EU GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE

EGE UNIVERSITY

MASTER'S THESIS

INVESTIGATING AND DEVELOPMENT OF ELECTROLESS PLATING CATALYST AND ACTIVATION SOLUTION IN ELECTROPLATING INDUSTRY

Şenay MACİT

Supervisor: Assist. Prof. Dr. Canan URAZ

Department of Chemical Engineering

Presentation Date : 22.09.2017

Bornova-İZMİR

2017

EU GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE

(MASTER OF SCIENCE THESIS)

INVESTIGATING AND DEVELOPMENT OF ELECTROLESS PLATING CATALYST AND ACTIVATION SOLUTION IN ELECTROPLATING INDUSTRY

Şenay MACİT

Supervisor : Assist. Prof. Dr. Canan URAZ

Department of Chemical Engineering

Date of Presentation: 22.09.2017

Bornova-İZMİR

2017

Şenay MACİT tarafından yüksek lisans tezi olarak sunulan "Investigating and Development of Electroless Plating Catalyst and Activation Solution in Electroplating Industry " başlıklı bu çalışma E.Ü. Lisansüstü Eğitim ve Öğretim Yönetmeliği ile E.Ü. Fen Bilimleri Enstitüsü Eğitim ve Öğretim Yönergesi'nin ilgili hükümleri uyarınca tarafımızdan değerlendirilerek savunmaya değer bulunmuş ve 22.09.2017 tarihinde yapılan tez savunma sınavında aday oybirliği/oyçokluğu ile başarılı bulunmuştur.

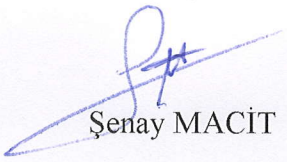
Jüri Üyeleri:		**İmza**
Jüri Başkanı	**: Yrd.Doç.Dr. Canan URAZ**	
Raportör Üye	**: Prof.Dr. Süheyda ATALAY**	
Üye	**: Prof.Dr. Muhsin ÇİFTÇİOĞLU**	

EGE ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ

ETİK KURALLARA UYGUNLUK BEYANI

EÜ Lisansüstü Eğitim ve Öğretim Yönetmeliğinin ilgili hükümleri uyarınca Yüksek Lisans Tezi olarak sunduğum "Investigating and Development of Electroless Plating Catalyst and Activation Solution in Electroplating Industry " başlıklı bu tezin kendi çalışmam olduğunu, sunduğum tüm sonuç, doküman, bilgi ve belgeleri bizzat ve bu tez çalışması kapsamında elde ettiğimi, bu tez çalışmasıyla elde edilmeyen bütün bilgi ve yorumlara atıf yaptığımı ve bunları kaynaklar listesinde usulüne uygun olarak verdiğimi, tez çalışması ve yazımı sırasında patent ve telif haklarını ihlal edici bir davranışımın olmadığını, bu tezin herhangi bir bölümünü bu üniversite veya diğer bir üniversitede başka bir tez çalışması içinde sunmadığımı, bu tezin planlanmasından yazımına kadar bütün safhalarda bilimsel etik kurallarına uygun olarak davrandığımı ve aksinin ortaya çıkması durumunda her türlü yasal sonucu kabul edeceğimi beyan ederim.

22/09/2017



Şenay MACİT

ÖZET

METAL KAPLAMA SEKTÖRÜNDE KULLANILMAK ÜZERE AKIMSIZ KAPLAMA KATALİZÖRÜ VE AKTİVASYON ÇÖZELTİSİ GELİŞTİRİLMESİ VE UYGUN ÇALIŞMA KOŞULLARININ BELİRLENMESİ

MACİT, Şenay

Yüksek Lisans Tezi, Kimya Mühendisliği Anabilim Dalı
Tez Danışmanı: Yrd.Doç.Dr.Canan URAZ
Eylül 2017, 59 sayfa

Bu çalışmada, Akrilonitril Bütadien Stiren (ABS) plastiği üzerine akımsız nikel ve bakır kaplama tekniği uygulanmıştır.

Akımsız kaplama işlemi plastik üzerine metal kaplamanın temel adımlarından biridir. Bu işlem plastik parçayı iletken duruma getirir ve istenilen kalınlıkta, homojen ve sert bir kaplamayı mümkün kılar. Endüstride bu banyoda kullanılan çok çeşitli katalizör ve aktivasyon çözeltileri bulunmaktadır. Ülkemizde tamamen geleneksel yöntemlerle yapılan bu kaplama işlemi için çevreye dost banyo çözeltileri ve yeni kaplama katalizörü geliştirmek bu çalışmanın amacını oluşturmaktadır.

Bu çalışmada katalizör olarak oda sıcaklığındaki iki farklı iyonik sıvı, zımpara kağıt boyutunun etkileri ve kaplama süresi sabit kaplama sıcaklığı ve sabit pH değerlerinde araştırılmıştır. Deneyler, 1-etil-3-metil imidazolyum klorür (EMIC) ve 1-etil-3-metil-imidazolyum dikyanamit (DCA) olmak üzere iki çeşit iyonik sıvı kullanılarak, 120-800 kum boyut aralığındaki zımpara kağıtları ile aşındırma işlemi uygulanarak, 30-150 dakika kaplama süre aralığında gerçekleştirilmiştir. Kaplanan parçaların Fischerscope X-Ray XDL-B System, X-ray Diffraction (XRD) ve Scanning Electron Microscopy (SEM) cihazlarıyla analizleri yapılmıştır. Deneylerden elde edilen sonuçlara göre ABS plastiği üzerine nikel ve bakır kaplama tekniğinde başarılı olunmuştur.

Anahtar Kelimeler: EMIC, DCA, ABS, Metal kaplama, Akımsız kaplama banyosu.

ABSTRACT

INVESTIGATING AND DEVELOPMENT OF ELECTROLESS PLATING CATALYST AND ACTIVATION SOLUTION IN ELECTROPLATING INDUSTRY

MACİT, Şenay

MSc in Chemical Eng.
Supervisor: Assist.Prof. Canan URAZ
September 2017, 59 pages

In this thesis, electroless nickel and copper plating on acrylonitrile butadiene styrene (ABS) engineering plastic were studied.

Electroless plating is a fundamental step in the metal plating on the plastic. This step makes the plastic conductive and makes it possible to a homogeneous and hard plating. In the industry there are many distinct chemical materials both catalysts and activation solutions for the electroless bath. The main goal of the thesis is to develope the useful (or profitable) and environmental friendly activation solutions and catalysts for the electroless bath.

In this thesis, the effects of the ionic liquids as catalyst, sanding paper size, and plating time were investigated at constant plating temperature and constant pH value. Experiments were carried out with two different types of ionic liquids, 1-ethyl-3-methyl imidazolium chloride (EMIC) and 1-ethyl 3-methylimidazolium dicyanamide (DCA), with 120-800 grit sandpaper by applying sand attrition process and 30-150 minutes of deposition time.

Due to the results, both copper and nickel plating on ABS plastic was succeed. The surface morphology and amount of deposit analysis were done by Fischerscope X-Ray XDL-B System, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM).

Key Words: EMIC, DCA, ABS, Metal plating, Electroless plating.

ACKNOWLEDGEMENT

I owe sincere thankfulness to my research advisor, Assist. Prof. Dr. Canan URAZ made me believe in myself and guided me through the whole process of dissertation writing.

I am also pleased to thank TKF Metal Corporation to their contribution for performing analyses at Fischerscope X-Ray XDL-B System.

The thesis has been supported by Ege University BAP Project with the Project number 2016-MUH-129 and TÜBİTAK with the Project number 216M372. I would like to thank Ege University and TÜBİTAK for their support.

Finally I owe my deepest gratitude to my family for their patience and support.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

TABLE OF FIGURES

Figure Page

TABLE OF FIGURES (continued)

TABLE OF FIGURES(continued)

Figure Page

TABLE OF FIGURES(continued)

Figure Page

TABLE OF FIGURES(continued)

Figure Page

LIST OF TABLES

NOMENCLATURE AND ABBREVIATIONS

C	Concentration	g/L
T	Temperature	°C
Ɵ	Contact Angle	degree
t	Thickness	nm
λ	Wavelength	nm
d	Particle Diameter	A°
B	Beta	degree, radyan

1.INTRODUCTION

Acrylonitrile butadiene styrene (ABS) is a thermoplastic polymer prepared by polymerizing styrene and acrylonitrile in the presence of polybutadiene which may have 15 to 35wt% acrylonitrile, 5 to 30wt% butadiene and 40 to 60wt% styrene. Plating of plastic materials enables a long term use of these materials. ABS plastic is an important engineering material with high thermal, mechanical, and chemical stability and is very suitable for plating research and applications (Tang et al., 2009).

Ionic liquids (ILs) are electrically conductive liquids composed merely of ions. Room Temperature Ionic Liquids (RTILs) are salts with very low vapor pressures close to zero at room temperature. The ionic liquid losses due to evaporation during their use as a catalyst or solvent even at high temperatures are very low. They have a large liquidus range and are very stable even at high temperatures. 1-ethyl-3-methyl imidazolium chloride ($C_6H_{11}N_2Cl$ or EMIC) and 1-ethyl 3-methylimidazolium dicyanamide ($C_8H_{11}N_5$ or DCA) currently are widely used as a cationic source for low temperature molten salts. 1-ethyl 3-methyl imidazolium triflouromethylsulfonate for example has a liquidus range of 471^oC with a melting point of -15^oC and a decomposition temperature of 455^oC (Ngo et al., 2000). This characteristic property enables the use of RTILs in applications involving reactions (Murugesan and Linhardt, 2005).

Recent research indicated that RTIL has a positive effect on plating performance. Aluminium plating was conducted by using ionic liquid at room temperature in a recent work (Koura, N. et al., 2007) and coating in the electrolitic aqueous solution was not obtained. 1-ethyl 3- methyl imidazolium dicyanamide (DCA) was used for nickel plating and this ionic liquid was approved as a metal plating electrode as stated by Deng et al.(Ming-Jay Deng et al., 2008).

Electroless plating is the main step of the metal coating process where the plastic substrate material must have a conductive behavior. Electroless plating provides a durable homogeneous coating with desired thickness. The polymeric substrate is nonmagnetic with a high stretching ratio with does not fail or break under distortion or elongation. The main difference of the electroless plating from

the electroplating is about their energy requirements. Electroless plating does not need electrical energy which results in uniform film formation. This method is widely used because of the formation of more uniform surface films/coatings with superior abrasion and corrosion resistance (Linka and Riedel, 1987; Kılıçarslan, 2016).

Catalysts and activation solutions for the electroless baths currently used mainly contain colloidal suspension of palladium metal and tin ions. The primary function of the bath is to precipitate colloidal palladium (palladium-tin) on the porous ABS surface. Palladium is used as a catalyst and the nickel and copper electroless precipitation reaction occurs. Nickel and copper are most widely used metals for the decorative plating of plastics (Ang et al., 2000; Liu ve Chen, 1998; Rudnik et al., 2008).

Extensive research has been conducted on electroless metal plating where the use of a catalyst forms the first step of the application. Electroless nickel and copper plating on carbon nanotubes and graphite was investigated (Ang et al., 2000, Caturla et al., 1995). Fukuhara and coworkers implemented electroless plating process by preparing copper surface catalysts (Fukuhara et al., 2005). Electroless coating of silver by using nickel phosphite catalyst was reported in another work (Song et al., 2007). The surface characterization of activated ABS plastic was conducted by using Scanning Electron Microscopy (SEM) and Ni coating was also characterized by X-Ray diffraction (XRD) (Tang et al., 2009).

