DECLARATION

I **ADEGOR EDNA ESTHER** declare that the project presented for the award of bachelor of Engineering in Chemical Engineering Department has not been presented either wholly or partially for any other degree elsewhere. References made from others work has been acknowledged.

Student

5th/12/07

Date

DEDICATION

This work is dedicated to Almighty God for his love & mercies also to my beloved parent Mr. & MRS French Joseph Adegor, my siblings and to all those who work in God vineyard.

ACKNOWLEDGEMENT

Foremost glory to the Almighty God for the health, strength and wisdom which it has pleased him to endow me with during my sojourn at FUT Minna.

Thanks to my supervisor Dr Duncan Aloko who provided an avenue to work under his supervision ,going through this work step by step and making useful suggestion..

My sincere gratitude also goes to my Dad and Mum Mr. & Mrs. French Joseph Adegor. Who have always been there for me both financially, morally, spiritually when I needed them most, u have really touched me in my most sensitive chords.

To whom much is given much is expected I thank my brother and sisters-Vera, Paulina, Ejiro, Kate, Jude, Queen & Edith for their understanding and support during my academic life as an undergraduate.

It is pertinent to acknowledge the broad array of valuable support assistance and words of encouragement of individual who have contributed to the success of my project Rev. Adegoke & chief Kayode of FIIRO as well as Kemi thank you for been there for me.

My sincere appreciation to head of Department Dr Edoga, other members of staff for been there for us all.

My appreciation also goes to all my Buddies Bankole,sunny,Ebera , Tope, Ib, obus, soji, A.Y, Taiwo, Salome, Audu, Dinma, Emmy,sola Mary, Asabe, Tony, Gorge, whom we have strive together through hard times, may God continue to show us the right path.

ABSTRACT

This research project gives a clear view of the technology of electroplating process. It shows how zinc plating of metals serves the purpose of strength, beautification and protection against corrosion.

To achieve this experiment was carried out at room temperature & at constant electrolyte of 3.8 pH. The variation of voltage & plating time brings about an increase in weight (Z) of the metals and the thickness (Y) . The values of these parameters were observed. A quadratic equation was obtained to establish the voltage & time require for the appearance of electroplated metals which is

$$Y = 0.0000\,28 + 0.000163x_1 + 0.000094x_2 + 0.0000\,56x_1x_2 + 0.000108x_1^2 - 0.000094x_2^2$$

The confidence of this equation is 95% , since the optimum performances was obtained . Thus the quadratic equation model best represent the experimental data .

TABLE OF CONTENT

CHAPTER ONE

1.0 INTRODUCTION

This project titled optimization of process parameters of Zinc plating of metals using the second order design approach is basically the electroplating of metallic objects for the purpose of strength , beautification and for protection against corrosion .Electroplating simply means the coating of metals which corrode easily with one which is highly resistant to corrosion .Among the highly resistant metals commonly used are copper, chromium , silver, gold ,zinc, cadmium, tin, lead, nickel, cobalt .

In this project ,zinc plating is being considered .Using the second order factorial design approach for the optimization.

The technology of electroplating is actually an interesting one, which instantly brings to mind the theory of electrolysis.

1.1 Historical Background

In 1805 , an Italian chemist,luigi brugnateei invented electroplating by performing the electro deposition of gold using the voltaic pile discovered by his college allenssandro volta in 1800.

This work was rebuffed by the dictator napoleon banaparte which caused luigi brugnatelli to suppress any further publication of his work though he wrote concerning electroplating.

It was about forty years later that John Wright, a Birmingham doctor, first showed that items could be electroplated by immersing them in a tank of silver held in solution through which an electric current was passed.

Later, the Elkingtons patented electroplating process in 1840 and held a monopoly on electroplating for many years though 1857 ,the next new wonder in economical jewelry arrived electroplating . When the process was first used for costume jewelry. It was in Russia that the first large scale of electroplating of copper ,silver and gold took place where hundreds perhaps thousands of items were plated .With time, chemical developments were made through research to improve the electroplating process.

Nevertheless, there was no standard for the factors affecting the electroplating process and therefore optimization of zinc and other types of plating have not been carried out, hence, the reason for this work.

1.2 Aims and Objectives

This project proposal aims at giving a breakdown on how to carry out optimization process on electroplating of zinc with a view to having quality endorsed products. Also, to have a standard for electroplating and at same time to be able to utilized available resources maximally.

1.3 Approach

For the purpose of carrying out this experiment, the Federal Institute of Industrial Research ,Oshodi (FIIRO) was consulted so as to obtain the literature and also to interact with their electroplating set-up.

The experiment is to be carried out using the second –order factorial design approach (3^2 approach).This means three level & two factors approach. The factors to be varied are the voltage of the process and the time of electroplating These factors are to be varied in nine different ways for each of zinc plating after which a certain set of condition gives the optimum result. Then ,a model equation is obtained.

