ELECTRODEPOSITION OF NICKEL ALUMINIDE BASED ALLOY ON FE SUBSTRATE IN DEEP EUTECTIC SOLVENT

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons).

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

……..

(Dr. Muhammad Zaimi bin Zainal Abidin)

ABSTRAK

Penyiasatan penggunaan pelarut eutektik sebagai elektrolit dalam elektrodeposi Nickel Aluminide dijalankan dalam kajian ini kerana fabrikasi aloi binari dalam pelarut eutektik belum dieksplorasi dengan sepenuhnya. Tujuan kajian ini adalah untuk menghasilkan lapisan aloi berasaskan Nickel Aluminide pada substrat Fe dengan elektrodeposisi serta menggunakan pelarut eutektik sebagai elektrolit. Mula-mulanya, substrat Fe digilap sehingga permukaan mirip cermin. Seterusnya, substrat masing-masing degreased, dibilas menggunakan etanol dan air suling. Kemudian, substrat akan dipasang dengan resin epoksi. Akhirnya, sampel elektrodeposited dengan ketumpatan arus 0.001, 0.002, 0.004, 0.005, dan 0.01 A/dm^2, SERTA masa penyaduran dari 15, 30 dan 45 minit. Mandi plating terdiri daripada campuran Nikel (Ⅱ) Klorida dan Aluminium (Ⅲ) Klorida bercampur homogen dengan larutan ChCl: EG akan dihasilkan. Pengimbasan mikroskop elektron (SEM) dan X-ray difraksi (XRD) digunakan untuk menentukan morfologi permukaan dan komposisi elemen sampel bersalut. Kemudian, pengukuran elektrokimia dilakukan dalam 3.5% berat natrium klorida untuk mengkaji sifat kakisan aloi bersalut. Akhirnya, ujian kekerasan dan kekasaran permukaan sampel bersalut masing-masing dapat ditentukan dengan penguji mikro Vickers hardness dan profilometer.

ABSTRACT

The investigation of the use of deep eutectic solvent as the electrolyte in the electrodeposition of Nickel Aluminide is conducted in this study due to the fabrication of binary alloy in deep eutectic solvent has not been fully explored. The aim of this study is to produce a coating of Nickel Aluminide based alloy on Fe substrate using deep eutectic solvent as electrolyte by electrodeposition. Fe substrate is first polished until a mirror-like surface. Next, the substrate degreased, rinsed using the ethanol and distilled water respectively. Then, the substrate were mounted by epoxy resin. Finally, the sample was electrodeposited with current density of 0.001, 0.002, 0.004, 0.005, 0.01 A/dm^2, and plating time from 15, 30 and 45 minutes. The plating bath consists of Nickel (Ⅱ) Chloride and Aluminium (Ⅲ) Chloride were mixed homogenously with the ChCl:EG solution. Scanning electron microscope (SEM) and X-ray diffraction (XRD) were used to determine the surface morphology and the elemental composition of the coated samples. Then, electrochemical measurements were done in 3.5 wt.% of sodium chloride to study the corrosion behaviour of the coated alloy. Lastly, hardness test and surface roughness of the coated samples were determined by micro Vickers hardness tester and profilometer respectively.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Appreciated friends

Honourable supervisor and lecturers

For giving me moral support, cooperation and encouragements.

Thank you.

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LIST OF ABBREVIATIONS

Cr	-	Chromium
Mo	-	Molybdenum
Zr	-	Zirconium
B	-	Boron
C	-	Carbon
Ti	-	Titanium
W	-	Tungsten
Si	-	Silicon
Ni	-	Nickel
Zn	-	Zinc
Co	-	Cobalt
Ag	-	Silver
Al	-	Aluminium
Fe	-	Iron
AgCl	-	Silver Chloride
KCl	-	Potassium Chloride
HCl	-	Hydrochloric acid
ChCl	-	Choline Chloride
NaCl	-	Sodium Chloride
H_2	-	Hydrogen gas
Ni_3Al	-	Nickel Aluminide
Al_2O_3	-	Aluminium Oxide
TiO_2	-	Titanium Oxide
$AlCl_3$	-	Aluminium (Ⅲ) Chloride
$NiCl_2$	-	Nickel (Ⅱ) Chloride
SEM	-	Scanning Electron Microscopy
XRD	-	X-ray Diffraction
PVD	-	Physical Vapour Deposition
CVD	-	Chemical Vapour Deposition

