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Contents

Part I 2018 Symposium on Functional Nanomaterials: Discovery and Integration of Nanomaterials

2-D Nanosheets and Rod-Like WO_3 Obtained via Chemical Precipitation Method for Detecting Formaldehyde 3
HuiMin Yu and JianZhong Li

Electrochemical Fabrication of Micro/Nanoporous Copper by Electrosynthesis-Dealloying of Cu–Zn Alloy in Deep Eutectic Solvent 13
Shujuan Wang, Xingli Zou, Xueliang Xie, Xionggang Lu, Yinshuai Wang, Qian Xu, Chaoyi Chen and Zhongfu Zhou

Electrosynthesis of CuNPs from e-Waste 21
M. Islas Hernández, P. A. Ramírez Ortega, L. García Hernández and U. M. Flores Guerrero

Experimental Investigation of the Effect of ZnO-*Citrus sinensis* Nano-additive on the Electrokinetic Deposition of Zinc on Mild Steel in Acid Chloride 35
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

Obtaining of Iron Nanoparticles (Fe NP's) for Treatment of Water Contaminated with As 41
D. Barrón-Romero, L. García-Hernández, P. A. Ramírez-Ortega, I. A. Reyes-Domínguez, M. U. Flores Guerrero, M. J. Ivey Cruz and M. N. Hernández Escamilla

Synthesis of Gold Nanoparticles Using the Extract of *Sedum praealtum* and Its Deposition on a Ceramic Substrate 49
L. García-Hernández, B. Aguilar-Pérez, J. Ramírez-Castro, P. A. Ramírez-Ortega, M. U. Flores-Guerrero and D. Arenas-Islas

Part II Accident Tolerant Fuels for Light Water Reactor

Effects of Ce Addition on the Microstructure and Mechanical Properties of Accident-Tolerance Fe-Cr-Al Fuel Cladding Materials 61
Naimeng Liu, ZhongWu Zhang, Yang Zhang, Ye Cui, Dan Chen, Yu Zhao, SongSong Xu and Hao Guo

Part III Additive Manufacturing of Metals: Fatigue and Fracture

Evaluation of the Mechanical Properties of 15Cr-5Ni Stainless Steel Produced by Direct Metal Laser Sintering 75
Davoud M. Jafarlou, Victor K. Champagne and Ian R. Grosse

Creep and Thermomechanical Fatigue of Functionally Graded Inconel 718 Produced by Additive Manufacturing 85
V. A. Popovich, E. V. Borisov, V. Heurtebise, T. Riemslag, A. A. Popovich and V. Sh. Sufiiarov

Part IV Additive Manufacturing: Building the Pathway towards Process and Material Qualification

Defect Detection in LENS AM Using In Situ Thermal Camera Process Monitoring 101
Tom Stockman, Judith Schneider, Cameron Knapp, Kevin Henderson and John Carpenter

Part V Advanced High-Strength Steels

Studying Hydrogen Embrittlement in Nano-twinned Polycrystalline Fe-12.5Mn-1.2C Austenitic Steel 113
Mahmoud Khedr, Wei Li and Xuejun Jin

Non-metallic Inclusion and Their Effect on Fatigue Strength for Case-Hardened Carbon Steel in Gears 123
Izudin Dugic, Robin Berndt, Simon Josefsson and Martin Hedström

Influence of Austenitizing Temperature and Time on Microstructure and Mechanical Properties of an YP460 Grade Crack Arrest Steel 135
Dan Chen, Wenqing Jiang, Songsong Xu, Naimeng Liu, Hao Guo, Ye Cui, Yang Zhang and Zhongwu Zhang

The Evolution of Microstructure of an High Ni HSLA X100 Forged Steel Slab by Thermomechanical Controlled Processing 145
S. H. Mousavi Anijdan and M. Sabzi

Effects of Matrix Microstructure on the Nanoscale Precipitation and Precipitation Strengthening in an Ultra-high Strength Steel 157
Songsong Xu, Hao Guo, Yu Zhao, Naimeng Liu, Dan Chen, Ye Cui, Yang Zhang and Zhongwu Zhang

The Technology Study of Silicon Reduction of Chromite Powder in Microwave Field 165
Hua Liu, Shenghui Guo, Yu Duan, Jinhui Peng, Libo Zhang and Linqing Dai