CHAPTER TWO

2.0 LITERATURE REVIEW

Electroplating is basically a process in which a metal which corrodes easily is coated with one which is highly resistant to corrosion (Olmsted Williams) it covers quite a wide range of applications, it could be done to give a material aesthetic value (beautify it), to give the material a longer life like machine parts or just to give the material a good finishing.

There are quite a variety of electroplating types; copper plating, zinc plating, chrome plating, nickel plating, gold plating, silver plating, tin plating and some others. Most of these types of plating follow basically the same procedure with minor differences.

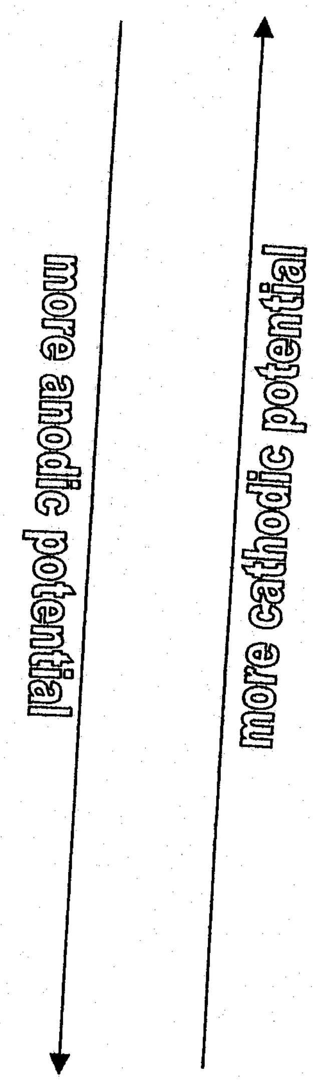
2.1 Electrochemical Series

The electrochemical series, lists the elements in the order of their standard electrode potentials and to a degree indicates the relative ease with which they ionize.

The Electrochemical series:

Electronegative Metals

Manganese	-1.18
Zinc	-0.76
Chromium	-0.56
Iron (ferrous)	-0.44
Cadmium	-0.40
Indium	-0.34
Cobalt	-0.28
Nickel	-0.25
Tin (stannous)	+ 0.14
Lead hydrogen	+ 0.12
Copper (cupric)	+ 0.34
Copper (cuprous)	+ 0.52
Silver	+ 0.80



Gold (auric)	———	+ 1.50
Gold (aurous)	———	+ 1.68

The electrochemical series can be considered in a number of different ways.

As a reactive series:

When metals react, formation of ions occurs and as a rule, the metals with the higher negative values are more active chemically than those at the other end of the scale. Metals having a positive potential are termed noble metals.

As a displacement series:

In this case, the more electronegative metals will displace one lower in the series.

2.2 Electrodeposition

This is the application of metallic coatings to metallic or other conductive surfaces by electrochemical process.

The material to be electroplated is immersed in a solution containing the dissolved salts of the metals to be deposited and made the cathode by connecting it to the negative lead of a low voltage D.C supply.

For electric circuits to be complete , anodes are immersed in the solution and these are connected to the positive lead the potential for commercial deposition processes is usually 2 and 16 volts D.C applied between anode and cathode and derived from a transformer rectifier set.

2.3 Zinc Electroplating

Zinc is a bluish, lustrous metal, which is hard, crystalline and brittle. It is electronegative to iron and gives excellent corrosion resistance particularly in industrial and urban environments. It is almost always deposited in the fully bright condition and dissolves readily in dilute acids and alkalis.

The value of zinc as a rust proof finish for iron and steel has long been appreciated and galvanizing by means of molten metals practiced for at least two centuries. Zinc has made rapid strides and is now used extensively for finishing all manners of iron and steel products including castings forgings and in electrical industries for components. The protection afforded to iron and steel is not due to an envelope effect alone but due to the behavior of zinc as the anode in any electro-chemical reaction that may occur. Rapid corrosion which might lead to a short duration of the zinc develops upon its surface a film of oxide, which resists further attack unless it is exposed to exceptionally humid atmosphere. To ensure further protection, it may be passivated.

The electrolyte contains mainly zinc chloride, potassium chloride, boric acid and 95% dil. Hcl so as to prevent attack on zinc. The material to be plated must be Polished, pick or sand blasted then swilled in water after which degrease can then be carried out to remove grease from the surface of the material. It is of great importance that grease, scales, rusts and oxides must be removed from the surface of the material for complete and uniform plating.

The material to be plated is then made the cathode by hanging it with a copper wire on the cathode rod. A plastic or rubber lined tank should be used to prevent reaction of the tank with the electrolyte.

The set-up is then connected to a rectifier and the required voltage is set. After a fixed time the plating would have been completed and post-plating procedures like bright zinc plating or rinsing in water, passivation can be carried out.

2.4 Factorial Design

Theory and application

A review of factorial design is necessary here to give a clear and precise understanding of what is involved and what is to be looked for in such an experimental design.

