ELECTRODEPOSITION OF BINARY NICKEL-CHROMIUM (Ni-Cr) ALLOY ON ALUMINIUM 1000 SERIES SUBSTRATE IN ORGANIC SOLVENT

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

By

SII HEE HING

B051410093

931214-13-6567

FACULTY OF MANUFACTURING ENGINEERING

Year 2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **ELECTRODEPOSITION OF BINARY NICKEL-CHROMIUM (Ni-Cr) ALLOY ON ALUMINIUM 1000 SERIES SUBSTRATE IN ORGANIC SOLVENT.**

Sesi Pengajian: **2017/2018 Semester 2**

Saya **SII HEE HING (931214-13-6567)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:
2A, Jalan Punai, 96000 Sibu,
Sarawak

Cop Rasmi:

Tarikh: 1st July 2018

Tarikh: ______________________

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitle "Electrodeposition of Binary Nickel-Chromium (Ni-Cr) Alloy on Aluminium 1000 Series Substrate in Organic Solvent" is the result of my own research except as cited in references.

Signature : ………………………………………….
Author's Name : SII HEE HING
Date : 6 June 2018

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory are as follow.

…………………………………………

(Dr. Muhammad Zaimi bin Zainal Abidin)

ABSTRAK

Penyiasatan mengenai penggunaan pelarut organik dalam tembaga kromium telah dipelajari secara komprehensif. Walau bagaimanapun, etilena glikol masih belum diterokai sepenuhnya untuk menghasilkan bersama aloi binari. Tujuan utama kajian ini dilaksanakan adalah untuk menghasilkan lapisan aloi kuprum biner Ni-Cr pada substrat siri aluminium 1000 melalui kaedah elektrodeposisi dalam etilina glikol. Siri aluminium 1000 digunakan sebagai substrat dan substrat ini digilap sehingga permukaannya berupa seperti cermin. Substrat kemudiannya degenerasi, dibilas dan dipasang dengan menggunakan etanol, air suling dan resin epoksi. Akhirnya, sampel yang bercampur homogen dengan etilena glikol telah elektrodeposit menggunakan ketumpatan arus 125, 250, and 500 mA/dm^2 dalam penyaduran bersama nikel klorida dan kromium klorida. Pengimbasan mikroskop elektron, XRF dan XRD digunakan untuk menentukan morfologi permukaan dan komposisi elemen masing-masing. Selain itu, pengukuran elektrokimia dilakukan dalam 3.5 wt % natrium klorida untuk mengkaji sifat kakisan aloi bersalut. Selain itu, parameter salutan terbaiki Ni-Cr ialah 250 mA/dm^2 dan dengan kepekatan 0.01M ion Cr (III). Ciri-ciri mekanikal tertinggi aloi bersalut dilakukan dengan menggunakan ujian kekerasan (70HV), dan ujian kekasaran permukaan (0.33µm) oleh ujian kekerasan mikro Vickers dan profilometer masing-masing.

ABSTRACT

The investigation regarding the use of organic Solvents solution in Nickel Chromium has been studied comprehensively. However, to produce a binary alloy with the ethylene glycol has not yet fully explored. The main purpose of this study is to produce coating of binary nickel alloy of Ni-Cr on the aluminium 1000 series substrate using the electrodeposition method in the organic solvent solution. The aluminium 1000 series was used as the substrate and the substrate is polished until the mirror-like surface. The substrate is then degreased, rinsed and mounted using the ethanol, distilled water and epoxy resin respectively. Finally, the sample is electrodeposited using the different current density of 125, 250 and 500 mA/dm^2. The plating bath with nickel chloride and chromium chloride which are mixed homogenously with the ethylene glycol solution. Scanning electron microscope, X-ray Fluorescence and X-ray diffraction were used to determine the surface morphology and the elemental composition respectively. Moreover, the electrochemical measurements were done in the 3.5 wt.% of sodium chloride to study the corrosion behaviour of the coated alloy. Additionally, the best parameter of plating Ni-Cr is 250 mA/dm^2 and with the 0.01M concentration of Cr (III) ions. This is because with this parameter, the highest mechanical properties (70HV) and (0.33μm) of the coated alloy are done using the hardness test, and the surface roughness test by the micro Vickers hardness test and profilometer respectively.

DEDICATION

I would like to dedicate this work to my.

Beloved parents and family.

Honourable supervisor and lecturers.