The traditional process basically includes sensitization and activation steps. The plastic substrate is placed in a sensitizing solution and an activation solution during the process. The surface adsorbs some discontinuously distributed Sn as the chemical reductant so that noble metals such as Ag and Pd can be further reduced from the activating solution to serve as the catalyst for electroless plating. This process is complicated and involves the use of not only poisonous Sn but also noble metallic elements. The process also produces waste streams and contributes to environmental pollution (Caturla et al., 1995).

The aim of this study was to investigate alternative electroless plating catalysts and to develop activation solutions to be used in the electroplating

industry. Electroless baths were prepared by using environmentally friendly chemicals (EMIC & DCA) for copper and nickel plating processes on ABS plastic. The etching and the plating processes were performed with environmentally friendly chemicals instead of chromic and sulphuric acids used in the traditional processes.

The long-term impact of this study may be towards the development of a simple and effective method for a palladium-free surface activation process to improve the activity of the surface of plastics. An activation solution containing acid and salt without any Sn or Pd (Ag) was utilized and ultrasonic treatment of the surfaces of the ABS plastic was expected to produce the necessary surface defectswhich serves as the active sites for the direct electroless nickel plating. This new electroless plating process is considerably simpler when compared with the currently used traditional methods and does not involve any noble or poisonous metals as well as any expensive equipment which may reduce the process cost and environmental pollution significantly (Caturla et al., 1995).

2. LITERATURE SURVEY

2.1 Electroplating

Electroplating is the application of a metal coating to a metallic or other conducting surface by an electrochemical process (Osborne, K., 2017). Electroplating is a very widely used and diverse technology. In principle, the choice of substrate and coating metals may encompass large number of single metals and alloys; in fact, the substrate may also be polymer, a ceramic, an alloy or a composite. The coating may be a single metal, an alloy or, indeed, a metal-polymer or metal-ceramic composite (Pletcher and Walsh, 1990).

The process used in electroplating is called electro deposition (Wikipedia, 2017). The objective of an electroplating process is to prepare a deposit which adheres well to the substrate which has the required some mechanical, chemical and physical properties. Many metals may be deposited with different properties because it is not possible to define a single set of conditions for electroplating each metal. These are the bath, current density, temperature… etc. (Pletcher and Walsh, 1990).

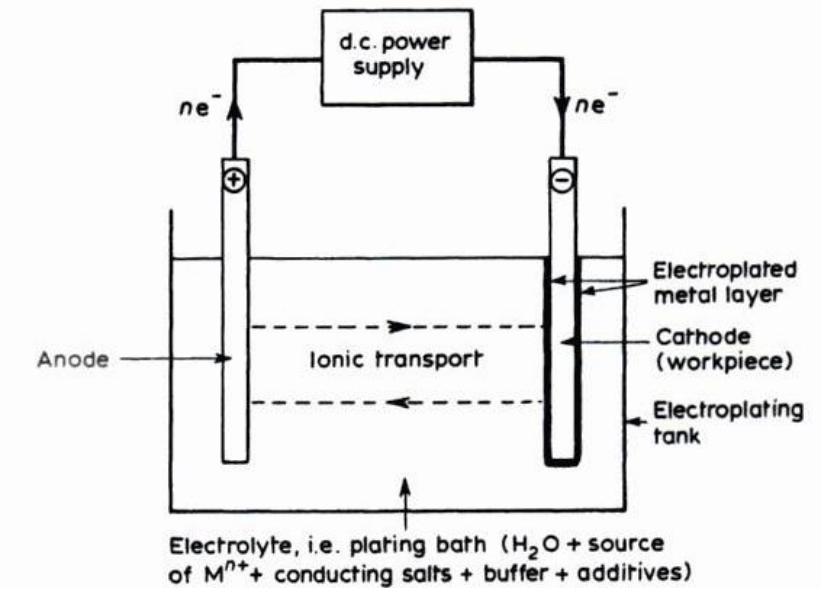


Figure 2.1 Principle of electroplating (Pletcher and Walsh, 1990).

The principle of electroplating is demonstrated on Figure 2.1 (Pletcher and Walsh, 1990). The essential components include:

1. An electroplating bath containing a conducting salt and the metal to be plated in a soluble form, as well as perhaps a buffer and additives.
2. The electronically conducting cathode, i.e. the workpiece to be plated.
3. The anode (also electronically conducting) which may be soluble or insoluble.
4. An inert vessel to contain (1) ➔ (3), typically, e.g. steel, rubber-lined steel, polypropylene or polyvinylchloride.
5. A d.c. electrical power source, usually a regulated transformer/rectifier.

The work is made the cathode (negative electrode) of an electrolysis cell through which a direct electric current is passed. The sample is immersed in an aqueous solution (the bath) containing the required metal in an oxidized form, either as an aquated cation or as a complex ion. The anode is usually a bar of the metal being plated. During electrolysis metal is deposited on to the work and metal from the bar dissolves:

at cathode: $M^{n+}_{(aq)} + ne^- \rightarrow M_{(s)}$

at anode: $M_{(s)} \rightarrow M^{n+}_{(aq)} + ne^-$

Faraday's laws of electrolysis govern the amount of metal deposited. Mathematically Faraday's laws of electrolysis can be expressed as:

$$Q \propto zm/M$$

$$Q = It = zFn$$

where Q is the charged passed, I is the current passed, t is the time the current is passed, z is the change in oxidation state, m and M are the mass and molar mass respectively of oxidized or reduced species, F is the Faraday constant (96 485 C mol^{-1}, the charge of one mole of electrons), and n is the amount of substance oxidised or reduced (Osborne, K., 2017).

These laws correctly predict that:

1. by measuring the quantity of electricity passed, one has a measure of the amount of chemical change that will thereby be produced;

2. knowing the chemical equivalent weight of a substance, one can predict the amount of that substance that will be liberated by a given quantity of electricity.

The purposes of electroplating are appearance, protection from corrosion special surface properties, engineering or mechanical properties (Mittal, V., 2015). Most electroplating coatings can be separated into categories given in Table 2.1.

Table 2.1 Categories of electroplating coatings (Mittal, V., 2015).

Sacrificial Coating	is used primarily for protection. The metal used for the coating is sacrificial, being used up, in the reaction. Common metals include: zinc and cadmium (now forbidden in many countries).
Decorative Coating	is used primarily for appeal and attractive purposes. Common metals include: copper, nickel, chromium, zinc and tin.
Functional Coatings	are coatings done based on necessity and functionality of the metal. Common metals include: gold, silver, platinum, tin, lead ruthenium, rhodium, palladium, osmium, and iridium.
Minor Metals	are normally iron, cobalt, and indium because they are easy to plate, but are rarely used in plating.
Unusual Metal Coating	are metals that are even more rarely used for plating than the minor metals. These include: As, Sb, Bi, Mn, Re, Al, Zr, Ti, Hf, V, Nb, Ta, W, and Mo.
Alloy Coatings	An alloy is a substance that has metallic properties and is made up of two or more elements. These coatings are made by plating two metals in the same cell. Common combinations include: gold–copper–cadmium, zinc–cobalt, zinc–iron, zinc–nickel, brass (an alloy of copper and zinc), bronze (copper–tin), tin–zinc, tin–nickel, and tin–cobalt.

Electroplating is widely used in industries such as automobile, airplanes, electronics, jewelry, and toys (Mittal, V., 2015). It has various industrial uses not only for corrosion protection but also to improve many features (TutorVista, 2017). Some of the examples are:

- Automobile parts are plated with chromium to give them fine finishing.
- Nickel plating is done on electrical connectors to improve friction.
- Metals such as gold, zinc- nickel can withstand high temperature; therefore, engine parts are coated with these metals or alloys to reduce the damage caused by overheating.
- For magnetic properties, nickel is coated on hard-drives which make them easier to read.
- Electroplating is used to improve premature tarnishing of metals.
- It makes brittle substances more durable and stronger.
- Nickel plating with absorption properties make wide use in aviation, and aerospace.
- Palladium plating is used to increase the thickness of the surface.

2.2 Electroless Plating

Electroless plating, also known as chemical or auto-catalytic plating, is a non-galvanic plating method that involves several simultaneous reactions in an aqueous solution, which occur without the use of external electrical power. It is mainly different from electroplating by not using external electrical power (Wikipedia, 2017). Electroless depositions have one basic characteristic in common: No power supply is necessary to drive the deposition reaction (Schlesinger and Paunovic, 2010):

$$M^{n+}_{(aq)} + ne^- \xrightarrow[electrode]{} M_{lattice}$$

In the electroless deposition process n electrons are supplied by a reducing agent, R, presenting the solution. The electron-donating species R donates electrons to the catalytic surface. In general, an electrode with lower electrode potential will reduce ions of an electrode with higher electrode potential (Schlesinger and Paunovic, 2010).

The term electroless plating was originally adopted by Brenner and Riddell to describe a method of plating metallic substrates with nickel or cobalt alloys without the benefit of an external source of electric current. Over the years, the term has been subsequently broadened to encompass any process that continuously deposits metal from an aqueous medium. In general, electroless plating is characterized by the selective reduction of metal ions only at the surface of a catalytic substrate immersed into an aqueous solution of said metal ions, with continued deposition on the substrate through the catalytic action of the deposit itself. Since the deposit catalyzes the reduction reaction, the term *autocatalytic* is also used to describe the plating process (Mallory and Hadju, 1990).

It is important to distinguish between electroplating and electroless plating (Table 2.2). They differ in the nature of their anodic reaction. Considering the simple case of discharge of metal ion, the common cathodic process is given in equation as $M^{n+} + ne^- \rightarrow M$. This supported anodic process (taking place at the same rate) (Pletcher and Walsh, 1990).

Table 2.2 Comparison of electrochemical methods for metal deposition (Pletcher and Walsh, 1990).

Property	**Electroplating**	**Electroless Deposition**
Driving force	Power supply	Autocatalytic redox reaction
Cathode reaction	$M^{n+} + ne^- \rightarrow M$	$M^{n+} + ne^- \rightarrow M$
Anode reaction	$M^n - ne^- \rightarrow M$ or $\frac{n}{2}H_2O - ne^- \rightarrow \frac{n}{4}O_2 + nH^+$	$R - ne^- \rightarrow O$
Overall cell reaction	$M_A \rightarrow M_C$ or $\frac{n}{2}H_2O + M^{n+} \rightarrow \frac{n}{4}O_2 + nH^+ + M$	$M^{n+} + R \rightarrow M + O$
Site of cathode reaction	Substrate (work-piece)	Substrate (work-piece) which must have a catalytic surface
Site of anode reaction	Separate anode	Substrate (workpiece)
Anode reactant	M or H_2O	R, reducing agent in solution
Nature of deposit	Pure metal (or definite alloy)	Usually M contaminated by O/R derived species
Thickness limit/μm	1-100	1-100

In electroplating dissolution of separate anode, M_a occurs: $M_A - ne^- \rightarrow M_A^{n+}$ (or oxygen evolution takes place). The overall cell reaction is then: $M_A \rightarrow M_C$. In ideal case, metal is simply transferred from anode to cathode (Pletcher and Walsh, 1990).