Factorial design is a statistical design which tests all combination of effect at all levels of all factors enabling:

_ All the main effects of every factor to be estimated independently of one another.

_ The determination of the dependence of the effect of any factor on the level of any factor on the level of interaction.

In this analysis we are concerned with the voltage and time which are combined on a 3^2 factorial design in three different levels of each factor (maximum, normal, and minimum) .

Factorial design enables one to understand how the interaction of two or more factors effects the output (Edun, 2002).It also shows the response to changes in factors of the electroplating process.

The combination of one of these variations in factors yields an optimum condition, which gives the best product.

Optimization comes to play when this combination of factors emerges and is used as standard to form a model equation. This drastically reduce time spend in calculating the values of various factors before electroplating can proceed.

CHAPTER THREE

3.0 METHODOLOGY

The method used in carrying out this project is the second-order factorial design approach (3^2 approach). This means the three levels two factors approach.

The three levels are the maximum level, the normal level and the minimum level while the factors to be varied are the time of electroplating and the voltage of the process. These factors are going to be varied in nine different ways for each zinc plating.

Each outcome give a thickness Y and weight Z .One of these thicknesses and weight gives the best result.

3.1 Material And Chemicals Used

The materials and chemicals used can be summarized in the table below.

Table:3.1 Chemicals used and their sources.

CHEMICALS	SOURCES	COMMENTS
Zinc sulphate/Zinc chlor	May & Baker	Industrial
Pure anode (99%zinc)		Industrial
Water	FIIRO	Tap water
HCL		Analytical/laboratory
Boric Acid	May & Baker	Laboratory
Sulphuric Acid	_	Laboratory
Sodium Carbonate		Laboratory
Sodium Cyanide		Analytical/Laboratory
Metal	Pan taker	Locally Fabricated

Table 3.2 Equipment Used and Their Sources

EQUIPMENT	SOURCES	COMMENTS
Electrolytic Vat/Bath	FIIRO	Locally Fabricated
Rectifier	FIIRO	Locally Fabricated
Polishing Machine	FIIRO	Imported
Swill	FIIRO	Locally Fabricated
Electrolytic Tank(Anode/Cathodic)	FIIRO	Locally Fabricated
Heater		Locally Fabricated

3.3 Preparation of The Cathode

This is the pre-plating processes which include polishing , derusting / picking , sand blasting , degreasing (anodic or cathode) .Swilling and at times , buffing .

The processes in electroplating are stated below.

3.3.1 Pre-plating process/ pre-treatment

This process covers mainly the preparation of the article to be plated for proper plating process. The processes that fall under this category are polishing derusting and degreasing.

Polishing could either be manual or electro mechanical, in the latter case , a polishing machine which is electrically automated , is used to carry out the polishing.

Derusting also known as picking is the removal of rusts and scales from the surface of the article to be plated by immersing it in an inorganic acids like

HCL, HNO_3, H_2SO_4 and HF but mostly HCL is used especially for ferrous metals being the fastest picking agent.

While degreasing is removal of oil or grease from the article / material to be plated. Degreasing is of two types , anodic electrolytic degreasing and the Cathodic electrolytic degreasing . The former requires heating and is basically used for ferrous metals while the later does not require heating and it is used for non-ferrous metals.

3.3.2 Plating process

The plating process involves the immersion of the work piece ,which is usually the cathode in the electrolyte by the use of racks, jigs, hooks and barrels depending in the size and nature of the work piece and connecting to the rectifier left for a fixed time after which material would have been plated.

3.3.3 Post-plating process

This is post - treatment and final stage of plating. The plated items are oven or air dried and some centrifugal-dried. Work pieces that are zinc plated must be passivated with yellow or blue solution (i e the surface is finally covered with a solution that makes surface passive to attack like oxidation), which can bring about surface tarnishing.