Part VI Advanced Magnetic Materials for Energy and Power Conversion Applications

Influence of Co-doping on the Crystal Structure, Magnetocaloric Properties and Elastic Moduli of the La(Fe, Si)$_{13}$ Compound 181
Dan Huang, Ronghui Kou, Jianrong Gao, Amanda Haglund, Jiaqiang Yan, Veerle Keppens, David Mandrus and Yang Ren

Part VII Advanced Real Time Optical Imaging

Mass Transfer in High-Temperature Laser Confocal Microscopy 193
Stephano P. T. Piva, Dai Tang, Deepoo Kumar and Petrus Christiaan Pistorius

Current State Art of Hot Thermocouple Technology—Novel Way for the Study of Mold Flux High-Temperature Properties 201
Lei Zhang, Wanlin Wang and Lejun Zhou

Part VIII Algorithm Development in Materials Science and Engineering

Dislocation-Based Finite Element Modelling of Hydrogen Embrittlement in Steel Alloys 213
Amir Abdelmawla, Tarek M. Hatem and Nasr M. Ghoniem

Part IX Biodegradable Materials for Medical Applications

Comparative Study on Corrosion Behavior of WE33 in Immersion and Polarization Influenced by Heat Treatment 227
Petra Maier, Maximilian Bechly, Benjamin Hess, Marino Freese and Norbert Hort

Metal Injection Molding (MIM) of Mg-Alloys 239
M. Wolff, J. G. Schaper, M. Dahms, T. Ebel, R. Willumeit-Römer and T. Klassen

Microstructure and Mechanical Properties of Mg-Gd Alloys as Biodegradable Implant Materials 253
Yiyi Lu, Yuanding Huang, Frank Feyerabend, Regine Willumeit-Römer, Karl Urich Kainer and Norbert Hort

Study on Polylactide-Coconut Fibre for Biomedical Applications 263
O. P. Gbenebor, R. A. Atoba, E. I. Akpan, A. K. Aworinde, S. O. Adeosun and S. A. Olaleye

Visualization of Implant Failure by Synchrotron Tomography 275
Regine Willumeit-Römer, Julian Moosmann, Berit Zeller-Plumhoff, D. C. Florian Wieland, Diana Krüger, Björn Wiese, Ann Wennerberg, Niccolò Peruzzi, Silvia Galli, Felix Beckmann and Jörg U. Hammel

Part X Biological Materials Science

3D Full-Field Mechanical Measurement of a Shoulder Bone Under Implant Loading 287
Yuxiao Zhou, Michael A. Hernandez Lamberty, Gregory S. Lewis, April D. Armstrong and Jing Du

The Influence of Plastic Deformation Mechanisms on the Adhesion Behavior and Collagen Formation in Osteoblast Cells 295
B. Uzer, F. Monte, Kamal R. Awad, Pranesh B. Aswath, Venu G. Varanasi and D. Canadinç

Part XI Bulk Metallic Glasses XV

Probabilistic Modeling and Simulation of Microstructural Evolution in Zr Based Bulk Metallic Glass Matrix Composites During Solidification 305
Muhammad Musaddique Ali Rafique

Part XII Computational Design and Simulation of Materials (CDSM 2018): Atomistic Simulations

The Adhesion Force in Nano-Contact During Approaching and Retrieving Processes 313
Biao Yang and Bailin Zheng

Atomistic Simulations of Carbon Diffusion and Segregation in α-Iron Grain Boundaries 323
Mohamed Hendy, Tarek M. Hatem and Jaafar A. El-Awady

Part XIII Computational Design and Simulation of Materials (CDSM 2018): Meso/Macroscale Simulations

Microstructure Prediction for TMW-4M3 During Heat Treatment 335
Takaaki Hara, Shinichi Kobayashi, Tomonori Ueno, Nobufumi Ueshima and Katsunari Oikawa

Study on the Effect of Die Coating Thickness on the Interfacial Heat Transfer Coefficient in Squeeze Casting of Aluminum Alloy 341
Feifan Wang, Xuyang Wang, Keyan Wu and Zhiqiang Han

Part XIV Computational Design and Simulation of Materials (CDSM 2018): Computational Design of Materials

Study on the Effect of Applied Pressure on Directional Dendritic Growth by In-Situ Observation 351
Shan Shang, Keyan Wu, Leewei Kuo and Zhiqiang Han