In electroless deposition process, the oxidation of a soluble reducing agent $R - ne^- \rightarrow O$ occurs on some sites on the substrate surface such that the overall process is: $M^{n+} + R \rightarrow M + O$. The deposition of the metal is a very favourable process which occurs at the fast rate on the growing deposit (Pletcher and Walsh, 1990; Schlesinger and Paunovic, 2010).

Distinction between electrolytic and electroless deposition processes must be made, as illustrated in Figure 2.2.

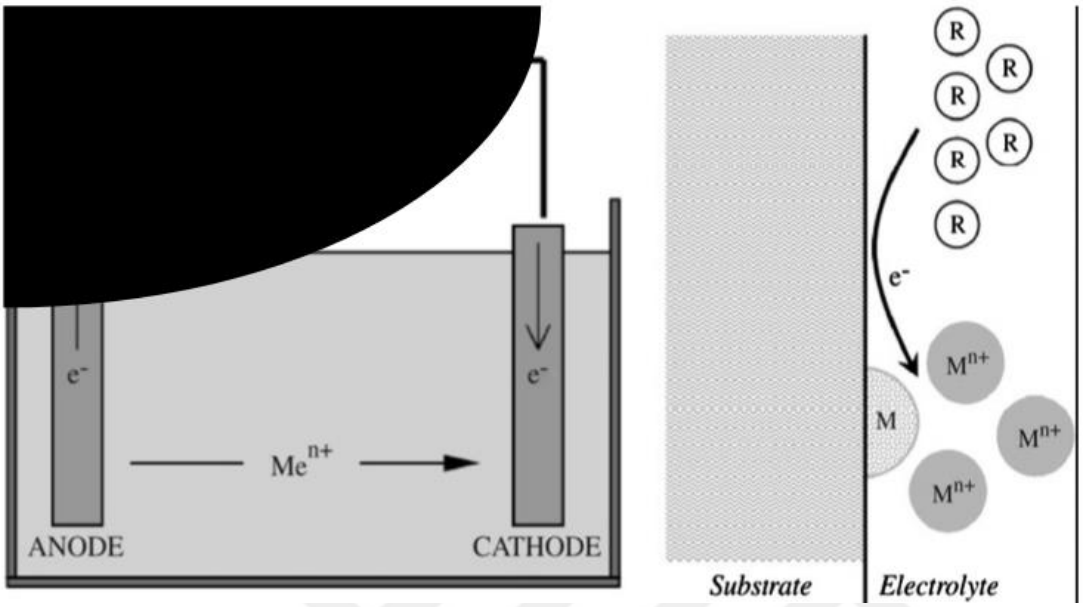


Figure 2.2 Cell set up for (left side) electrolytic deposition process plus external power source; (right side) electroless deposition with reducing agent R as the source of electrons (Carraro et al., 2007, from Sudagar et al., 2013).

In general, electroless plating bath contains a source of metal ions, reducing agent, complexing agent, stabilizer, buffering agent, wetting agent, and its parameters include controlled temperature and pH. Their role is briefly summarized in Table 2.3. The process of electroless deposition is one of the most elegant methods available for the deposition of alloy coatings. The technique involves autocatalytic reduction, at the substrate /solution interface of cations by electrons released from the suitable reducing chemicals (Scholder et al., 1931, from Sudagar et al., 2013) and significant degree of elemental release from these agents allowing, co-deposition of reduced metal, in order to product binary, ternary or even quaternary alloys (Gabe, 2009 and Gutzeit, 1958, from Sudagar et al., 2013). The co- deposition of composite materials in the alloy coating leads to electroless composite coatings.

Table 2.3 Component and parameters of bath and their functions (Sudagar et al., 2013).

Component/ parameter	**Function**
Metal ions	Source of metal
Reducing agents	Supply electrons to reduce the metal ions
Complexants	Prevent excess of free metal ions concentration
Accelerators	Accelerate the reducing agent and increase the deposition
Stabilizers	Stabilize the bath from decomposition by shielding catalytically active deposition
Buffers	Sustain the pH for long time
pH regulators	pH adjustment
Temperature	Energy for deposition

Electroless coating processes gained wide acceptance in the market due to the coatings' excellent corrosion and wear resistance properties and it is also good for soldering and brazing purposes. In electroless plating technique many metals like nickel, copper, gold, silver, palladium and cobalt as well as some alloys containing these metals plus phosphorus(P) and boron(B) are being deposited (Sudagar et al., 2013; Schlesinger and Paunovic, 2010). By far the most important examples of electroless deposition in industry are deposition of (Pletcher and Walsh, 1990):

1. Nickel onto steel substrates, largely for engineering applications, but also for uses in the electronics industry.
2. Copper onto printed circuit boards and plastics.

The cost of electroless coating a component is generally higher that of conventional electroplating owing mainly to the use of more expensive chemicals and the necessity of heating the solutions. Moreover, the rates of deposition are rather low, ranging from a typical 25 μm h^{-1} for acid electroless nickel baths down to the 2 μm h^{-1} for alkaline copper solutions at room temperature (although the recently developed 'heavy coppers' can plate at 6 μm h^{-1}) The use of electroless techniques is therefore restricted to those situations where the properties of the coating or the mode of application outweigh the overall cost of the process (Pletcher and Walsh, 1990).

Corrosion –resistant, light and resilient polymer substrates are electroless plated with metal for largely decorative and functional applications. Modern polymers which are decoratively plated (e.g. with Ni then Cr) include ABS, PPO (polyphenylene oxide) and PAE (polyarylether). Following cleaning and etching procedures, the polymer surface is 'activated' by depositing an adsorbed Pd layer by immersion in a Pd-containing solution. The Pd surface acts as a catalyst for electroless copper or nickel plating (Figure 2.3). Subsequent electroplating by, for example, copper, nickel then chrome provides a visually pleasing finish which also protects against excess heat, ultraviolet degradation, wear and the build-up of static electricity. An extremely wide range of components are finished in this fashion for consumer, domestic, electronic and automotive sectors of industry,examples including knobs on hi-fi equipment, top on perfume bottles, consume jewellery and car trim (Pletcher and Walsh, 1990).

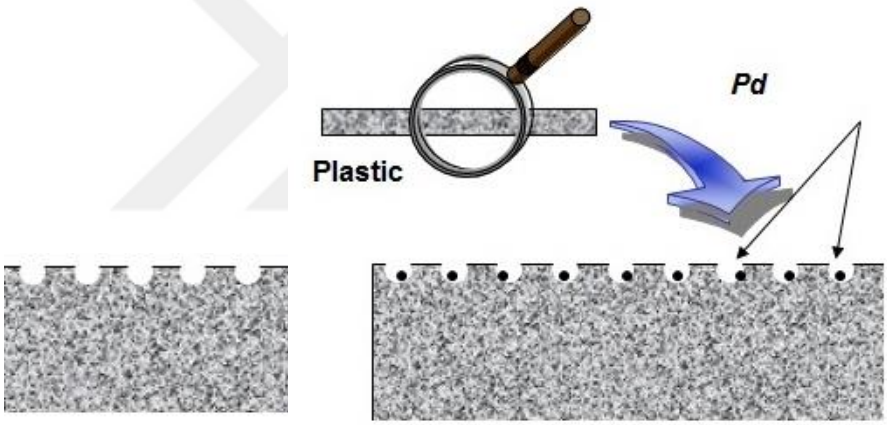


Figure 2.3 a) Etching state of plastic b) Pd surface acts as a catalyst (Boreas Kimya, 2017).

In the industry two main electroless baths are used which are also investigated in the thesis: Copper and nickel electroless baths. The important criteria abovementioned is reducing agent.

2.2.1 Electroless copper bath

The overall reaction for electroless copper deposition, with formaldehyde (HCHO) as the reducing agent, is

$$Cu^{2+} + 2HCHO + 4OH^- \rightarrow Cu + 2HCOO^- + 2H_2O + H_2$$

where $HCOO^-$ (formic acid) is the oxidation product of the reducing agent (Schlesinger and Paunovic, 2010).

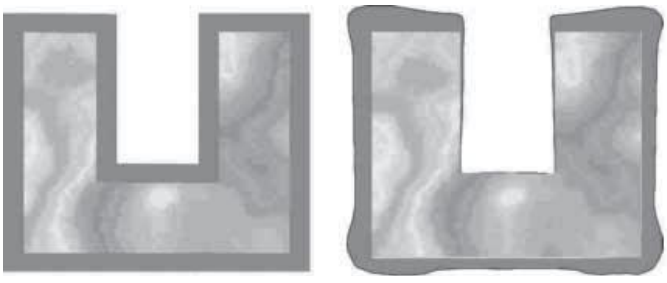
The reduction reaction, cathodic partial reaction is $Cu^{2+}_{(aq)} + 2e^-_{catalytic\ surface} \rightarrow Cu_{lattice}$ and the oxidation reaction, the anodic reaction is

$$HCHO + 2OH^- \rightarrow HCOO^- + H_2O + \frac{1}{2}H_2O + e^-$$

These two partial reactions, however, occur at one and the same electrode, namely the metal–solution interphase (Schlesinger and Paunovic, 2010).

2.2.2 Electroless nickel bath

Elecroless nickel coating is most widely accepted in engineering application due to its unique characteristics, including excellent corrosion, wear and abrasion resistance, ductility, lubrication, soldering and electrical properties. These coatings are more uniform in thickness than electroplated nickel coatings (Figure 2.4) (Sudagar et al., 2013).



(a) **(b)**

Figure 2.4 Comparison of the a) Electroless and b) Electrolytic metal plating homogenity of coated specimen (Kılıçarslan, 2016).

Four reducing agents have been used for the industrial deposition of the electroless nickel coatings. Sodium hypophosphite produces nickel-phosphorus alloy, which have a 90% share of the industrial application. Sodium borohydride and amine boron produces nickel-boron alloys. Hydrazine produces pure nickel, which is over 99% pure (Sudagar et al., 2013). Electroless nickel hypophosphite baths are preferred according to the electroless nickel bath consisting of boron compounds and hydrazine at the commercial usage because of the lower cost (Yazıcıoğlu, 2007; from Kılıçarslan, 2016).

The literature abounds in the number of possible bath formulations for the electroless deposition of nickel using many different reducing agents and under widely different plating conditions (Schlesinger and Paunovic, 2010). The plating baths for electroless nickel are composed mainly of nickel sulfate (source of Ni), sodium hypophosphate (reducing agent) and chemicals to prevent precipitation of insoluble nickel hydroxide (Sudagar et al., 2013). Table 2.4 gives a summary of possible bath formulations for the electroless deposition of nickel where no additives are suggested (except for baths 3 and 5 where the often-used additive Pb^{2+} is included) and with sodium hypophosphite as reducing agent.

At the basic constituents of autocatalytic nickel/phosphorus alloy deposition contains hypophosphite ions plus an organic chelating agent, but these solutions can be either weakly acid or alkaline. The alkaline baths can be used at temperatures between 30-90^{o}C and contain a relatively high concentration of ammonium ions. Additively, all autocatalytic baths deposition rate is very temperature dependent and so the alkaline baths have preferred to industrial use for thick coating depositions. Temperatures higher than 80^{o}C required to give a commercial acceptable rate of deposition (≈15µm/h), ammonia is lost rapidly from hot alkaline solutions, causing objectionable fumes and resulting in the bath becoming unbalanced. However, their use is advantageous when preparing plastics to be plated when these have to be processed at relatively low temperatures. The ammoniacal bath works well at temperatures below 40^{o}C (Schlesinger and Paunovic, 2010).

Table 2.4 Bath composition for electroless nickel deposition using hypophosphite reducing agent (Pearlstein, 1974, from Schlesinger and Paunovic, 2010).