A simple diagram of the set up is shown below

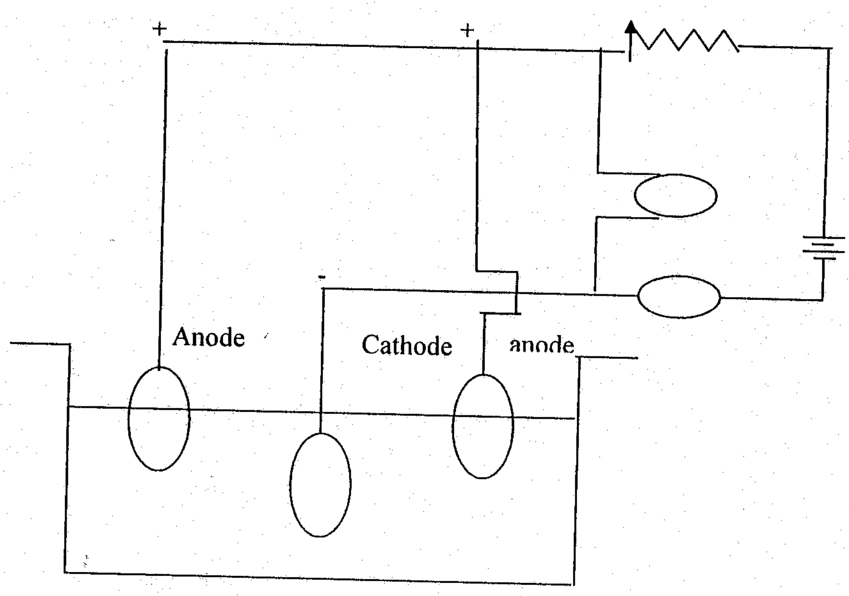


Figure 3.1 Electroplating circuit

3.4 The Experimental Design Table or Matrix

The experimental design table is shown below

Table 3.3 3^2 Experimental Table

s/no	X_0	X_1	X_2	Y_1	Y_2	$Y(Y_1+Y_2)\backslash 2$	Z_1	Z_2	$Z=(Z_1+Z_2)\backslash 2$
1	+	+	+						
2	+	-	+						
3	+	0	+						
4	+	+	-						
5	+	-	-						
6	+	0	-						
7	+	+	0						
8	+	-	0						
9	+	0	0						

+ = Maximum level of each factor

- = Minimum level of each factor

0 =Normal level of each factor

Y_1 & Y_2 = 1^{st} & 2^{nd} measurement of the thickness of items to be plated in (mm)

Y =Average ThicknessZ_1 & Z_2 = 1^{st} & 2^{nd} measurement of the weight (masses) of items to be Plated

Z =Average Weight (masses

X_0 =Base value of each factor (the average value of the minimum and maximum values of each factor)

X_1 = Time of electroplating

X_2= voltage of the process

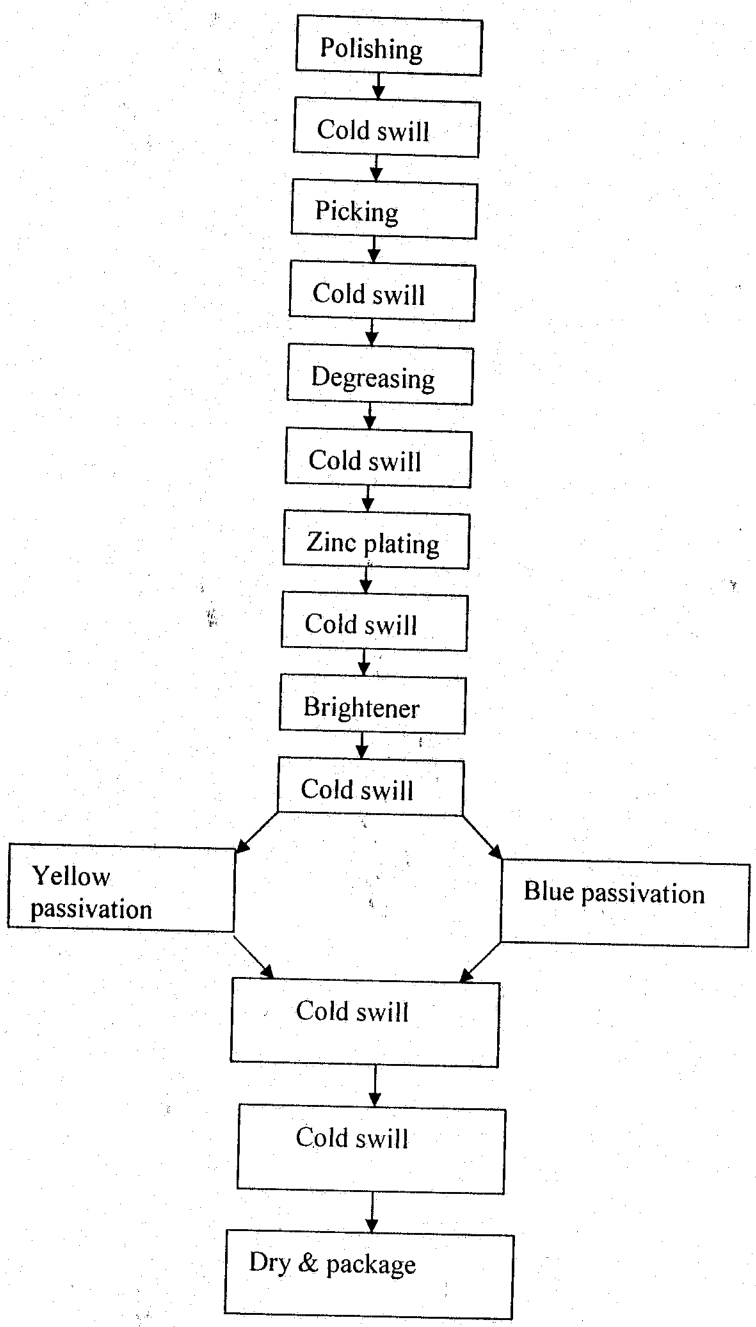


Figure 3.2 Zinc Electroplating Process Flow Chart

CHAPTER FOUR

4.0 RESULTS AND DICUSSION

Difference in weight of metals were measured and recorded as well as the thickness & current density The results obtained are tabulated and the voltage , time of plating are recorded and the physical appearances were observed. A model equation emerges which gives a minimum graph. Effect of voltage and time were discussed as well.