Modeling of Solute-Dependent Fluidity and Hot Tearing Sensitivity of Conductive Aluminum Alloys 359
Hengcheng Liao, Qigui Wang, Xiaojin Suo, Zixing Feng and Qin Huang

Coupling Void Coalescence Criteria in Finite Element Models: Application to Tensile Test 369
A. Abdelkader and Ch. A. R. Saleh

Design of a New Multi-element Beta Titanium Alloy Based on d-Electron Method 377
S. Sadeghpour, S. M. Abbasi and M. Morakabati

Part XV Computational Materials Science and Engineering for Nuclear Energy

Effects of Oxygen on the Density of States and Elastic Properties of Hafnium—First Principles Calculations 389
Yang Zhang, Yajie Wen, Naimeng Liu, Hao Guo, Ye Cui, Dan Chen and Zhongwu Zhang

Morphological Study of Dispersion Phases in Heterogeneous Waste Form Materials for Efficient Nuclear Waste Containment 399
K. Patel, M. Riaz, F. Rabbi, R. Raihan and K. Reifsnider

Part XVI Computational Thermodynamics and Kinetics

Compare the Energies of Different Structures in Aluminium Electrochemical Cell 413
Mohsen Ameri Siahooei, Khirollah Mehrani and Mohammad Yousefi

Manganese Influence on Equilibrium Partition Coefficient and Phase Transformation in Peritectic Steel 419
Huabiao Chen, Mujun Long, Wenjie He, Dengfu Chen, Huamei Duan and Yunwei Huang

Mathematical Modeling on the Fluid Flow and Desulfurization During KR Hot Metal Treatment 431
Chao Fan, Alexis GoSa, Lifeng Zhang, Qingcai Liu and Dayong Chen

Part XVII Coupling Experiments and Modeling to Understand Plasticity and Failure

In-situ Characterization of Microstructural Damage in QP980 Steel 443
Diyar Salehiyan, Javad Samei and David S. Wilkinson

Part XVIII Deformation and Damage Mechanisms in High Temperature Ni, Co and Fe-Based Superalloys

Prediction of Incipient Melting Map and γ' Features of Ni-Base Superalloys Using Molecular Orbital Method 453
M. Mostafaei and S. M. Abbasi

Part XIX Dynamic Behavior of Materials VIII

Mechanical Properties and Shear Localization of High Entropy Alloy CoCrFeMnNi Prepared by Powder Metallurgy 469
Bingfeng Wang, Xiaoxia Huang, Yong Liu and Bin Liu

Effect of Phase Transformation on High Temperature Dynamic Flow Stresses of CP-Ti 481
Sindhura Gangireddy and Steven Mates

Shock-Induced Mechanical Response and Substructural Evolution of Ti–6Al–4V Alloy 489
Yu Ren, Shimeng Zhou, Zhiyong Xue and Chengwen Tan

The Use of Circumferentially Notched Tension (CNT) Specimen for Fracture Toughness Assessment of High Strength Steels 497
V. A. Popovich, T. Opraus, M. Janssen, B. Hu and A. C. Riemslag

A Low-Cost, Laboratory-Scale Method to Identify Regions of Microstructural Changes in Response to Dynamic Loading Conditions 509
Benjamin Lund and Judith Schneider

Part XX Environmentally Assisted Cracking: Theory and Practice

Environment-Induced Degradation in Maraging Steel Grade 18Ni1700 521
K. Devendranath Ramkumar, G. Gopi, Ravi Prasad Valluri, K. Sampath Kumar, Trilochana Jena and M. Nageswara Rao

Part XXI Fatigue in Materials: Fundamentals, Multiscale Modeling and Prevention

Thermal Fatigue Behavior of High Cr Roller Steel 531
G. Kugler, D. Bombač and M. Terčelj

Influence of Cold Spray on the Enhancement of Corrosion Fatigue of the AZ31B Cast Mg Alloy 541
S. K. Shaha, S. B. Dayani and H. Jahed

Part XXII Fracture: 65 Years After the Weibull Distribution and the Williams Singularity

High Temperature Cracking Damage of Calcium Aluminate Cements 553
John F. Zapata, Maryory Gomez and Henry A. Colorado

On the Experimental Evaluation of the Fracture Toughness of Shape Memory Alloys 565
Behrouz Haghgouyan, Ceylan Hayrettin, Theocharis Baxevanis, Ibrahim Karaman and Dimitris C. Lagoudas