Supportive friends.

ACKNOWLEFGEMENT

In performing this Final Year Project, I had receive the help and guideline from some respected persons, who deserve my greatest gratitude. I would like to express the deep gratitude to Dr. Muhammad Zaimi bin Zainal Abidin, my respected supervisors, for his great mentoring, patient guidance, enthusiastic, encouragement and useful critiques throughout this project. His willingness to give his time so generously has been very much appreciated.

In addition, I also grateful to Dr. Mohd Shukor Bin Salleh, coordinator of this Final Year Project. Thankful and indebted to him for sharing expertise, and sincere and valuable guidance and encouragement extended to us. Besides, I would like to give a special thanks to Hairulhisham bin Rosnan, lab assistant of material lab, for his guidance on using all the facility of grinding machine, optical microscope, micro Vickers hardness testing machine and XRD.

Finally, I would like to thanks to my housemate, course mates and everybody who was important to this FYP report. Thanks to all the people for their directly and indirectly help for me to complete my project as well as expressing my apology that I could not mention personally to each of you.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATION AND NOMENCLATURES

Al	-	Aluminium
Al_2O_3	-	Aluminium (III) oxide
$BaSO_4$	-	Barium sulphate
CBD	-	Chemical Bath Deposition
Cd	-	Cadmium
CE	-	Counter Electrode
Co-Cr	-	Cobalt Chromium
Cr	-	Chromium
$CrCl_3.6H_2O$	-	Chromium (III) Chloride hexahydrate
Cu^{2+}	-	Copper (II) ion
CVD	-	Chemical Vapour Deposition
DES	-	Deep Eutectic Solution
DMF	-	dimethylformamide
E_{corr}	-	Corrosion Potential
EDX	-	Energy Dispersive X-Ray
EG	-	Ethylene Glycol
EG	-	Ethylene Glycol
Fe-Cr	-	Iron chromium
H^+	-	Hydrogen ion
H_2.	-	Hydrogen gas
HCl	-	Hydrochloric acid
I_{corr}	-	Corrosion Current
$LiFePO_4$	-	lithium iron phosphate battery
LSV	-	Linear Scanning Voltammetry
N_2	-	Nitrogen gas
$NiCl_2.6H_2O$		Nickel (II) chloride hexahydrate
Ni-Cr	-	Nickel Chromium
Ni-Cr-C	-	Nickel Chromium Carbon
$PbCO_3$	-	Lead Carbonate

PEG	-	polyethylene glycol
PVD	-	Physical Vapour Deposition
Ra	-	Surface roughness
RE	-	Reference Electrode
SEM	-	Scanning Electron Microscopy
TEM	-	Transmission Electron Microscopy
$TiCl_4$	-	Titanium tetrachloride
TiN	-	Titanium Nitride
WE	-	Woking Electrode
XRD	-	X-ray Diffraction
XRF	-	X-ray Fluorescent
Zn	-	Zinc
$ZnCrO_4$	-	Zinc Chromate

LIST OF SYMBOLS

%	-	Percentage
μm	-	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
^{o}C	-	Degree Celcius
^{o}F	-	Degree Fehrenheit
s	-	Second
V	-	Volts
Wt.%	-	Weight Percentage
θ	-	Theta

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Aluminium alloys are widely utilized in engineering application especially in the aerospace, marine, automation and home appliance because of their outstanding light weight and high corrosion resistance. The addition of coating on the surface of the aluminium alloy has improves the mechanical and the physical properties of aluminium

Coating is a method used to improve the corrosion resistance and extend the material used of limitation to maximum of the material performance capabilities. Coating can improve both mechanical and physical properties of the substrate material. Coating also can be retained while protecting the substrate against wear and corrosion by a coated layer. The coating method can be divided into dry and wet process. The example of the dry coating methods are introduced such as physical vapour deposition (PVD), chemical vapour deposition (CVD). The example for the wet coating method are introduced such as electrodeposition, electroless deposition, painting, spraying and chemical conversion.