4.1 Results

Table 4.1 Thickness of items to be plated in millimeters (mm)

Experimental num	Y_1(mm)	Y_2(mm)	Y'(mm)
1	2.000	2.000	2.000
2	2.000	2.000	2.000
3	2.000	2.000	2.000
4	2.000	2.000	2.000
5	2.000	2.000	2.000
6	2.001	2.000	2.0005
7	2.000	2.000	2.000
8	2.000	2.000	2.000
9	2.000	2.001	2.0005

Where Y_1 and Y_2 are first and second measurement of the thickness of items to be plated in (mm)

Y is the average values of Y_1 and Y_2

Table 4.2 Thickness of it ems af **t er** plating in (mm)

Expt no	**Y_1(mm)**	**Y_2(mm)**	**Y_0(mm)**
1	2.05	2.04	2.0475
2	2.02	52.02	2.02
3	2.04	2.04	2.04
4	2.035	2.04	2.0375
5	2.018	2.01	2.014
6	2.03	2.03	2.03
7	2.03	2.03	2.03
8	2.013	2.013	2.013
9	2.025	2.025	2.025

Table 4.3 Masses of items to be plated in grams

Expt no	**Mass Z_1(g)**	**Mass Z_2(g)**	**Average mass Z'(g)**
1	40.061	40.061	40.061
2	41.150	41.158	41.154
3	39.565	39.566	39.5655
4	39.454	39.458	39.456
5	39.397	39.407	39.402
6	43.099	43.099	43.099
7	42.014	42.014	42.014
8	39.407	39.408	39.4075
9	40.412	40.412	40.412

Table 4.4 Masses of items after plating in grams

Expt no	Mass Z_1(g)	Mass Z_2(g)	Average Mass Z_0(g
1	41.0944	41.0944	41.0944
2	41.7874	41.7874	41.7874
3	40.3877	40.3877	40.3877
4	40.30945	40.30945	40.3095
5	39.8776	39.8776	39.8776
6	43.7301	43.7301	43.7301
7	42.9152	42.9152	42.9152
8	39.99885	39.99885	39.9989
9	41.1632	41.1632	41.1632

Table 4.5 Thickness of zinc deposited

Expt no	Y_0(mm)	Y'(mm)	Y=(Y_0-Y')*10^-6m
1	2.0457	2.000	47.5
2	2.02	2.000	20
3	2.04	2.000	40
4	2.0375	2.000	37.5
5	2.014	2.000	14
6	2.03	2.0005	30
7	2.03	2.000	30
8	2.013	2.000	13
9	2.025	2.0005	25

Table 4.6 Amount of Zinc deposited

Expt no	**Z_0 (g)**	**Z'(g)**	**$Z=(Z_0-Z')$(g)**
1	41.0944	40.061	1.0334
2	41.7874	41.154	0.6334
3	40.3877	39.5655	0.8222
4	40.3095	39.456	0.8535
5	39.8776	39.402	0.4756
6	43.7301	43.099	0.6311
7	42.9152	42.014	0.9012
8	39.9989	39.4075	0.5914
9	41.1632	40.412	0.7512

Table 4.7 Amount of current used up

Expt no	Mass deposited Z (g)	Plating current I=M/Zt (A)
1	1.0334	1.6950
2	0.6334	2.0779
3	0.8222	2.0229
4	0.8535	1.3999
5	0.4756	1.5602
6	0.6311	1.5527
7	0.9012	1.4782
8	0.5914	1.9401
9	0.7512	1.8482

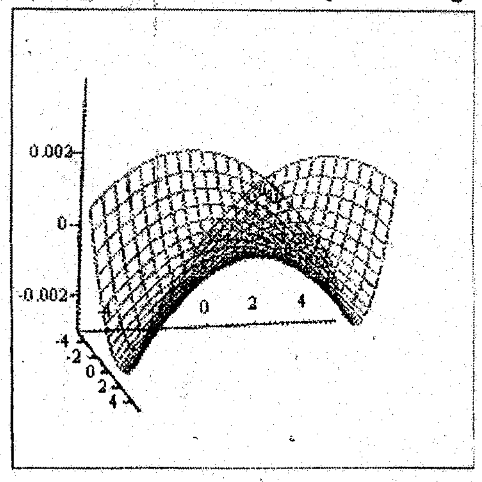
Table 4.8 Determination of current density