Baht Constituents (gL^{-1})	**Acid Baths**				**Alkaline Baths**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Nickel chloride, $NiCl_2.6H_2O$	30	30	-	21	26	30	20	-
Nickel sulfate, $NiSO_4.6H_2O$	-	-	25	-	-	-	-	25
Sodium hypophosphate, $NaH_2PO_3.H_2O$	10	10	23	24	24	10	20	25
Hydroxyacetic acid, $HOCH_2COOH$	35	-	-	-	-	-	-	-
Sodium citrate, $Na_3C_6H_5O_7.H_2O$	-	12,6	-	-	-	84	10	
Sodium acetate, $NaC_2H_3O_2$	-	5	9	-	-			
Succinic acid, $C_4H_6O_4$	-	-	-	-	-	-	-	-
Sodium fluoride, NaF	-	-	-	-	-	-	-	-
Lactic acid, $C_3H_6O_3$	-	-	-	-	-	-	-	-
Propionic acid, $C_3H_6O_2$	-	-	-	-	-	-	-	-
Ammonium chloride, NH_4Cl	-	-	-	-	-	-	-	-
Sodium pyrophosphate, $Na_4P_2O_7$	-	-	-	-	-	-	-	-
Lead ion, Pb^{2+}	-	-	-	-	-	-	-	-
pH	4-6	4-6	4-8	6	4-6	8-10	9-10	10-11
Temperature (^oC)	100	100	85	100	100	95	85	70

There are three possible reactions for nickel/phosphorus baths at the operating range of 60-95^{o}C (Yazıcıoğlu, 2007, from Kılıçarslan, 2016):

$$3\,NaH_2PO_2 + 3H_2O + NiSO_4 \rightarrow 3\,NaH_2PO_3 + H_2SO_4 + 2H_2 + Ni^0 \quad (1)$$

$$2H_2PO_2^- + Ni^{2+} + 2H_2O \rightarrow 2H_2PO_3 + H_2 + 2H^+ + Ni^0 \quad (2)$$

$$Ni^{2+} + H_2PO_2^- + H_2O \rightarrow Ni^0 + H_2PO_3^- + 2H^+ \quad (3)$$

The metallic nickel is produced at the reactions and the hydrogen production (reaction 1,2 &3) at the reactions cause the acidity in the bath.

$$H_2PO_2^- + H_{ads} \rightarrow H_2O + OH^- + P \quad (4)$$

$$3H_2PO_2^- \rightarrow H_2PO_3^- + H_2O + 2OH^- + 2P \quad (5)$$

As shown in reaction 4 & 5, phosphorus is produced with nickel. The coating consists of 3-15% Ni-P alloy at the nickel/phosphorus baths (Riedel, 1991, from Kılıçarslan, 2016).

Alkaline Baths are ideal for coating at lower temperature. Generally used for the coating of plastic material such as ABS. (Riedel, 1991; Turan, 2002, from Kılıçarslan, 2016).

The appearance of the electroless nickel plating is shown in Figure 2.5

Figure 2.5 Electroless nickel plating (TKF Metal Plating Co., 2017).

2.3 Room Temperature Ionic Liquids (RTIL)

An ionic liquid (IL) is a salt in which the ions are poorly coordinated, which results in these solvents being liquid below 100°C, or even at room temperature (room temperature ionic liquids, RTIL's). At least one ion has a delocalized charge and one component is organic, which prevents the formation of a stable crystal lattice (Wasserscheid and Keim, 2000).

Salts having a low melting point are liquid at room temperature, or even below, and form a new class of liquids usually called room temperature ionic liquids (RTIL). Information about RTILs can be found in the literature with such key words as: room temperature molten salt, low-temperature molten salt, ambient-temperature molten salt, liquid organic salt or simply ionic liquid (Galinski et al., 2006).

One of the first RTILs was a mixture of 1-ethyl-1 H-imidazolium (emim) Cl with $AlCl_3$ forming a series of equilibria between (emim)($AlCl_4$), (emim)(Al_2Cl_7), and (emim)(Al_3Cl_{10}). This RTIL is not water stable. The discovery of water-insoluble RTILs such as 1-buthyl-3-methyl-1 h-imidazolium (bmim)(PF_6) allowed the development of new work-up methods, including the separation of water-soluble byproducts by simple extraction. Some transition metal catalysts that are soluble in ionic liquids may be recycled together with the ionic liquid, after extraction with water and the non-polar organic solvent used for product separation. The catalyst and ionic liquid may be recycled several times (Wasserscheid and Keim, 2000).

The properties of a modern ionic liquid are summarized in Table 2.5 and Table 2.6 presents some illustrative data that how these ionic liquids compare with other liquids, especially those which conduct electricity. Particularly significant are (Table 2.5) the low vapor pressures in most instances which contrast the environmental problems of volatile organic solvents and (Table 2.6) moderate specific conductivities, usually in the same range as those of aqueous electrolytes. It is found that many such systems are excellent solvents or catalysts for organic reactions and some simple processes such as electro deposition.

Unfortunately, one finds reports of new “ionic liquids” without data on conductivities, which would establish that they are dissociated to some extent at least into ions (Johnson, K. E., 2007).

Table 2.5 Modern ionic liquids (Johnson, K. E.,2007).

Property	**Explanation**
A salt	Cation and/or anion quite large
Freezing point	Preferably below 100 ^{o}C
Liquidus range	Often > 200 ^{o}C
Thermal stability	Usually high
Viscosity	Normally <100cP, workable
Dielectric constant	Implied ≤ 30
Polarity	Moderate
Specific conductivity	Usually < mScm^{-1}, "Good"
Molar conductivity	<10 Scm^{2}mol^{-1}
Electrochemical window	>2V, even 4.5 V, except for Bronsted acidic systems
Solvent and/or catalyst	Excellent for many organic reactions
Vapor pressure	Usually negligible

Table 2.6 Properties of various liquids (Johnson, K. E.,2007).

Compound IonicLiquids	**Temp. ^{o}C**	**Molarity Mol L^{-1}**	**Spec. Cond Scm^{-1}**	**Molar Cond Scm^{2}mol^{-1}**	**Visc. cP**
NaCl	900	25.3	3.88	154	1.05
LiCl	780	35	7.59	217	-
$NaNO_3$	450	21.4	0.72	34	6.90
Na_2SiO_3	1750	≈18	4.8	≈270	-
$AlCl_3$(63%)-NaCl	175	5.8	0.24	41	3.85
LiCl-KCl	450	29.7	1.57	53	2.44
$[(CH_3)_3S][HBr_2]$	25	7.3	0.034	4.7	20.5
emimCl(%60)-$AlCl_3$	25	5.3	0.0065	1.2	47
emimAl_2Cl_7	25	3.4	0.015	4.4	14
bmimCF_3CO_2	20	5.1	0.0032	0.6	73
bupy BF_4	25	5.5	0.0019	0.3	103
emim$[(CF_3SO_2)_2N]$	25	3.7	0.0057	1.5	31
Others					
H_2O	25	55.3[a]	4x10^{-8}	7x10^{-7}	0.895
0.1 M aq. KCl	25	0.1[b]	0.013	129	0.9
Na	100	40.4	1.04x10^{5}	2.6x10^{6}	1.058
H_2SO_4	25	0.049[b]	0.0104	212	24.55
CH_3COOH	25	17.5[a]	8x10^{-9}	4.6x10^{-7}	1.056
HF	0	50.1[a]	1x10^{-6}	2x10-5	0.256
a:total molarity. b:ionic molarity. emim:1-ethyl-1 H-imidazolium. bmim: 1-buthyl-3-methyl-1 h-imidazolium. bupy: 1-buthylpyridinium					

2.3.1 EMIC

EMIC ($C_6H_{11}N_2Cl$, 1-ethyl-3-methyl imidazolium chloride), is widely employed as a cationic source for low temperature molten salts. The cation consists of a five-membered ring with two nitrogen and three carbon atoms, i.e. a derivative of imidazole, with ethyl and methyl groups substituted at the two nitrogen atoms (Figure 2.6).

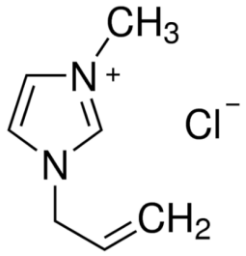


Figure 2.6 EMIC ($C_6H_{11}N_2Cl$, 1-ethyl-3-methyl imidazolium chloride).

The first generation of ionic liquids, formerly known as room temperature molten salts, were based on chloroaluminates in combination with organic halides, such as the type 1 eutectic aluminum chloride–1-ethyl-3-methylimidazolium chloride ($AlCl_3$–EMIC), and possessed the major disadvantage of being hygroscopic with an extreme sensitivity to moisture, requiring handling under a controlled inert gas atmosphere, in addition to being rather corrosive. Second- and third-generation air- and water-stable ionic liquids, such as the type 1 zinc chloride–EMIC and type 3 choline chloride–ethyleneglycol (ChCl:2EG) eutectic mixtures, do not require the special environments, generally dry nitrogen or argon, of their predecessors (Endres F et al., 2008). The eutectic types of ILs can be seen from the Table 2.7.

Table 2.7 Types of eutectic ILs based on complexing agent (Marsh et al., 2004).

Eutectic Type 1	$Y=MCl_x$	M=Zn, Sn, Fe, Al, Ge, Ga
Eutectic Type 2	$Y=MCl_x.yH_2O$	M=Cr, Co, Cu, Ni, Fe
Eutectic Type 3	Y=RZ	$Z=CONH_2$, COOH, OH

2.3.2 DCA

DCA ($C_8H_{11}N_5$,1-ethyl 3-methylimidazolium dicyanamide), is also widely used as a cationic source for low temperature molten salts. The cation consists of a five-membered ring with two nitrogen and three carbon atoms, i.e. a derivative of imidazole, with ethyl and methyl groups substituted at the two nitrogen atoms (Figure 2.7).

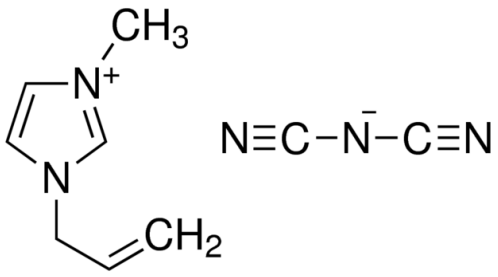


Figure 2.7 DCA ($C_8H_{11}N_5$,1-ethyl 3-methylimidazolium dicyanamide) .

2.4 ABS (Acrylonitrile Butadiene Styrene)

Acrylonitrile–butadiene–styrene (ABS) polymers are composed of elastomer dispersed as a grafted particulate phase in a thermoplastic matrix of styrene and acrylonitrile copolymer (SAN). The presence of SAN grafted onto the elastomeric component, usually polybutadiene or a butadiene copolymer, compatabilizes the rubber with the SAN component (Kulich et al., 2001). ABS materials have superior strength, stiffness and toughness properties to many plastics and so they are often considered in the category of engineering plastics (Crawford, 1998). The system is structurally complex. This allows considerable versatility in the tailoring of properties to meet specific product requirements. Numerous grades of ABS are available, including alloys and specialty grades for high heat, flaming-retardant, or static dissipative product requirements. Good chemical resistance combined with the relatively low water absorptivity (<1%) results in high resistance to staining agents (Kulich et al., 2001).