Part XXIII Frontiers in Solidification Science and Engineering

Inoculation in Lab Scale Low Alloyed Steel Castings 577
M. Gennesson, D. Daloz, J. Zollinger, B. Rouat, J. Demurger, D. Poirier and H. Combeau

Phase-Field Modelling of Intermetallic Solidification 587
Andrew M. Mullis, Peter C. Bollada and Peter K. Jimack

Analysis of Formability of Glassy Alloys by Surface Heating Under Convective Conditions 597
Rahul Basu

Study on the Formation and Control of TiN Inclusion in Mushy Zone for High Ti Microalloyed Steel 605
Tao Liu, Dengfu Chen, Wenjie He, Mujun Long, Lintao Gui, Huamei Duan and Junsheng Cao

Part XXIV General Poster Session

Additive Manufacturing of Epoxy Resin Matrix Reinforced with Magnetic Particles 619
Jose J. Restrepo and Henry A. Colorado

Admixture Optimization in Concrete Using Superplasticizers 625
Andrea Munoz, Sergio Cifuentes and Henry A. Colorado

Influence of Cold Spray on the Microstructure and Residual Stress of Resistance Spot Welded Steel-Mg 635
S. K. Shaha, B. Marzbanrad and H. Jahed

Part XXV High Entropy Alloys VI

Development of Oxidation Resistant Refractory High Entropy Alloys for High Temperature Applications: Recent Results and Development Strategy 647
Bronislava Gorr, Franz Mueller, Hans-Juergen Christ, Hans Chen, Alexander Kauffmann, Ruth Schweiger, Dorothée Vinga Szabó and Martin Heilmaier

First-Principles Calculations of Stacking Fault Energies in Quinary High-Entropy Alloy Systems 661
A. M. Scheer, J. D. Strother and C. Z. Hargather

Synthesis of FeCrVNbMn High Entropy Alloy by Mechanical Alloying and Study of their Microstructure and Mechanical Properties 669
P. Ajay Kumar and Chandra S. Perugu

Part XXVI Integrative Materials Design III: Performance and Sustainability

Magnesium-Based Metal Matrix Nanocomposites—Processing and Properties 679
Hajo Dieringa and Norbert Hort

Part XXVII Materials and Fuels for the Current and Advanced Nuclear Reactors VII

Investigation of Tin as a Fuel Additive to Control FCCI 695
Michael T. Benson, James A. King and Robert D. Mariani

Part XXVIII Mechanical Behavior at the Nanoscale IV

Mechanical Properties of Rapidly Solidified Ni_5Ge_3 Intermetallic 705
Nafisul Haque, Robert F. Cochrane and Andrew M. Mullis

Part XXIX Mechanical Characteristics and Application Properties of Metals and Non-metals for Technology: An EPD Symposium in Honor of Donato Firrao

Production of Cu_2O Powder Using Electrodeposition Method 715
Shadia J. Ikhmayies

Alumina Feeding System Changes in Aluminum Electrochemical Cell with D18 Technology for Energy Efficiency (Case Study: Almahdi-Hormozal Aluminum Smelter) 721
Mohsen Ameri Siahooei, Alireza Samimi and Borzu Baharvand

Hot Ductility of X70 Pipeline Steel in Continuous Casting 729
Wenxiang Jiang, Mujun Long, Dengfu Chen, Huamei Duan, Wenjie He, Sheng Yu, Yunwei Huang and Junsheng Cao

Ductile Fracture Assessment of 304L Stainless Steel Using 3D X-ray Computed Tomography 737
A. J. Cooper, O. G. C. Tuck, T. L. Burnett and A. H. Sherry

Thermo-Calc of the Phase Diagrams of the Nb-N System 755
Shadia J. Ikhmayies

Part XXX Multi-material Additive Manufacturing: Processing and Materials Design

Development of Novel Squeeze Cast High Tensile Strength Al–Si–Cu–Ni–Sr Alloys 763
Li Fang, Luyang Ren, Xinyu Geng, Henry Hu, Xieyuan Nie and Jimi Tjong

Part XXXI Nanocomposites V: Structure-Property Relationships in Nanostructured Materials

Carbon Nanocomposite for Reliable Seal Applications in High-Temperature, High-Pressure, Corrosive Environments 777
Lei Zhao and Zhiyue Xu