Expt no	Area of plated metals (m^2)	Current density $i=I/A(A/m^2)$
1	5.4048 *10^-3	313.6
2	5.856 *10^-3	354.83
3	5.952 *106-3	339.868
4	5.3269 *10^-3	262.798
5	5.578 *10^-3	279.71
6	5.874 *10^-3	264.33
7	6.103 *10^-3	242.21
8	5.481 *10^-3	353.97
9	5.2724 *10^-3	350.54

Table 4.9 Summary of Experimental Result

s/no	X_1(min	X_2(V)	Z_1(g)	Z_2(g)	Z_2-Z_1	Y(10^-6	observation
1	30	6	40.061	41.0944	1.0334	47.5	Burnt blue
2	15	6	41.154	41.7897	0.6334	20	Burnt blue
3	20	6	39.565	40.3877	0.8222	40	Burnt blue
4	30	2	39.456	40.3095	0.8535	37.5	Brighter blue
5	15	2	39.402	49.8776	0.4756	14.5	Brightest blue
6	20	2	43.099	43.7301	0.6311	30	Brighter yellow
7	30	3	42.014	42.9152	0.9012	30	Bright yellow
8	15	3	39.407	39.9989	0.5914	13	Brighter blue
9	20	3	40.412	41.1632	0.7512	25	Brighter blue

$$y(x_1, x_2) := .000028 + .000163x_1 + .000094x_2 + .000056x_1 x_2 + .000108x_1^{\,2} - .000094x_2^{\,2}$$



y

Figure4.1 **3 DIMENSION PLOT OF THE MODEL EQUATION**

↑

Thickness of the plated metals (Y)

→

Voltage of the process (X_2)

↘

Time of electroplating (X_1

4.2 Discussion of Experimental Result

In the process of coating the metals ,different voltage and time were varied and the surface appearance after passivation were noted as well as differences in weight and thickness (Y) . In this experiment two types of passivation solution were used for the plating of the metals so as to have an improved surface appearance. Passivation of the surface means covering of the zinc – plated items with solution that make the surface passive to attacks like oxidation , which can bring about surface tarnishing.

It was observed that at a voltage of 6(v) with time 30 mins there is 1.0334g in differences in weight with 47.5*10^-6m thicknesses and a bright burnt blue colour was noted. When the time was reduce to 15mins with corresponding voltage of 6(v) there is 0.633g in difference in weight with 20*10^-6m thickness and a brighter burnt blue colour was noted. At normal time of 20mins and corresponding voltage of 6(v) there is 0.8222g in differences in weight with 40*10^-6m thickness and a Brighter burnt blue colour was noted.

Also , at time 30min and voltage of 2(v) a thickness of 37.5*10-6m was recorded and a brighter blue colour was noted while at a reduce time and voltage of 15 mins and 2v yielded a reduced in weight difference to be 0.4756g and a thickness of 14*10^-6m with a brightest blue colour was noted .At normal time 20 and minimum voltage 2v there is 0.6311g in differences in weight with 30*10^-6m thickness and a brighter yellow colour was observed. More so ,at maximum time of 30mins and normal voltage of 3v a bright yellow surface and a thickness of 30*10^-6m was recorded while at a minimum time of 15mins and normal voltage of 3v there is different in weight to be 0.5914g and thickness 13*1110^-6m with a brighter blue surface appearance were noted .

Lastly, at normal time & voltage of 20mins & 3v the weight difference is 0.7512g and a thickness of 25*10^-6m with a brighter blue surface appearance was noted.

From the experimental result it was observed that as plating time and voltage increases there is an increase in weight difference and thickness of the metals.

4.2.1 Discussion of Simulated result

Combination of these factors emerges &is used as a standard to form a model equation which is

$$Y=0.000028+ 0.000163X_1+0.000094X_2+ 0.000056X_1X_2+ 0.000108X_1^2 +0.000094X_2^2$$

Using MathCAD a chemical engineering soft- ware the model equation gave a minimum graph. from the graph $Y=0.00018$,$X_1=12$mins,$X_2=2$v.comparing the value obtain with the experimental value it was observed that the differences were within the acceptable limits, thus, this simply means that the mathematical model best represent the experimental data

4.3 Effect of the Parameters

4.3.1 Effect of voltage

High voltage causes damages (burning) to the surface of the base metals, therefore the voltage 6v applied were too high, moderate voltage of 2v was applied so as to obtain the brightest appearances. It was observed that any increase in voltage would bring about increase in weight difference and thickness Y.

4.3.2 Effect of time

Time is very essential in the process of electroplating ;it was observed that at different plating time, different result was obtained .In table (4.9) it was observed that increase in time will bring about corresponding increase.in thickness Y

4.4 Other Effect on Zinc plating

4.4.1 Effect of anode

Zinc anode must be kept in polypropylene bag or in cotton ; anode that is not been kept properly might bring about direct corrosion into the surface of the cathode . This might result to a rough physical appearance.