ABS is a terpolymer that its chemical formula $(C8H8)x\cdot(C4H6)y\cdot(C3H3N)z$ (Figure 2.8). The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene (Wikipedia,2017).

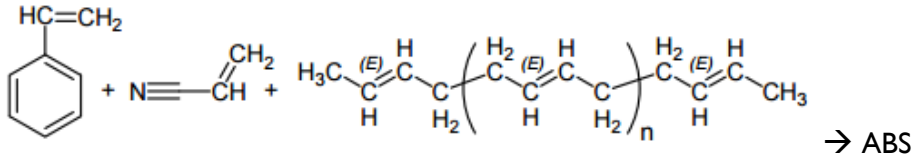


Figure 2.8 (Styrene + Acrylonitrile + Polybutadiene → ABS) Structure of ABS (Beşergil, 2017).

The three commercial processes for manufacturing ABS are emulsion, mass, and mass-suspension. ABS can be processed by compression and injection molding, extrusion, calendering, and blow molding. Post-processing operations include cold forming, painting, and adhesive bonding (Kulich et al., 2001).

It is widely used for machining pre-production prototypes since it has excellent dimensional stability and is easy to paint and glue. Applications of ABS

are housings for vacuum cleaners, kitchen appliances, telephones, toys, the automotive industry, fascia panels, hair brush handles, luggage, helmets, the electrical/electronics segment (primarily in white goods & computer/communication electronics) (Wikipedia,2017; Crawford, 1998).

Blending of polymers is often used as a means to obtain desired properties and/or properties intermediate between certain polymers. Blends can be divided into two classes, those in which the blend properties are approximately an average of the properties of the constituents, and those of the individual polymers, i.e. there is a synergistic effet on blending. Polymer blends containing ABS contribute a large volume of ABS usage (Table 2.8) (Adams et al., 2017).

Table 2.8 Example of blends with ABS (Adams et al., 2017).

Blend	**Key Properties**	**Applications**
PC/ABS	Heat resistance, low temperature impact, processability, ease of flame retarding	Automotive, computer housing, lawn and garden, power tools, recreational vehicles
PVC/ABS	Impact strength and toughness, flame retardance, UV stability, processability	Electrical components, appliances, business machine housing, housewares
Nylon/ABS	High impact, chemical resistance, low moisture sensivity	Automtive body panels and underhood components, vacuum cleaner housing
TPU/ABS	Chemical and abraision resistance, low temperature toughness	Auto bumper fascia
PBT/ABS	Processability, impact strength, heat and chemical resistance	Lawn and garden equipment, small appliances, fluid engineering industry
Polysulphone/ABS	Processability, low cost, heat resistance, can be plated	Appliances, auto window handles, faucets, food trays

It is important to realize also that within the range of grades that exist for a particular plastic, there can be significant differences in mechanical properties. Fig. 2.9 illustrates the typical variation which occurs for the different grades of ABS. It may be seen that very often a grade of material selected for some specific desirable feature (e.g. high impact strength) results in a decrease in some other property of the material (e.g. tensile strength) (Crawford, 1998).

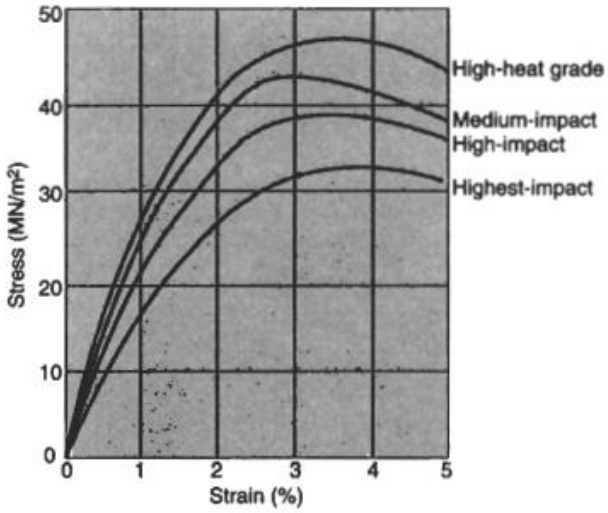


Figure 2.9 Effect of grade on mechanical properties of ABS (Crawford, 1998).

There are some mechanical, specific and general properties of ABS. They are illustrated in Table 2.9 and Table 2.10.

Table 2.9 Short term and thermal properties of ABS (high impact)(Crawford, 1998)

Density (kg/m^3)	1040
Tensile Strength (MN/m^2)	38
Flexural Modulus (GN/m^2)	2.2
% Elongation at Break	8
Specific Heat(kJ/kg K)	1.3
Thermal Conductivity (W/m/K)	0.25
Coefficient of Thermal Exp. ($\mu m/m/^oC$)	90
Thermal Diffusivity (m^2/s) $*10^{-7}$	1.7
Glass Transition Temperature, T_g (^oC)	115
Max. Operating Temp. (^oC)	70

Table 2.10 Melt flow analysis for ABS (Crawford, 1998)

Moulding Temperature (^oC)	230
Mould Temperature (^oC)	60
Freeze-off Temperature (^oC)	140
Thermal Diffusivity (m^2/s)	$0.9 * 10^{-7}$

The used ABS plastic is LG MP 220 ABS in the experiments.

3.EXPERIMENTAL STUDY

3.1 Materials (Chemicals)

The chemicals used in the experiments were listed in Table 3.1.

Table 3.1 Chemicals used in the experiments.

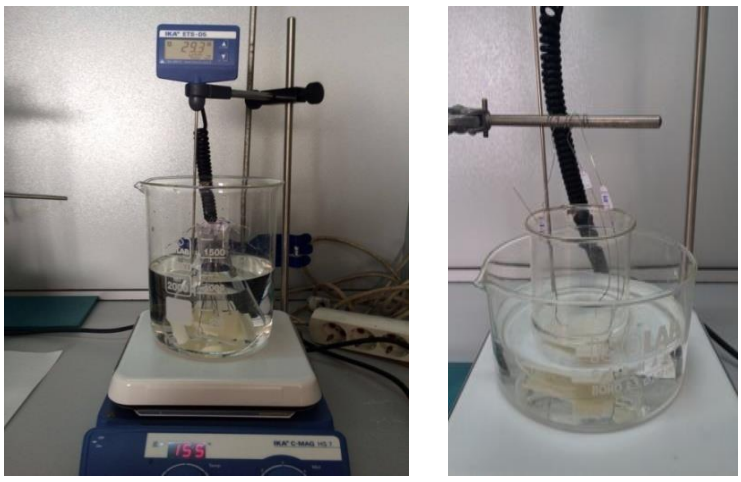
Chemical	Formula	Trademark	Usage, Aim
EMIC	$C_6H_{11}N_2Cl$	TCI	RTIL, Catalyst
DCA	$C_8H_{11}N_5$	TCI	RTIL, Catalyst
Sodium Hydroxide	NaOH	Merck	pH Adjustment
Ammonia	NH_3	Merck	pH Adjustment
Ammonium Nitrate	NH_4NO_3	Atabay Kimya	Composition of Aqueous Solution (Luo, L-M. et all, 2014)
Hydrogen Peroxide	H_2O_2	Galenik Ecza ve Kimyevi Maddeler Deposu	
Ammonium Fluoride	NH_4F	Alfa Aesar	
Nickel Chloride	$NiCl_2 \cdot 6H_2O$	Analar Trade Mark	Composition of the Electroless Nickel Plating Solution (J. Sudagar et all, 2014)
Sodium Hypophosphate	$NaH_2N_2PO_3 \cdot H_2O$	Aldrich Chemistry	
Sodium Citrate	$Na_3C_6H_5O_7 \cdot H_2O$	Merck	
Ammonium Chloride	NH_4Cl	Merck	
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	Sigma Aldrich	Composition of the Electroless Copper Plating Solution (Luo, L-M. et all, 2014)
EDTA-2Na	$C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$	Merck	
2,2-Dipyridyl	$C_{10}H_8N_2$	Alfa Aesar	
Formalin	CH_2O	Sigma Aldrich	

3.2 Electroless Plating Procedure

The electroless plating experiments were performed in fume hood at atmospheric pressure and at different plating temperatures. The experiments consist of four steps: preparing the chemicals and materials, etching, plating and the analysis characterization of samples. The investigated parameters were sandpaper size, plating time, plating temperature, pH and effects of ionic liquid types (RTIL). In this study two different metals (copper and nickel) were used for the electroless plating of ABS plastic.

3.2.1 Electroless copper plating procedure

Initially, 20 mm x 35 mm x 1.5 mm ABS plastic samples were grounded with the 120-320-500 grit size sandpapers to increase the surface area for molecular bonding. The samples were placed in a 65 ^{0}C oven for 4 to 5 h to remove the stress. The samples were taken from oven and placed in a 10g/L NaOH alcoholic solution (Figure 3.1.a) and NaOH alcoholic solution was placed into in a 35-40 ºC water bath for 30 min. to dislodge the grease and for a hydrophilic plastic surface (Figure 3.1.b) (Luo et al., 2014).



(a) **(b)**

Figure 3.1 a) Samples in alcoholic solution, b) Alcoholic solution in water bath.

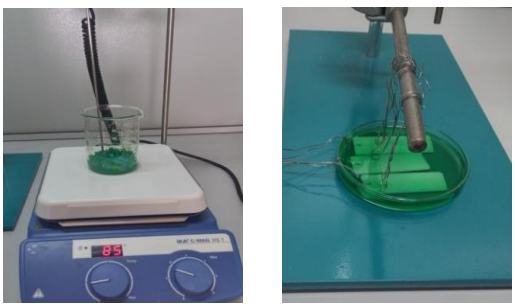
The samples were placed in an aqueous solution with a certain ratio of nitric acid, hydrogen peroxide and ammonium fluoride (Table 3.2). It was exposed to ultrasonic wave for 30 min. for non-noble metal activation pretreatment (Figure 3.2). Then resultant samples were washed with deionized water (Luo et al., 2014).

Table 1.2 Composition of aqueous solution (Luo et al., 2014).

Chemical	**Density (g/ cm^3)**	**Mass (g)**	**Volume (mL/L)**
HNO_3	1.51	378.2 - 453.9	250 - 300
H_2O_2	1.45	13.6 – 20.41	9.38 – 14.08
NH_4F	1.009	2 - 4	1.98 – 3.96

Figure 3.2 Ultrasonic bath (Decon FS-100B ultrasonic cleaner digital timer & heater).

For the material pretreatment solution of $CuCl_2$ and ionic liquid were weighed with the molar ratio 2:1 and the samples were immersed in the ionic liquid solution and was left for a week (Figure 3.3).



(a) **(b)**

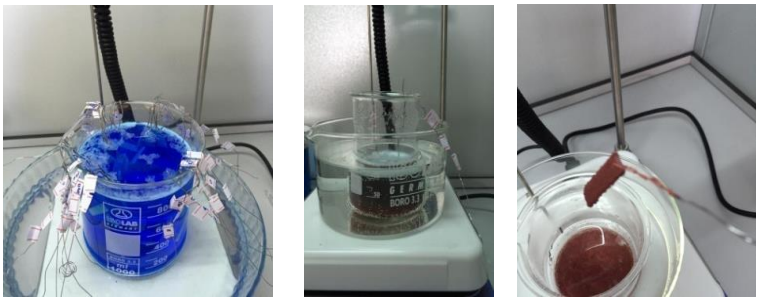
Figure 3.3 a) Ionic liquid solution, b) Material pretreatment.