The Dielectric Behavior in Reduced Graphene Oxide/Polymer Composites with a Segregated Structure 787
Yonghua Li and Mengkai Li

Part XXXII Phase Transformations and Microstructural Evolution

Solid State Phase Transformation Mechanism in High Carbon Steel Under Compressive Load and with Varying Cr Percent 797
Rumana Hossain, Farshid Pahlevani and Veena Sahajwalla

Microstructure Characterization of Aged Heat Resistant Steels 803
Maribel L. Saucedo-Muñoz, Arturo Ortiz-Mariscal, Victor M. Lopez-Hirata, Jose D. Villegas-Cardenas and Ana Maria Paniagua-Mercado

Sublimation and Self Freezing of Planar Surfaces in Rarefied Atmospheres 811
Rahul Basu

Effect of Precipitation on Creep Properties of Ferritic Steels 821
Maribel L. Saucedo-Muñoz, Arturo Ortiz-Mariscal, Shi-Ichi Komazaki and Victor M. Lopez-Hirata

Microstructural Evolution of a New Beta Titanium Alloy During the Beta Annealing, Slow Cooling and Aging Process 829
S. Sadeghpour, S. M. Abbasi and M. Morakabati

Part XXXIII Powder Metallurgy of Light, Reactive and Other Non-ferrous Metals

A Review of the Preparation Methods of WC Powders 841
Yijie Wu, Jie Dang, Zepeng Lv, Shengfu Zhang, Xuewei Lv and Chenguang Bai

Influence of Hot Rolling on Mechanical Behavior and Strengthening Mechanism in Boron Carbide Reinforced Aluminum Matrix Composites 851
Hao Guo, JianNeng Zhang, Yang Zhang, Ye Cui, Dan Chen, Yu Zhao, SongSong Xu, NaiMeng Liu and ZhongWu Zhang

Preparation of Titanium Foams with Uniform and Fine Pore Characteristics Through Powder Metallurgy Route Using Urea Particles as Space Holder 861
Qiu Guibao, Lu Tengfei, Wang Jian and Bai Chenguang

Leaching Characteristics of Non Ferrous Metals Recovery from Korean Municipal Solid Waste Incineration Bottom Ash Samples 869
T. Thriveni, Ch. Ramakrishna and Ahn Ji Whan

Part XXXIV Surface Engineering for Improved Corrosion Resistance

Anti-corrosion Properties of Rosemary Oil and Vanillin on Low Carbon Steel in Dilute Acid Solutions 883
Roland Tolulope Loto, Cleophas Akintoye Loto, Bryan Ayozie and Tayo Sanni

Stainless Steel Corrosion Resistance in 0.5 M H_2SO_4 Using *Cassia fistula* Extract 891
Olugbenga Adeshola Omotosho, Joshua Olusegun Okeniyi, Cleophas Akintoye Loto, Abimbola Patricia Popoola, Sunday Adeniran Afolalu, Emmanuel Obi, Oluwatobi Sonoiki, Timi Oshin and Adebanji Ogbiye

Synergistic Effect of Benzonitrile and Benzothiazole on the Corrosion Inhibition of 316 Stainless Steel in 6M HCl Solution 901
Roland Tolulope Loto, Cleophas Akintoye Loto, Alexander McPepple, Gabriel Olanrewaju and Akanji Olaitan

Corrosion Resistance of Aluminium in 0.5 M H_2SO_4 in the Presence of *Cassia fistula* Extract 909
Olugbenga Adeshola Omotosho, Joshua Olusegun Okeniyi, Cleophas Akintoye Loto, Abimbola Patricia Popoola, Adeoluwa Oni, Ayomide Alabi and Abisola Olarewaju

Part XXXV Surface Interactions in Materials

Pt Decorating Effect on CNT Surface Towards Adsorption of SF_6 Decomposed Components 921
Hao Cui, Xiaoxing Zhang, Dachang Chen, Jiani Fang and Ju Tang

Part XXXVI Thermo-Mechanical Response of Materials with Special Emphasis on In-situ Techniques

"In Situ" Measurement of Electrical Resistivity, Dilatometry and Thermal Analysis of Cast Iron 931
Primož Mrvar and Mitja Petrič

