were partially immersed in 150 ml of acid chloride bath. The cathode was connected to the negative terminal while the zinc anodes were connected to the positive terminal of the direct current (DC) power supply, current was set to 0.8 A. The additives concentrations and plating time were varied as shown in Table 2. The weight of the mild steel was measured before and after the plating to determine the mass deposited. The experiment was replicated to arrive at an average coherent value.

Results and Discussion

Effect of Electrodeposition Time

The result of the electro deposition experiment revealed the different mass addition of zinc on mild steel substrate in the bath for varying orange zinc oxide nanoparticle

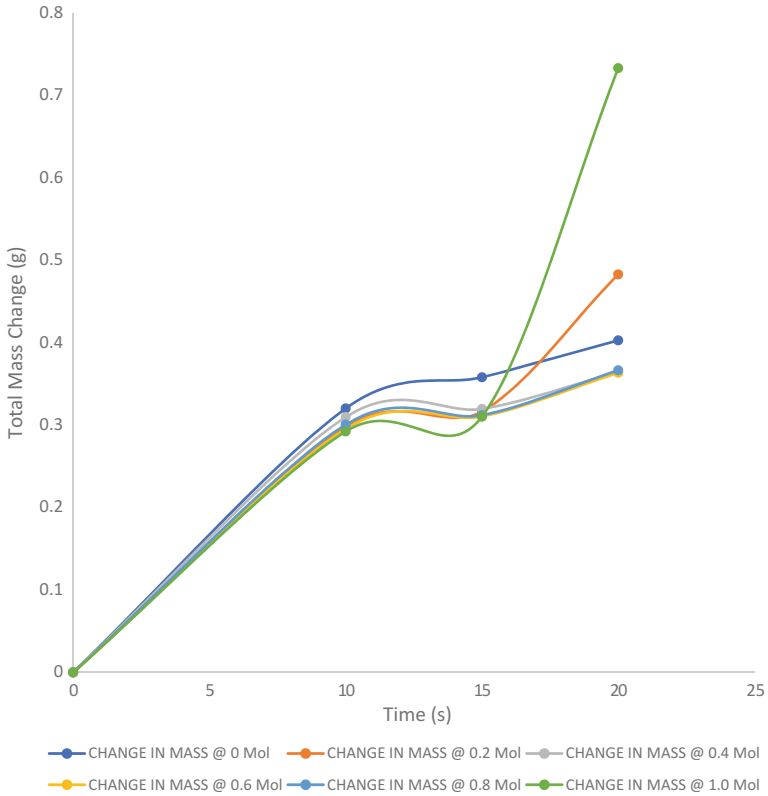


Fig. 1 A graph of the change in mass against deposition time for 0, 0.2, 0.4, 0.6, 0.8 and 1.0 M additive concentration

additive concentrations. The results obtained were for plating time of 10, 15 and 20 min. Figure 1 showed the graph of the change in mass against time at 0, 0.2, 0.4, 0.6, 0.8 and 1.0 M additive concentrations. A steady increase in total mass change was observed as the electrodeposition time increased for all the additive concentration used. Thus, irrespective of the additive concentration, the total mass change increases with electrodeposition time.

Effect of the ZnO-Citrus Sinensis Nano-additive

Figure 2 shows the effect of ZnO-Citrus sinensis nano-additive on the electrodeposition of Zinc on steel at different deposition time. For deposition done at 10 and 15 min, there was no significant impact of the additive concentration on the mass change. However, at 20 min electrodeposition time, a significant increase in total mass changed was observed at 1 M additive concentration.

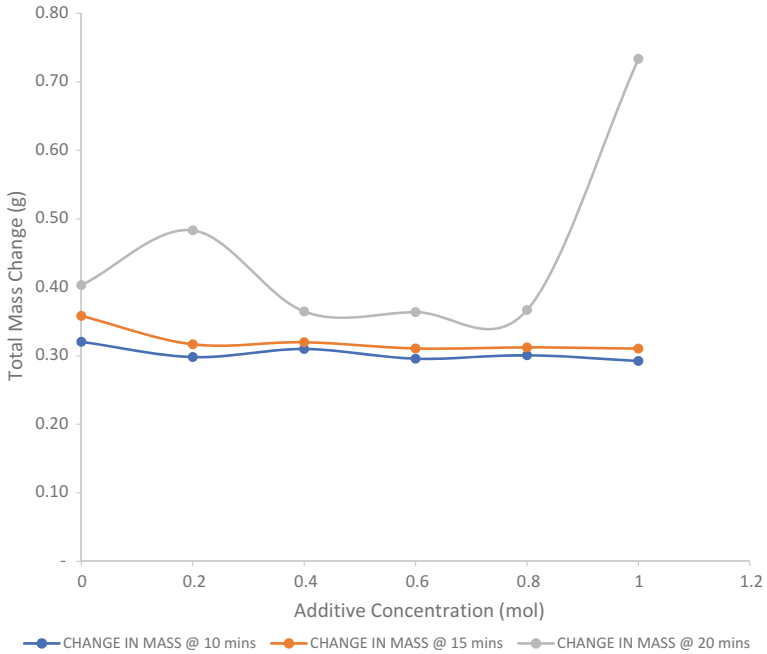


Fig. 2 A graph of the change in mass against the additive concentration at different electrodeposition time

Conclusion

Nanodeposition of zinc on steel in acid chloride environment with ZnO-*Citrus sinensis* nano-additive increases with electrodeposition time.

Moreover, physical examination of the zinc deposited mild steel shows a smoother surface finish with an increase in the concentration of ZnO-*Citrus sinensis* as nano-additive in the electrolyte solution.

Also, the study of the effect of ZnO-*Citrus sinensis* nano-additive on the mass change shows that optimum combination of factors to yield optimum deposition of zinc on mild steel occurred at the additive concentration of 1 M when electroplated for the period of 20 min.

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