The samples were placed at 60-80^{o}C bath (Figure 3.4.b) containing the plating solution prepared with the chemicals at Table 3.3.

Table 2.3 Composition of the electroless copper plating solution (Luo. et al., 2014).

Chemical	**Formula**	**Concentration (g/L)**
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	12-15
EDTA-2Na	$C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$	40-45
2,2-Dipyridyl	$C_{10}H_8N_2$	0.04-0.05
Formalin	CH_2O	20-25

NaOH was gradually added during the process to ensure the pH. The operating condition of pH of the plating solution was 11-12. No apparent phenomenon was observed at the initial stage (10 min to 20 min). The reaction then produced numerous bubbles for 50 min to 60 min (Figure 3.4). After being washed by deionized water, the final copper plating specimen was placed in a 45 °C oven to dry.



(a) **(b)** **(c)**

Figure 3.4 a) Plating solution at the beginning of the experiment, b) Plating solution during plating, c) Plating solution at the end of experiment.

Finally, the surface morphology and amount of deposit analysis were done by Fischerscope X-Ray XDL-B System, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM-EDX).

3.2.2 Electroless Nickel Plating Procedure

Previously, 20 mm x 35 mm x 1.5 mm ABS plastic samples were grounded with the 400-800 grit size sandpapers to increase the surface area for molecular bonding. The samples were placed in a 65 ^{0}C oven for 4 to 5 h to remove the stress. The samples were taken from oven and placed in a 10g/L NaOH alcoholic solution (Figure 3.1.a) and NaOH alcoholic solution was placed into in a 35-40 ºC water bath for 30 min. to dislodge the grease and for a hydrophilic plastic surface (Figure 3.1.b) (Luo et al., 2014).

The samples were placed in an aqueous solution with a certain ratio of nitric acid, hydrogen peroxide and ammonium fluoride (Table 3.2). It was conducted to ultrasonic wave for 30 min. for non-noble metal activation pretreatment (Figure 3.2). Then resultant samples were washed with deionized water (Luo et al., 2014).

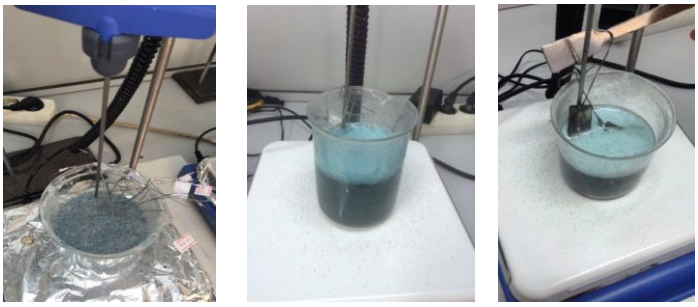
For the material pretreatment solution of $NiCl_2$ and ionic liquid were weighed with the molar ratio 2:1 and the samples were immersed in the ionic solution and was left for a week (Koura et al., 2008). The samples were placed at 60-80^{o}C bath (Figure 3.5b) containing the plating solution prepared with the chemicals at Table 3.4.

Table 3.4 Composition of the electroless nickel plating solution (J. Sudagar et all, 2014).

Chemical	**Formula**	**Concentration (g/L)**
Nickel Chloride	$NiCl_2 \cdot 6H_2O$	20
Sodium Hypophosphate	$NaH_2N_2PO_3 \cdot H_2O$	20
Sodium Citrate	$Na_3C_6H_5O_7 \cdot H_2O$	45
Ammonium Chloride	NH_4Cl	30

NaOH and NH_3 was gradually added during the process to ensure the pH. The operating condition of pH of the plating solution is 8-9. No apparent phenomenon was observed at the initial stage (10 min to 20 min). The reaction

then produced numerous bubbles for 50 min to 60 min. (Figure 3.5a). After being washed by deionized water, the final nickel plating specimen was then placed in a 45 °C oven to dry.



(a) **(b)** **(c)**

Figure 3.5 a) Starting time of bubbles b) Plating solution during plating c) Plating solution at the end of experiment

Finally, the surface morphology and amount of deposit analysis were done by Fischerscope X-Ray XDL-B System, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM-EDX).

3.3 Analysis Techniques

Fischerscope X-Ray XDL-B System, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM and SEM-EDX) equipment were used for surface morphology and amount of deposit analysis.

(a) **(b)** **(c)**

Figure 1. 6 a) Fischerscope X-Ray XDL-B system, b) X-ray diffraction (XRD), c) Scanning electron microscopy (SEM)

Deposition amounts were determined by using X-ray analysis (Figure 3.6a) that was performed in TKF Metal Plating Industry. According to the results obtained from X-ray analysis, the samples that gave the best plating results were analyzed in XRD at Metallurgical and Materials Engineering Department in Izmir Dokuz Eylül University (Figure 3.6b). After determination of XRD analysis of the samples SEM-EDX (Figure 3.6c) analyses were performed at Metallurgical and Materials Engineering Department Laboratory in Izmir Dokuz Eylül University.

4. RESULTS AND DISCUSSION

In this thesis, the electroless copper and nickel plating on ABS plastic was performed. The effects of RTIL as catalyst, sandpaper size and plating time were investigated at constant temperature and pH, for the amount of deposit in the experiments:

4.1 Electroless Copper Plating with EMIC & DCA

In the study, the electroless copper plating was performed with RTIL used as catalyst. The effects of EMIC and DCA ionic liquid types, 120-320-500 sandpaper sizes and 90-120-150 min. plating times were investigated for the amount of deposit. The plating bath temperature was taken as constant at 60^0C. The plating bath pH was adjusted to 11-12. The samples were analyzed by Fischerscope X-Ray XDL-B System. The Figure 4.1 - 4.8 of results were obtained.

The experimental procedure was given in the Part 3.2.1.

Plating time effect for DCA and EMIC was illustrated at Figures 4.1-4.4.

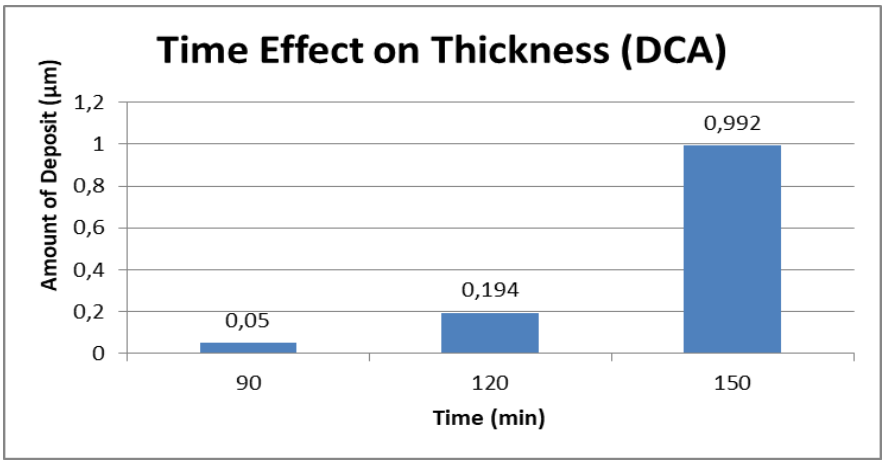


Figure 2.1 Time effect on amount of deposit for DCA and 320 grit size sandpaper.

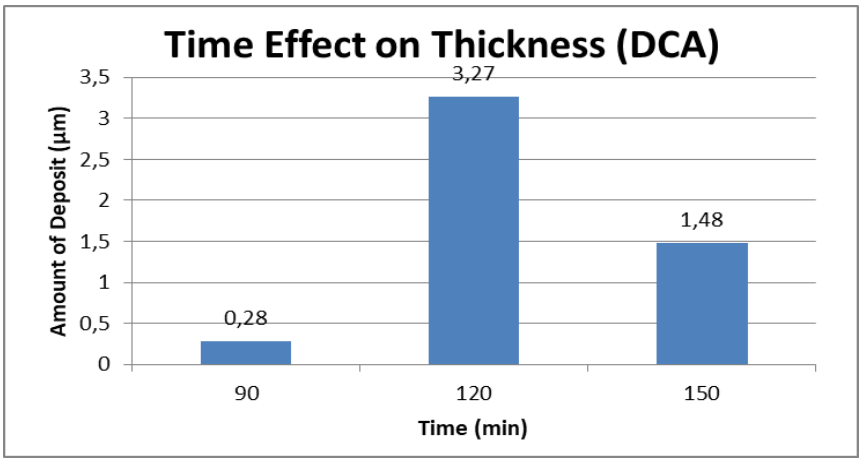


Figure 4.2 Time effect on amount of deposit for DCA and 120 grit size sandpaper.

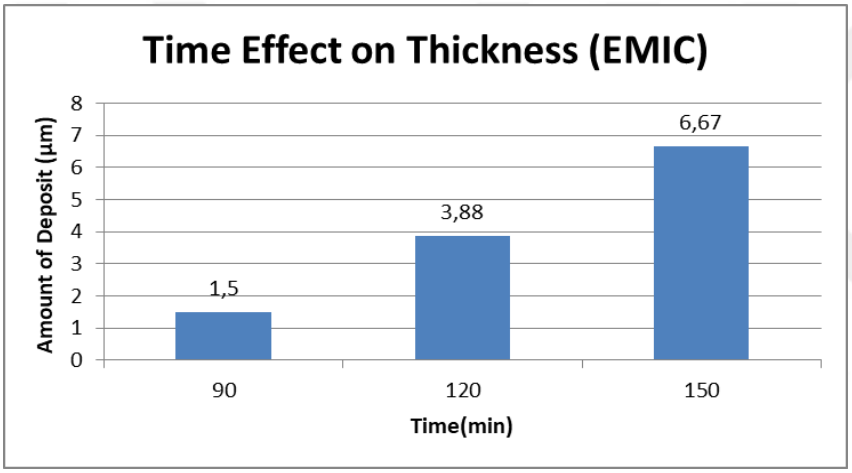


Figure 4.3 Time effect on amount of deposit for EMIC and 500 grit size sandpaper.

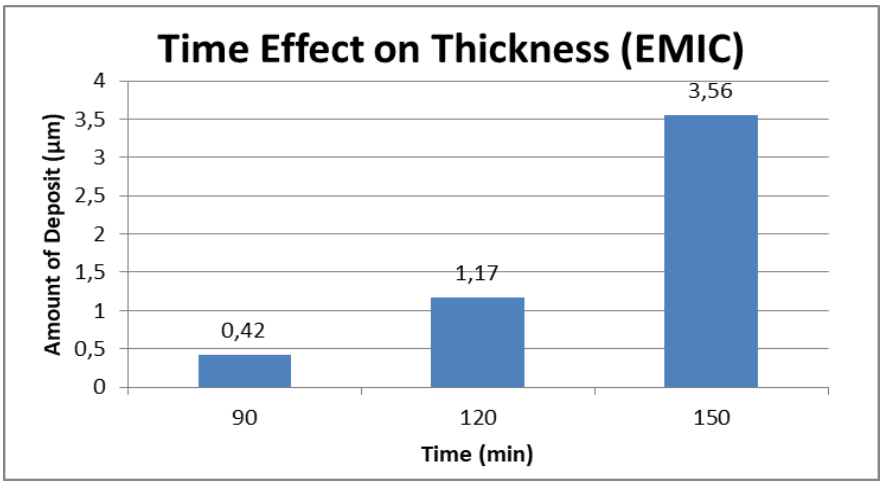


Figure 4.4 Time effect on amount of deposit for EMIC and 120 grit size sandpaper.