HVOF	-	High-velocity Oxy Fuel
DES	-	Deep eutectic solvent
EG	-	Ethylene Glycol
EMIM	-	1-ethyl-3-methylimiazolium chloride
FCC	-	Face centered cubic
R	-	Reducing agent
Me	-	Metal to be deposited
WE	-	Working electrode
CE	-	Counter electrode
RE	-	Reference electrode
E_{ocp}	-	Open-circuit potential
I_{corr}	-	Corrosion current density
E_{corr}	-	Corrosion potential

LIST OF SYMBOLS

%	-	Percentage
Mm	-	Micrometre
A	-	Area
A	-	Current
cm	-	Centermetre
d	-	Density
GPa	-	Giga Pascal
HV	-	Hardness Vicker
K	-	Kelvin
M	-	Mol
Mm	-	Millimetre
Mpy	-	milli-inches per year
N	-	Newton
Nm	-	Nanometre
℃	-	Degree Celcius
S	-	Second
V	-	Volts
wt.%	-	Weight Percentage
Θ	-	Theta
Q	-	charged passed
I	-	current passed
t	-	the time the current is passed
z	-	change in oxidation state
m	-	mass for oxidized/reduced species
M	-	molar mass for oxidized/reduced species
F	-	faraday constant
n	-	amount of substance oxidized or reduced

CHAPTER 1

INTRODUCTION

A coating refers to a masking which can be applied onto the surface of certain object. Practically, the purpose of the coating is to provide protection, improve wear resistance, improve corrosion resistant property and improve appearance of an object. Coating processes can be classified into 7 main category namely, electrochemical technique, vapour deposition, galvanizing, powder coating, diffusion coating, conversion coating and thermal spraying. The study focused on one of the technique under the 'Electrochemical Techniques' called, electrodeposition. The study of electroplating metallic alloys and metals has been practiced for about a century and the prior endeavours are all well recorded. Electrodeposition was used to prepare metallic mirrors and create corrosion resistant surface on certain objects in the past. The exploration of electrodeposition tracked back to Michael Faraday and his laws of electrolysis. The principle law expressed that the total quantity of chemical change generated by an electrical current is always proportional total amount of charge passing through the electrolyte.

1.1 Background Of Study

Electrodeposition referred to a process whereby a layer of metal is deposited or coated on another electrode by electrolysis. This process can be achieved by an electrolytic cell, which involves passing electric current through a solution called electrolyte. In electrodeposition, the cathode which is the piece to be plated is connected to the negative terminal whereas the anode is connected to the positive terminal. Both electrodes are immersed in an electrolyte, which is a solution consisting a salt of the same metal as the anode. An example of copper plating onto brass will be discussed to clarify the basic

mechanism of electrodeposition. The brass electrode (substrate to be plated) connected to the negative terminal is referred as cathode whereas the copper electrode connected to the positive terminal is called anode. The electrolyte chosen has to be a solution of a salt of the same metal as the anode, thus the electrolyte used in this example is copper sulphate solution. Both anode and cathode will be dipped into the copper sulphate solution after connected to the positive and negative terminal of the battery. When electric field is applied, the positively charged copper ions will be drawn to the negatively charged brass electrode and accumulate on its surface, slowly forming a thin layer of copper plate on the bass substrate.

In this study, Nickel Aluminide based alloy is used to coat on Fe substrate. Nickel Aluminide (NiAl) is known as an intermetallic alloy made up of aluminium and nickel which exhibits similar properties to both ceramic and metal. Nevertheless, intermetallic based alloys exhibit several specific features such as, high melting point, high temperature strength, but low ductility compare to those conventional metals and alloys. All these properties resulted intermetallic compounds possesses similar properties like ceramics but different from ceramics by having good thermal and electric conductivity.

1.2 Problem Statement

Nickel aluminide based alloys are known to have high tensile and compression strength, high corrosion resistance in atmospheres that are rich with oxygen and carbon, high corrosion resistance towards sodium chloride, acid and base solution as well as excellent high temperature wear resistance. Conventional electrodeposition method uses water as a solvent for cation and anion movement. Nickel deposition can be done easily in aqueous bath, but deposition of Aluminium is hard to conduct because Aluminium ions form oxides on the surface of the substrate when react with water. Unlike the nature of electrolytes used for plating processes which poses certain limitations such as, hydrogen evolution in specific conditions, reactive towards specific metals and narrow potential window, deep eutectic solvent possesses extensive potential windows and better chemical inertness. Also, current Nickel Aluminide based alloy coating is fabricated using other coating method like thermal spraying and CVD which consume a lot of energy, time and cost. Therefore, the deposition of Nickel Aluminide in deep eutectic solvent is less known and requires further investigation regarding plating bath composition, plating parameter and its coating various properties.