4.4.2 Effect of impurities

It could be in the form of organic constituents , whenever zinc solution comes in contact with these contaminants it causes roughness of the surfaces of the material. Roughness also arises when anode bag is punctured. Pitting is caused by gas bubble adhering to the cathode surface and electro deposition grows around the attained gas bubble and hence a hole is produced in the coating.

4.4.3 Effect of proper agitation

Agitation of the plating solution (zinc electrolyte) is very essential that is the solution must be well stirred to avoid ions settlement , which will affect the surface of the substrate.

CHAPTER FIVE

.0 CONCLUSION AND RECOMMENDATION

.1 Conclusion

The model equation gave a minimum graph. From the graph $Y=0.00018m, X_1=12mins, X_2=2v$ which means at minimum time of approximately 5mins &minimum voltage of 2v the optimum performance was obtained which gave

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CERTIFICATION

This is to certify that this project **"OPTIMIZATION OF THE PROCESS PARAMETERS OF ZINC PLATING OF METALS "**is the work of **ADEGOR EDNA ESTHER.** This work was carried out by her, under my supervision and approved for submission to the department of chemical engineering, school of engineering and engineering technology, federal university of technology Minna.

------------------ 5-12-2007

Supervisor Date

Dr Duncan

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Head of department Date

Dr .M. O .Edoga

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External supervisor Date

APPENDIX A

Plating Current

Plating current for each experiment is calculated using faraday's first law

i.e. m =ZIt

Where m=amount of zinc deposited

t = plating time

Z =electrochemical equivalent of Zn^{2+} ion

Also,

Z= M/ (e*96500) = 65.37/ (2*96500) =0.0003387

Where M =molecular mass of zinc metals

e = electronic charge of zn^{2+} ion

96500 = 1 faraday of electricity

For plated metal one

B=2.5cm

L=10.2cm

H=0.12cm

Area =2(LB+LH+BH)

A=5.4048*10^-3m

For plated metal two

B=2.8cm

L=10cm

H=0.1cm

Area =2(LB+LH+BH)

=5.856*10^-3m

For plated metal three

B=2.7cm

L=10.3cm

H=0.15cm

Area =2(LB+LH+BH)

=5.952*10^-3m

For plated metal four

B=2.45cm

L=10.2cm

H=0.13cm

Area =2(LB+LH+BH)

=5.3269*10^-3m

For plated metal five

B= 2.6cm

H=0.15cm

Area =2(LB+LH+BH)

L= 10cm

=5.578*10^-3m

For plated metal six

B=2.7cm

L=10.3cm

H=0.12cm

Area = 2(LB+LH+BH)

=5.874*10^-3m

For plated metal seven

B=2.8cm

L=10.2cm

H=0.15cm

Area =2(LB+LH+BH)

=6.103*10^-3m

For plated metal eight

B= 2.5cm

L=10.2cm

H=0.15cm

Area =2(LB+LH+BH)

=5.481*10^-3cm

For plated metal nine

B=9.9cm,L=2.5cm,H=0.13cm,Area =2(LB+LH+BH)

= 5.277724*10^-3 cm

DETERMINATION OF THE MODEL EQUATION USING STATICTICAL ANALYSIS

$$Y=b_o + \sum_{i=1}^{K} b_i x_i + \sum_{i \neq j}^{K} b_{ij}(x_i x_j)_u + \sum_{i=1}^{K} b_{ii} x_i^2$$

For two factors k= 2

No of members is 6

$Y=b_0 + b_1 x_1 + b_2 x_2 + b_{12} x_1 x_2 + b_{11} x_1^2 + b_{22} x_2^2$

$N = 2^k + 2k + no$

$= 2^2 + 2(2) + 1 = 9$

$b_0 = \frac{\sum_{U=1}^{N}}{N}$ = (+47.5 +20 + 40 +37.5 +14+ 30 +13+25)/ 9

= 257/9 = 28.555810^-6m

When i=1

$$X^2_{iu} = (+)^2 + (-)^2 + (+)^2 + (+)^2 + (-)^2 + (+)^2 + (+)^2 + (-)^2 + (+)^2 = +1$$

$$b_1 = \frac{\sum_{U=1}^{N} x_{iu} y_u}{\sum_{U=1}^{N} x_{iu2}} = (+47.5 - 20 + 40 + 37.5 - 14 + 30 + 30 - 30 - 13 + 25)/+1 = 163*10^{-6}m$$