The dependence of plating time on the amount of deposit was investigated for both ionic liquids (Figures 4.1 & 4.4). The amount of deposit increased with increasing plating time of the substrate at constant temperature (60^0C). The maximum amount of the deposit was about 6.67 μm for 150 min and 500 grit sizes for EMIC. But the amount of deposit decreased with increasing plating time of the substrate at constant temperature (60^0C) for DCA. The maximum amount of the deposit was found as 4.09 μm for 90 min by using DCA. As a result, it is concluded that EMIC was more suitable ionic liquid then DCA type ionic liquid as catalyst for metal plating on ABS plastic.

Sandpaper size effect for DCA and EMIC was illustrated at Figures 4.5-4.8.

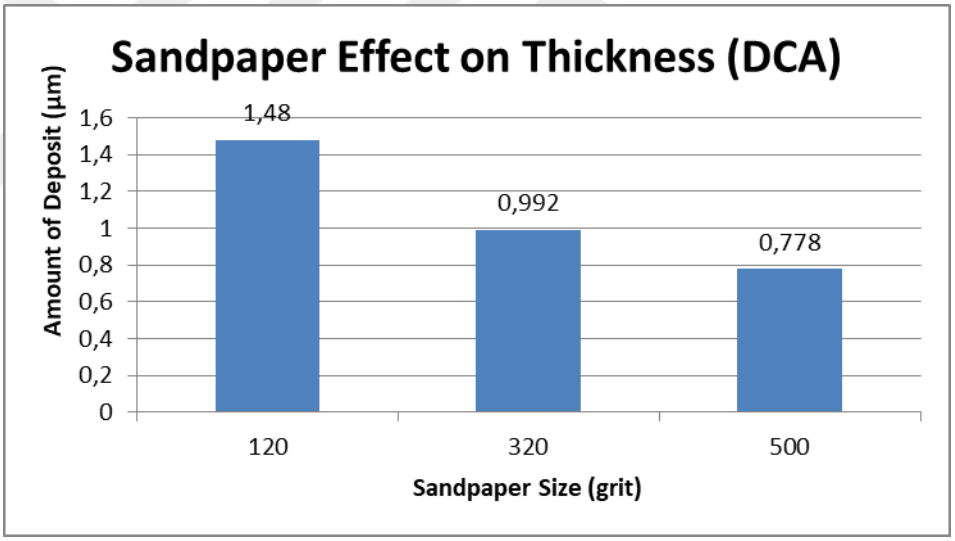


Figure 4.5 Amount of deposit versus sandpaper size for DCA and 150 minutes.

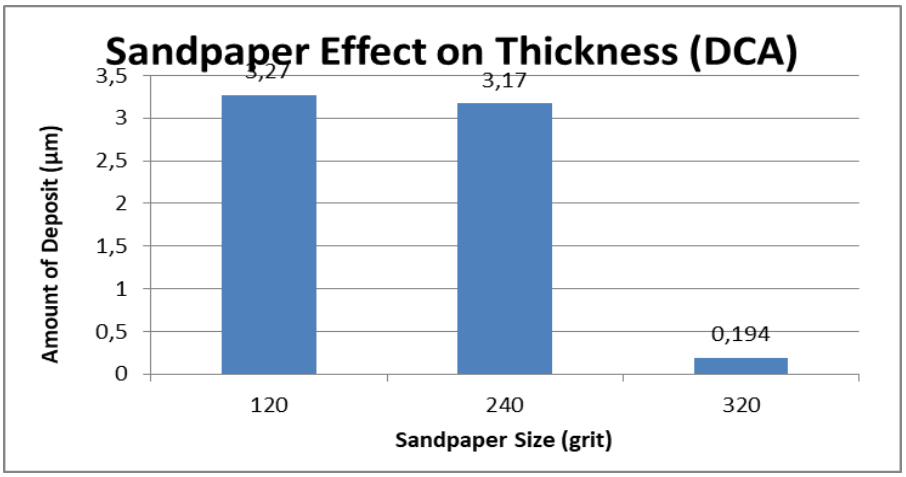


Figure 4.6 Amount of deposit versus sandpaper size for DCA and 120 minutes.

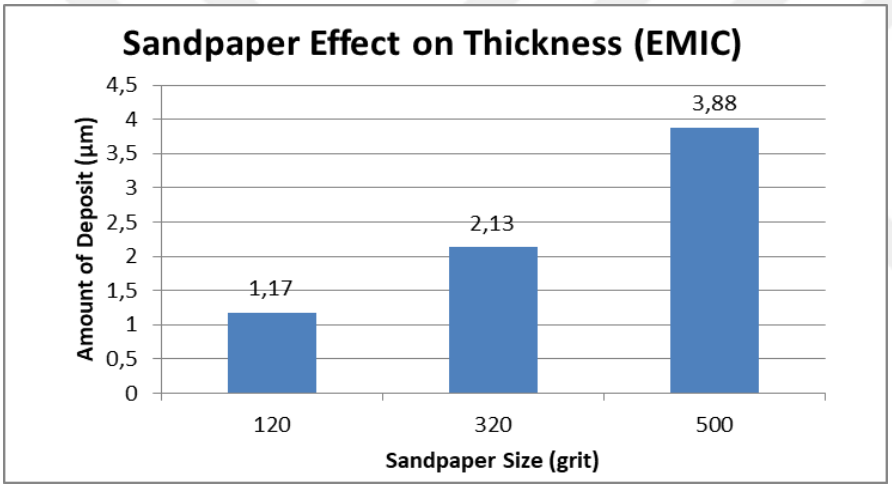


Figure 4.7 Amount of deposit versus sandpaper size for EMIC and 120 minutes.

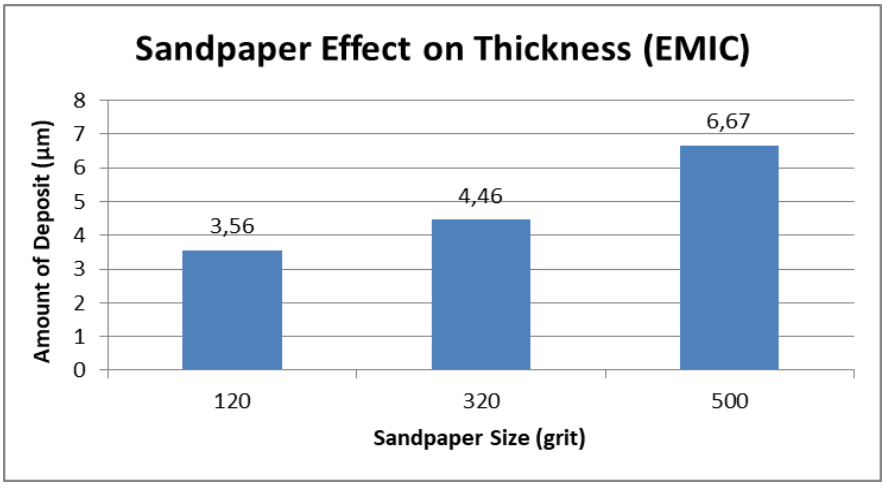


Figure 4.8 Amount of deposit versus sandpaper size for EMIC and 150 minutes.

Results obtained from X-Ray analysis were evaluated and thickness versus sandpaper size graphs were plotted (Figures 4.5- 4.8). It was shown from Figure 4.7 & 4.8 that, the thickness of the copper film increased when sandpaper size increased by using EMIC. The maximum amount of the deposit was about 6.67 μm for 500 grit of sand paper. Although sandpaper size increased, increase in the thickness of the copper film could not be obtained by using DCA (Figure 4.5).

According to the results from X-Ray analysis of DCA, stable increase could not be obtained. When time increased, the amount of deposit increased first from 0.28 to 3.27, and then at 120 min, it was decreased from 3.27 to 1.48.

As it was expected amount of deposit should be increased when sandpaper size was increased but as it could be seen from Figure 4.6, amount of deposit decreased when sandpaper size increased with using DCA. The reason can be that stable increase could not be obtained ingredients of activation solution (alcohol solution) or solution that includes nitric acid, hydrogen peroxide and ammonium fluoride.

Stable increase was obtained with X-Ray analysis of EMIC, as expected based on the literature. (Koura et al., 2008). As it could be seen from Figure 4.7 and 4.8, when time and sandpaper size increased, amount of deposit increased.

After X-ray measurements, the XRD and SEM analyses were performed for plated samples.

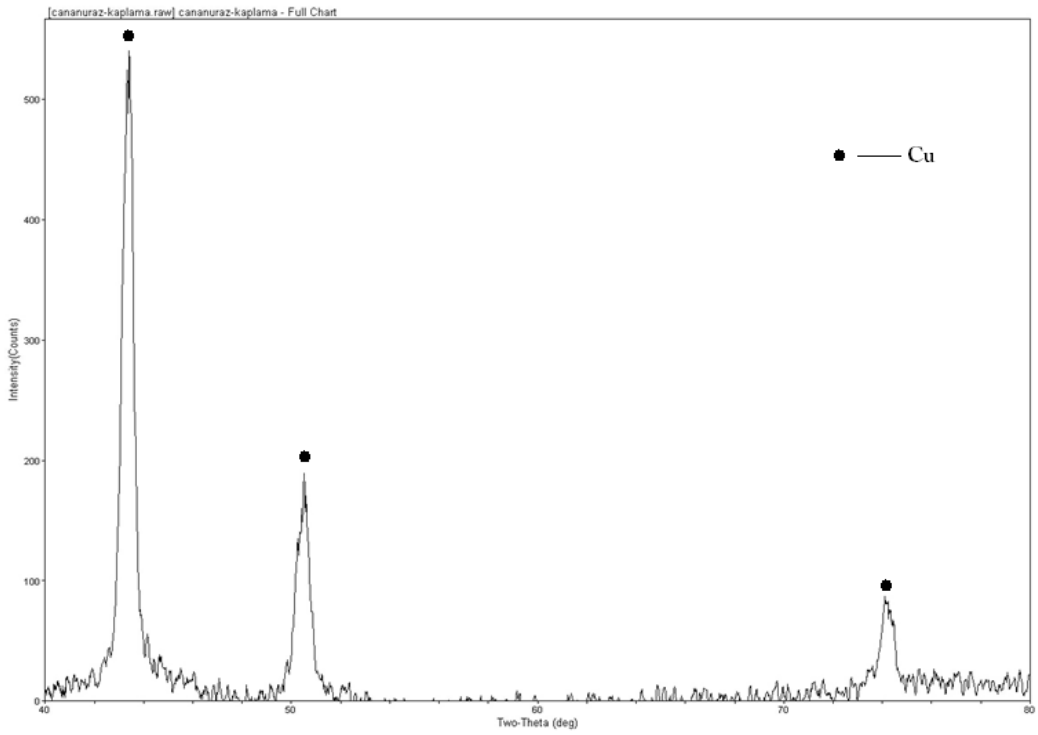


Figure 4.9 XRD analysis for copper plating with EMIC

Figure 4.9 shows the XRD patterns of plating, it also reveals the absence of other elements' diffraction peaks, which states that the plating only includes Cu. According to the literature, the results of XRD analysis was obtained as expected. Diffraction peaks was obtained at approximately 45, 50, and 75 degree (Luo et al., 2014).

The results of the SEM analysis were shown in the Figures 4.10a – 4.12e. The figures were displayed according to different optical zooms and indicated the best result.