Electrodeposition is referred to use electric or current to coat the surface substrate with a thin and even a layer of another metal. Electrodeposition oxidised metal into cation at anode in the chemical bath then the mobile cation is reduced at cathode to form a metal which is the formation of the coating metal. An example of copper electroplating in acid aqueous solution. At anode the copper metal dissolves form anode by releasing 2 electron to form Cu^{2+} ions. At the cathode, Cu^{2+} ions are discharged by accepting 2 electrons to form copper alloy and is deposited on the surface of the substrate. This result the effective transfer of the copper sources form anode source to plate the surface of the cathode. However, the binary alloy like Ni-Cr is difficult electrodeposit on substrate in the water due to the potential different is not same. Besides, the electrodeposit of electronegative metal like chromium (Cr), zinc (Zn) and cadmium (Cd) is hard to deposit in aqueous solution because of the oxidation is occurred in between the electronegative metal and water to form metal oxide.

By using the organic solvent as electrolyte, these binary alloy and electronegative material can be electrodeposit on the substrate. Using the Organic solvents as the electrolyte have the properties like high conductive, and high solubility of metal salts. Organic solvent also will not produce the secondary reaction like the water electrolysis as compare to the non- aqueous or orga90nic solvent (A. P. Abbott *et al*., 2015)

Co-Cr are successfully electrodeposited in the organic solvent based electrolytes which make up of EG. (Saravanan & Mohan, 2012). Besides the Co-Cr alloy, electrodeposition of Ni-Zn alloy in the organic solvent based bath also has been done by the Koura *et al*,. (Koura *et al*., 2007). However the electrodeposition of the Ni-Cr alloy in the organic solvent based bath is still less documented.

In this study, Ni-Cr alloy is produced using electrodeposition in solvent by adding the Ni (II) and Cr (III) salts in EG based Organic solvent bath. The aluminium Al 1000 series substrate is being used. The corrosion behaviour of the coating in 3.5 wt.% NaCl aqueous solution are studied. The surface morphology is studied using the X-ray Diffraction (XRD), Scanning Electron Microscope (SEM) and X-ray Fluorescence (XRF) for the elemental composition. The coating's surface hardness also ben measured using micro Vickers Hardness tester. The surface roughness of coated alloy is analysed using profilometer.

1.2 Problem Statement.

Ni-Cr alloy are strength, ductility, resistance to oxidation, stability at high temperatures, and resistance to the flow of electrons, nichrome is widely used in electric heating elements due to it is having high electrical resistance to produce heat. Most of the Ni-Cr alloys are used in applications such as hair dryers and heat guns. Typically, nichrome is wound in coils to a certain electrical resistance, and when current is passed through it the Joule heating produces heat. Conventionally Ni-Cr was processed through powder methodology. Based on the powder methodology processing the superalloy Ni-Cr was designed with the aid of the thermodynamic calculation results and d-electron theory. However, the study of electrodeposition of Ni-Cr alloy on Al 1000 series substrate in the ethylene glycol is still less known. The properties of the Ni-Cr alloy coating on Al 1000 series is then analysed to investigate its corrosion behaviour in 3.5 wt% NaCl aqueous solution, surface morphological properties, composition and hardness are studies using SEM, XRF, XRD and micro Vickers hardness test respectively. The surface roughness of coated alloy is analysed using profilometer.

1.3 Objective

The objectives of this study are as per below:

1. To study the surface morphology, and the composition of Ni-Cr alloy coating.

2. To investigate the mechanical properties of Ni-Cr alloy coating.

3. To examine the effect of corrosion properties of Ni-Cr alloy coating.

1.4 Scope

The focus of this study is aimed to the electroplating of the Ni-Cr alloy on Al 1000 series substrate in organic solvent. The electrodeposition of Ni-Cr alloy using variant current density and concentration of $CrCl_3.6H_2O$ which are studied. The current density used in this studies are 125, 250 and 500 mA/dm^2 respectively. The concentration of $CrCl_3.6H_2O$ used in this studies are 0M, 0.001M, 0.05M and 0.1M respectively. The surface morphology and composition of the coating alloy are using SEM, XRF and XRD. The corrosion behaviour in 3.5 wt% NaCl aqueous solution is investigated using the electrochemical measurement methods such as Linear Scanning Voltammetry (LSV). The hardness of the alloy coating is determined by using micro Vickers Hardness tester. The surface roughness of coating alloy is analysed by profilometer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Coating

Coating is the layer of a thin layer which covering on the surface of any substance. The surface on which coating is applied is named as substrate. The purpose of coating can be classifies into two classes by the purpose for good appearance and by the good improvement of the surfaces properties. This thin layer of coated surface is applied on any surface of any object, essentially to improve its properties or to create a protective barrier against corrosion of the surface due to it reaction with atmosphere reactance for example water, oxygen and etc. Thus, coating is important to improve properties of the substrate for the useful life of structures pipelines and other vital equipment, and eliminates some of the life threatening failures and costs related to repair and premature replacements.