When i=2

$$X^2_{iu} = (+)^2 + (+)^2 + (+)^2 + (-)^2 + (-)^2 + (-)^2 + (+)^2 + (+)^2 + (+)^2$$

$$\frac{\sum_{i=1}^{N} x_{iu}\, y}{\sum_{U=1}^{N} x_i{}^2{}_u} = (+47.5 + 20 + 40 - 37.5 - 14 - 30 + 30 + 13 + 25) / +1 = 94*10^{-6}m$$

b_2=~~When i=~~1, j=2

$$(x_i x_j)^2{}_u = (+*+)^2 + (-*+)^2 + (+*+)^2 + (+*-)^2 + (-*-)^2 + (+*-)^2 + (+*+)^2 + (-*+)^2 + (+*+)^2$$

$$b_{ij} = \frac{\sum_{U=1}^{N} ((x_i x_j)_u y_u}{\sum_{U=1}^{N} (x_i x_j)^2}$$

$$b_{12} = (+47.5 - 20 + 40 - 37.5 + 14 - 30 + 30 - 13 + 25)/+1 \quad = 56*10^{-6}m$$

$$b_{ii} = \frac{\sum_{U=1}^{N} x'_{iu} y_2}{\sum_{U=1}^{N} x_{iu}{}^2} =$$

X_1'=-, +, +,+,-,+,+,-,+

X_2'= -,-,-, +, +, +,-,-,-

$$b_{11} = (-47.5 + 20 + 40 + 37.5 - 14 + 30 + 30 - 13 + 25)/+1 = 108*10^{-6}m$$

$$b_{22} = (-47.5 - 20 - 40 + 37.5 + 14 + 30 - 30 - 13 - 25)/=1 = -94*10^{-6}m$$

b_{22}=(-47.5-20-40+37.5+14+30-30-13-25)/=1 =-94*10^-6m

$Y=b_0+b_1x_1+b_2x_2+b_{12}x_1x_2+b_{11}x_1^2+b_{22}x_2^2$

$\mathbf{Y=0.000028+0.000163x_1+0.000094x_2+0.000056x_1x_2+0.000108x_1^2-0.000094x_2^2}$

(the model equation)

Where u=number of expected thickness values

N= number of experiment carried out

X_1= time of electroplating

X_2= voltage of the process

y = thickness of plated metals

From the graph

On the Y axis

10cm=0.002unit

0.9cm=Y

Y=0.0018/10=0.00018m

On the Z axis

1.5cm=2unit

0.9cm=X_1

X_1=1.8/0.15=12mins

On the X axis

X_2=2v

APPENDIX B

GLOSSARY OF ELECTROPLATING

Activation: Elimination of a passive condition on a surface.

Adhesion : (1) The attractive force that exists between an electrodeposits and its substrate. (2)The force required separating electrodeposits from its substrate

Alloy: A substance having metallic properties composed of two or more elements of which at one is metal.

Anion : Anion, which is negatively charged.

Anode: The electrode at which current enters or electrons leaves the solution; the positive electrode in electrolysis, the electrode at which negative ions are discharge, positive ions are formed ,or at which other oxidizing reactions occur

Anodizing: Anodic treatment of metals ,particularly aluminum to form an oxide film of controlled properties.

Brightener: An addition agent, leads to the formation of a brightener plated; or which improves the brightness of the deposit over that which is obtained without its use.

Cathode: The electrode through which current leaves , or electrode in electrolysis . the electrodes at which positive ions are discharged, negative ions are formed , or other reducing reactions occur in electroplating, the electrode which receives the deposit.

Chemical picking: The surface layer is removed from metal by chemical picking, or the removal rust from the metal surface

Coating: A protective layers

Corrosion: Gradual destruction of a material usually by solution, oxidation or other means attributable to chemical process.

Degreasing: The removal of grease and oils from a surface by using solvent

Electrode: A conduction by electrolytic cell; at which there is a change from conduction by electrons to conduction by particles of matter, or vice versa

Electro deposition: The process of depositing a substance upon an electrode by electrolysis. Includes electroplating, electro-fining and electro-winning.

Electrode potential: The difference in potential between an electrode and the immediately adjacent electrolyte, referred to some standard electrode potential difference as zero

Electrolyte : A conducting medium in which the flow of current is accompanied by movement of matter. Most often an aqueous solution of acids, bases or salts but includes many other media as fused salts some solids e.t.c

Electrolysis: production of chemical changes by the passage of current through an electrolyte

Electrolytic cell : A unit apparatus designed for carrying out an electro-chemical reaction; includes a vessel, two or more electrodes and one or more electrode for the purpose of securing a surface with properties or dimensions different from those of the basic metal.

Electro-polishing: The improvement in surface finishing of a metal affected by making it anodic in a appropriate solution.

Polishing: The smoothing of a metal surface by means of wheels or bells.

Tarnish: Dulling, staining or discoloration of metals due to superficial corrosion. The film so formed.

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OPTIMIZATION OF PROCESS PARAMETERS OF ZINC ELECTROPLATING OF METALS

A RESEARCH PROJECT PRESENTED TO THE CHEMICAL ENGINEERING DEPARTMENT

BY

ADEGOR EDNA ESTHER
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