Nevertheless, the study on electrodeposition of Nickel aluminide based alloys on Fe substrate is carried out due to several reasons mainly due to the limitations of iron substrate namely highly reactive, corrodes rapidly in moist air and elevated temperature. Besides, the surface roughness, surface morphological properties, composition and hardness after the coating of nickel aluminide based alloys on iron substrate is analysed as well.

1.3 Objectives

The objectives of this study are as per below:

1. To coat Nickel Aluminide based alloy on Fe substrate.
2. To study the surface morphology, composition of Ni-Al based alloy coating on Fe substrate.
3. To investigate the mechanical properties of Ni-Al based alloy coating on Fe substrate.
4. To examine the effect of corrosion behaviour of Ni-Al based alloy coating on Fe substrate.

1.4 Scope

The focus of this study is the electrodeposition of Nickel Aluminide based alloy coating on Fe substrate in deep eutectic solvent. Also, the electrolyte used in this study is deep eutectic solvent instead of aqueous based solvent. Deep eutectic solvent provides the medium without the presence of hydroxide that will oxidize Al surface. The electrodeposition of Ni_3Al based alloy coating on Fe substrate in deep eutectic solvent using variant current density, bath temperature and plating time are studied. The current density used in this study are 0.001, 0.002, 0.004, 0.005 and 0.01 A/dm^2, whereas the plating time will ranged from 15, 30 and 45 minutes. After the electrodeposition process is completed, surface morphology and composition of Ni_3Al based alloy coating on Fe substrate are investigated using Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD) analysis for phase identification. The hardness of Ni_3Al based alloy coating on Fe substrate

is determined by using Micro Vickers Hardness Tester and the surface roughness of Ni-Al based alloy coating on Fe substrate is analysed by profilometer. Lastly, the corrosion behaviour in is investigated using electrochemical measurements.

CHAPTER 2
LITERATURE REVIEW

2.1 Coating

A coating is a layer of covering spread over the surface of a substance, normally referred as substrate. The coating can be defined as a layer of material, deposited naturally or synthetically on the surface of a substrate made of another material, in order to obtain desired decorative or technical properties (Burakowski and Wierzchon, 1999). A material sometimes might fail to possess certain specifications or requirements, hence this is where coating plays a significant role. For instance, a rougher surface might needed to be flattened or polished for lower frictional resistance, whereas a smoother surface might need harder surface to strengthen the wear resistance of the substance. Also, an unappealing object might have to aesthetically enhanced to be improved in decorative intention (Audigié *et al*., 2018). In short, coating are mostly conducted for decorative or functional purposes. Depending on the demand of applications, surface coatings able to either improve the aesthetic appearance, surface roughness, corrosion resistance, frictional resistance and also wear resistance of a material. There are several coating processes exist which can be categorized into 7 categories namely vapour depositions, galvanizing, powder coatings, diffusion coatings, conversion coatings, thermal spraying and electrochemical techniques. Each technique has its own limitations and advantages. A suitable coating method can be selected based on the required specifications or applications.

2.2 Types Of Coating Techniques

2.2.1 Vapour depositions

Vapour deposition is a coating process whereby the materials in its vapour state are condensed either through conversion, condensation or chemical reaction to develop a solid material. Vapour depositions normally conducted in a vacuum chamber. The purpose of vapour depositions are applied to develop coatings in order to modify the electrical, optical, thermal, mechanical properties as well as enhancing wear and corrosion resistance of the substrate (Audigié *et al*.,2018). Vapour deposition process can be classified into Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD).

2.2.1.1 physical vapour deposition

In Physical Vapour Deposition, materials needed to be deposited are converted into vapour form, and then condensed onto the substrates' surface. Thickness of the coating formed will ranged from 0-20mm. The desired material is atomized and ionized in 2 different ways. It is either through physical evaporation or plasma sputtering. In physical evaporation, material is heated in high vacuum to develop a high vapour pressure which is adequate for the condensation to take place on the substrate, whereas in plasma sputtering involves the bombardment of the material surface (Kumar *et al*., 2015). In this technique, cathode will be the coating material and an inert gas.

2.2.1.2 chemical vapour deposition

Chemical Vapour Deposition is one of the coating process whereby the deposits are formed due to the reaction between the hot substrate and its atmosphere containing gases or vapour of the coating material. The substrate is heated to temperature above 850° C (Audigié *et al*., 2018). CVD are normally chosen to obtain hard coatings.