The main deliberation for most coating processes is that the coating is to be applied at a controlled thickness, and a various number of processes are used to achieve this control, ranging from a simple brush for painting a wall, to some technology of machinery applying coatings in the electronics manufacturing.

2.1.1 Coating improves surfaces properties of a substrate.

Coating process can improve numbers of the improvement of a substrate as compare to its original metal without coated. For example the Al–Al_2O_3 cold spray coatings had improve the surface properties of magnesium substrate. Through the Al–Al_2O_3 cold spraying had improved the surface properties such as the corrosion resistance, wear resistance, and the mechanical properties of the magnesium (Huo *et al*., 2004). Beside from this, coating also improve the conductivity of a substrate. For example, the surface modification of the silver coating on lithium iron phosphate battery ($LiFePO_4$) had improve its electrical conductivity (Park *et al*., 2004).

2.1.2 Coating improves corrosion resistance of a substrate.

Huo *et al* (2004) had stated about, the corrosion resistance of the AZ91D alloy was improved by the chemical conversion treatment in alkaline stannate bath, and the conversion coating was mainly $MgSnO_3.H_2O$. Ni–P coating also can be effectively plated on the chemical conversion coating for the AZ91D alloy. The result indicating that, the specimen with the composite coating, no hydrogen evolved immersion in 3.5 wt.% NaCl solution for 100 h. This implied that the composite coating could provide an excellent protection to the substrate. The microstructure and composition ensured that the coating would have outstanding corrosion resistance the chemical conversion treatment and an electroless nickel plating can improve the corrosion resistance of a substrate (Huo, *et al*., 2004). Thus, coating process can improve the corrosion resistance of a substrate.

2.1.3 Coating improves the wear resistance of a substrate.

Spencer *et al* (2009) had detailed that, the Increasing Al_2O3 additions to the coating progressively changes the wear mode the substrate from adhesive to abrasive. The result had indicating that the substrate with cold spraying have the smallest wear volume per unit wear distance as compare to its original. This change in wear mode is accompanied by an increased but more stable friction coefficient. When the wear mode becomes fully abrasive the wear rate is reduced by several orders of magnitude. The transition in wear mode occurs with a much lower Al_2O3 content for the 6061 alloy based composite coatings than that for pure Al-based coatings. (Spencer *et al*., 2009).

2.1.4 Coating improves the mechanical properties of a substrate.

Shi *et al* (2009) had resulted that, the coating of the epoxy coating modified with silica nanoparticles showed a significantly enhanced Young's modulus of 2.5 GPa. Nonetheless, the modification with nanoparticles does not always enhance the stiffness of the epoxy coatings. An approximately 30% increase in Young's modulus was observed for the nano-Zn modified epoxy coating, whereas the nanoclay and nano-Fe_2O_3 modified samples showed ~30% and ~25% decrease relative to the unmodified epoxy coating, respectively (Shi *et al*., 2009)

2.1.5 Coating improves the electrical conductivity of a substrate.

Park *et al* (2004) had introduced that the surface modification by silver coating. This surface modification of the $LiFePO_4$ by aqueous coating had enhanced the electronic conductivity and increase the capacity. The result had shown the capacities of the silver coated $LiFePO_4$ with various current densities are analogous to those of the metal doped $LiFePO_4$ of which electronic conductivity is greater than in un-doped $LiFePO_4$ by a factor of, 10^8. Besides the voltage profiles of $LiFePO_4$ at the rate of C=5: The cells were measured at room temperature. Initial capacity is increased from 121 to 139 mAh/g by silver coating. Thus, the silver coating can be an authoritative method to enhance the conductivity and preserve the capacity well even at the high current densities (Park *et al*., 2004).

2.2 Type of Coating Method.

The majority of coatings are applied on outer surfaces to protect the metal from natural atmospheric corrosion and atmospheric pollution. Besides, it may also be necessary to provide protection from accidental spills and splashes. In some cases, coatings are applied internally in vessels for corrosion resistance. Under these circumstances, the applied material is usually referred to as a coating. Essentially, there are four different classes of coatings which is organic coating, inorganic coating, conversion coating and metallic coating.