Part XXXVII Ultrafine-Grained Materials X

Mechanical Properties of Ultrafine Grain 2519 Aluminum Alloy 943
Gbadebo Owolabi, Temitayo Daramola, Nadir Yilmaz, Horace Whitworth and Ahmet Zeytinchi

Author Index 951

Subject Index 955

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) mm^3 mild steel samples were cut, cleaned with dilute H_2SO_4 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 H_3BO_3 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 automative 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 × 10 × 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 1litre 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 supernant 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

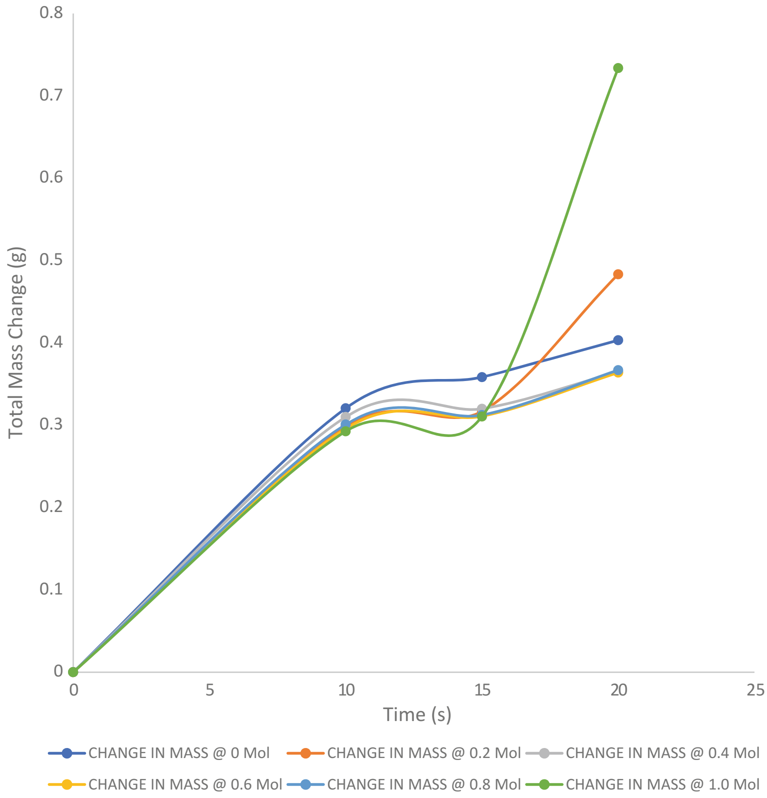

Fig. 1 A graph of the change in mass against deposition time for 0, 0.2, 0.4, 0.6, 0.8 and 1.0 M additive concentration

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.

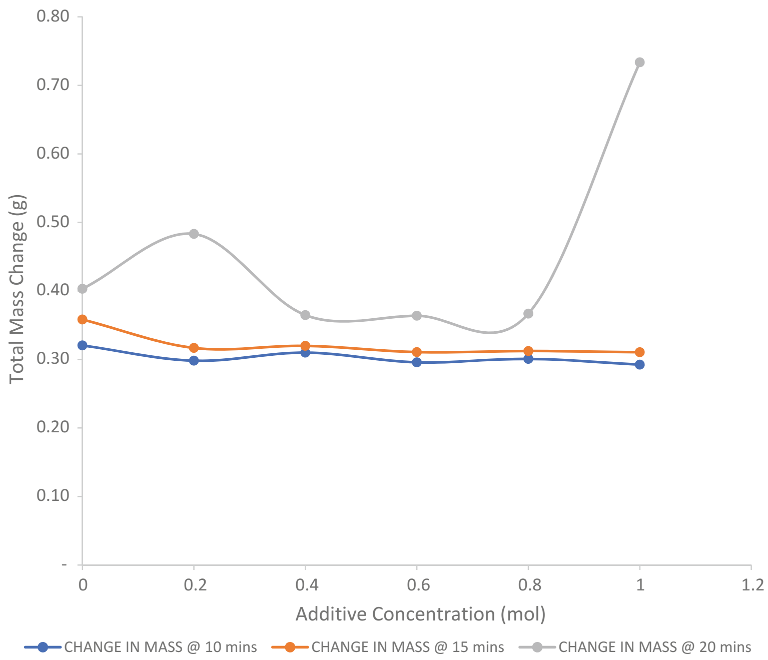

Fig. 2 A graph of the change in mass against the additive concentration at different electrodeposition time

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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