DEVELOPMENT OF NANOCRYSTALLINE COMPOSITE COATINGS FOR MARINE APPLICATION

ABIOYE, OLUWABUNMI PAMILERIN

(17PCM01600)

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By

ABIOYE, OLUWABUNMI PAMILERIN

(17PCM01600)

B.Sc, Metallurgical and Materials Engineering, Obafemi Awolowo University, Ile Ife.

M.Sc, Materials Science and Engineering, Obafemi Awolowo University, Ile Ife.

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D) IN MECHANICAL ENGINEERING, IN THE DEPARTMENT OF MECHANICAL ENGINEERING, COLLEGE OF ENGINEERING, COVENANT UNIVERSITY, OTA.

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LIST OF PLATES

LIST OF ABBREVIATIONS

AFM:	Atomic Force Microscope
AP:	Anodic Protection
ASTM:	American Society for Testing and Materials
CP:	Cathodic Protection
CR:	Corrosion Rate
DP:	Deposition process
Ecorr:	Corrosion Potential
EDS:	Energy Dispersion Spectrometry
Eprot:	Protection Potential
HVN:	Vickers Microhardness Number
Icorr:	Corrosion Current Density
IGC:	Intergranular Corrosion
IGSCC:	Intergranular Stress Corrosion Cracking
OCP:	Open Circuit Potential
OPM:	Optical Microscopy
Rp:	Polarisation Resistance
rpm:	Revolution per Minute
SCC:	Stress Corrosion Cracking
SEM:	Scanning Electron Microscopy
XRD:	X-ray Diffraction

ABSTRACT

Failure of engineering components in service, especially in marine applications, has recently been a major global concern, and corrosion resulting from biofouling has been the primary source of these failures. Ultimately, biofouling and corrosion are detrimental to the lifespan of parts in service. Thus, there is a need to develop protective coatings which are highly resistant to the biofouling-corrosion system. This study developed affordable, eco-friendly and durable bi-phase of Zn-ZnO and nanocrystalline particulates of *Arachis hypogaea* (Groundnut) husks (H) and *Micropogonias undulatus* (Croaker Fish) scales (S) through electrolytic deposition technique; and determined the influence of process variables on the properties of the deposited coatings. Box-Behnken Design from the Minitab 17 Design of Experiment was used to analyse and model the effects of the deposition parameters and process runs on the performance properties. The coatings were characterised through Dura scan diamond-based Vickers hardness tester for microhardness properties, Potentiostat Galvanostat (PGStat 101) for corrosion properties, Optical Microscope and Scanning Electron Microscope equipped with Energy Dispersive Spectrometer (SEM/EDS) for structural characterisation. For a deeper perception of the structural morphology, Atomic Force Micrograph (AFM) was used to obtain the surface topography and undulation. X-ray diffraction was used to examine the intermetallic bi-phase existing within the interface. From the results, the crystalline structures of the deposited coated samples were made up of duplex grains of crystals and lamellar noodles at Zn-15ZnO-20H coating series. The microstructures developed at Zn-15ZnO-20S showed the formation of colonies of the homogenous equiaxed pattern at the interface situating the stability and an indication of a preferred coating. The microhardness Vickers analysis revealed the same trends based on the process variable. The x-ray diffraction study exposed the presence of a single intermetallic ZnSi, ZnAlSi, ZnSiO phases in the Zn-15ZnO-20H coatings. On the other hand, the x-ray diffraction of Zn-15ZnO-20S gave a bi and tri-phase intermetallic pattern of Zn_3Ca_2O, $Zn_4Ca_2Mg_2$, and Zn_2MgO_2 at distinctive intensity micro-stable coatings. The electrochemical corrosion test of the samples exposed to a biofouling simulated solution revealed excellent durability and biofouling-corrosion polarisation resistance. The improvement in the surface properties generally had positive impacts on the developed coatings' performance. The outcome indicated that coating with Zn-15ZnO-20S compared with Zn-15ZnO-20H and Zn-15ZnO formations performed best under the biofouling-corrosion system. This study showed improved efficiency and lifespan of components and parts made of mild steel in a simulated marine environment. Thin-film application of Zn-15ZnO-20S composite is thus recommended for enhancing the performance of mild steel for marine applications.

Keywords: Corrosion, Biofouling, Electrodeposition, Mild Steel, Composite coatings.

ACCEPTANCE

This is to attest that this thesis is accepted in partial fulfilment of the Doctor of Philosophy (Ph.D) requirements in Mechanical Engineering in the Department of Mechanical Engineering, College of Engineering, Covenant University Ota.

Mr. John A. Philip …….

Secretary, School of Postgraduate Studies Signature and Date

Prof. Akan B. Williams …….

Dean, School of Postgraduate Studies Signature and Date

DECLARATION

I, **ABIOYE, OLUWABUNMI PAMILERIN (17PCM01600)**, declare that this research was carried out by me under the supervision of Dr. Ojo S. Fayomi and Prof. Roland T. Loto, of the Department of Mechanical Engineering, College of Engineering, Covenant University. I attest that the thesis has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data and scholarly information used in this thesis have been duly acknowledged.

ABIOYE, OLUWABUNMI PAMILERIN .....

Signature and Date

CERTIFICATION

We certify that this thesis titled **"Development of Nanocrystalline Composite Coatings for Marine Application"** is an original work carried out by **ABIOYE, OLUWABUNMI PAMILERIN (17PCM01600)** in the Department of Mechanical Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria, under the supervision of Dr. Ojo S. Fayomi and Prof. Roland T. Loto. We have examined and found this work acceptable as part of the requirements for the award of Doctor of Philosophy (Ph.D) in Mechanical Engineering.

Dr. Ojo S. Fayomi	…….
(Supervisor)	Signature and Date
Prof. Roland T. Loto	…….
(Co-Supervisor)	Signature and Date
Prof. Joshua O. Okeniyi	…….
(Head of Department)	Signature and Date
Prof. Joseph A. Omotoyinbo	…….
(External Examiner)	Signature and Date
Prof. Akan B. Williams	……
(Dean, School of Postgraduate Studies)	Signature and Date

DEDICATION

This project work is dedicated to the **God Almighty**, who has been my help in the ages past and my hope for years to come, for giving me good health, strength and resources to bring this work to reality.

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