The Figures 4.10a - 4.10d were obtained by using EMIC with 120 grit size sandpaper at 60 minutes. The deposit amount was 3.56µm.

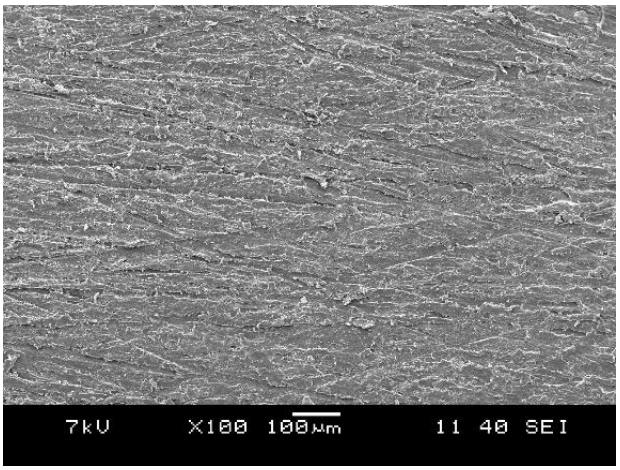


Figure 4.10a 100 X SEM analysis of sample which obtained by using EMIC with 120 grit size sandpaper at 150 minutes.

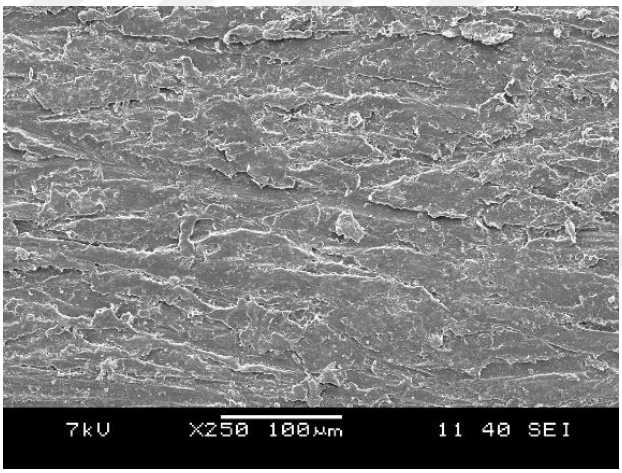


Figure 3 250 X SEM analysis of sample which obtained by using EMIC with 120 grit size sandpaper at 150 minutes.

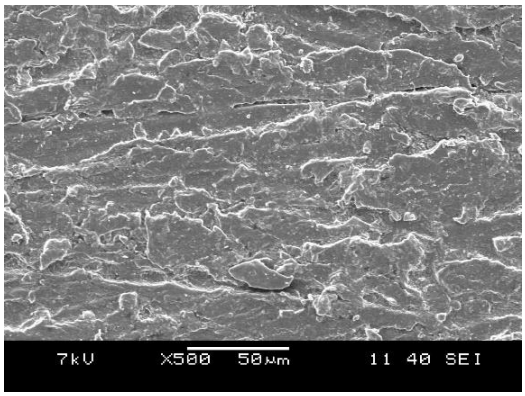


Figure 4.10c 500 X SEM analysis of sample which obtained by using EMIC with 120 grit size sandpaper at 150 minutes.

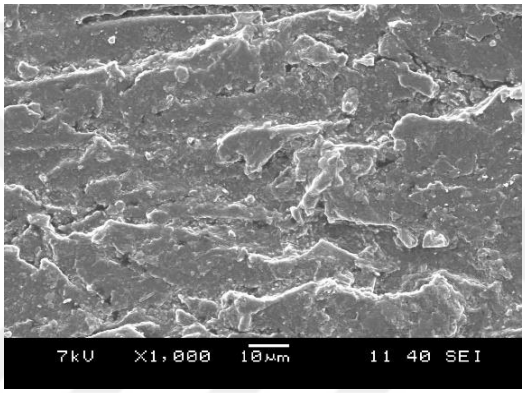


Figure 4.10d 1000 X SEM analysis of sample which obtained by using EMIC with 120 grit size sandpaper at 150 minutes.

The Figures 4.11a - 4.11e were obtained by using EMIC with 320 grit size sandpaper at150 minutes. The deposit amount was 4.46µm.

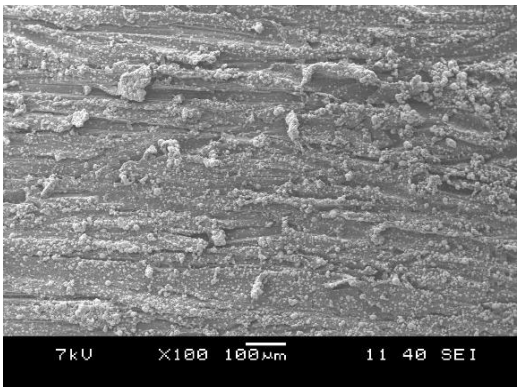


Figure 4.11a 100 X SEM analysis of sample which obtained by using EMIC with 320 grit size sandpaper at 150 minutes.

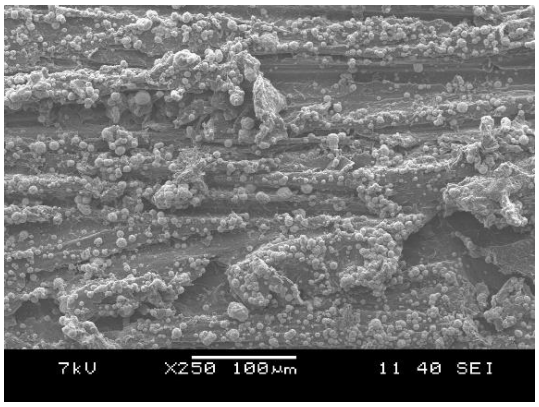


Figure 4.11b 250 X SEM analysis of sample which obtained by using EMIC with 320 grit size sandpaper at 150 minutes.

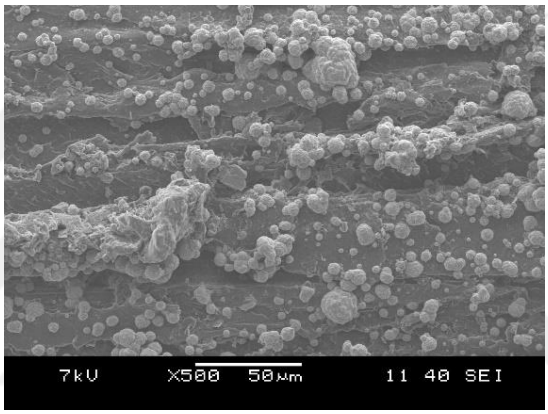


Figure 4.11c 500 X SEM Analysis of sample which obtained by using EMIC with 320 grit size sandpaper at 150 minutes.

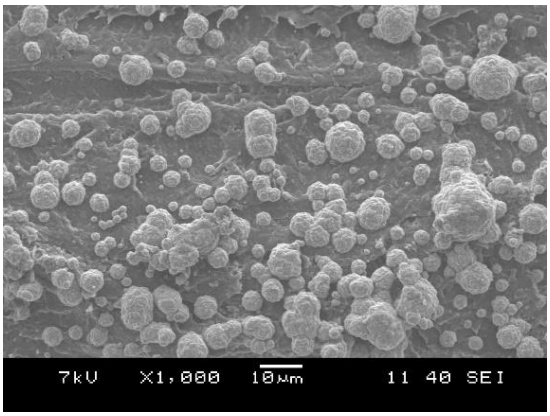


Figure 4.11d 1000 X SEM Analysis of sample which obtained by using EMIC with 320 grit size sandpaper at 150 minutes.

The Figures 4.12a - 4.12e were obtained by using EMIC with 500 grit size sandpaper at 150 minutes. The deposit amount was 6.67µm.

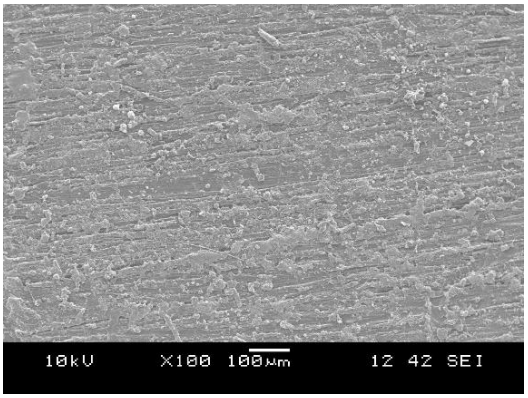


Figure 4.12a 100 X SEM analysis of sample which obtained by using EMIC with 500 grit size sandpaper at 150 minutes.

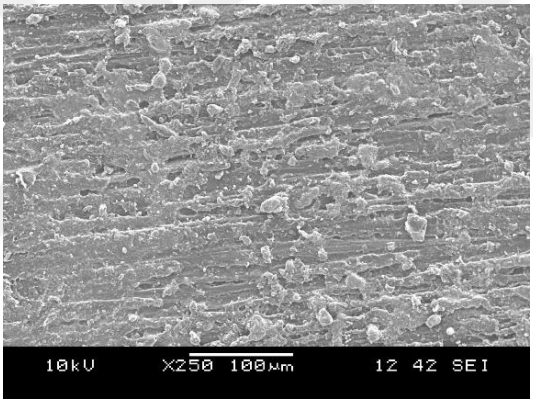


Figure 4.12b 250 X SEM analysis of sample which obtained by using EMIC with 500 grit size sandpaper at 150 minutes.

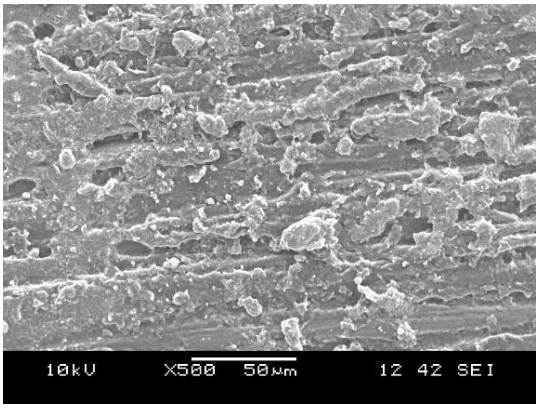


Figure 4.12c 500 X SEM analysis of sample which obtained by using EMIC with 500 grit size sandpaper at 150 minutes.

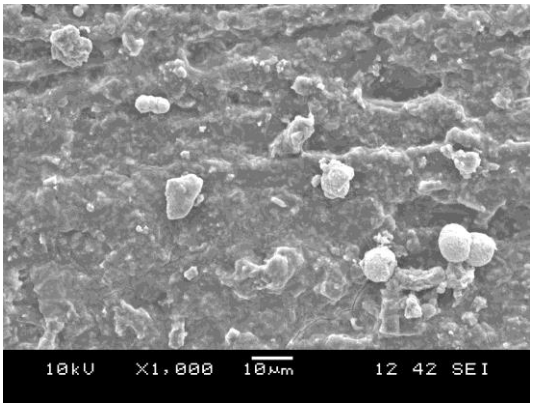


Figure 4.12d 1000 X SEM analysis of sample which obtained using EMIC with 500 grit size sandpaper at 150 minutes.

It was shown that a crystalline material was deposited on the surface of the substrate and it proved that electroless plating took place. The elemental mapping result by SEM-EDX also indicated that the plating film consisted of mainly copper 80 wt%, and the copper was homogeneously distributed on the surface of the film (Figures 4.13-4.15).

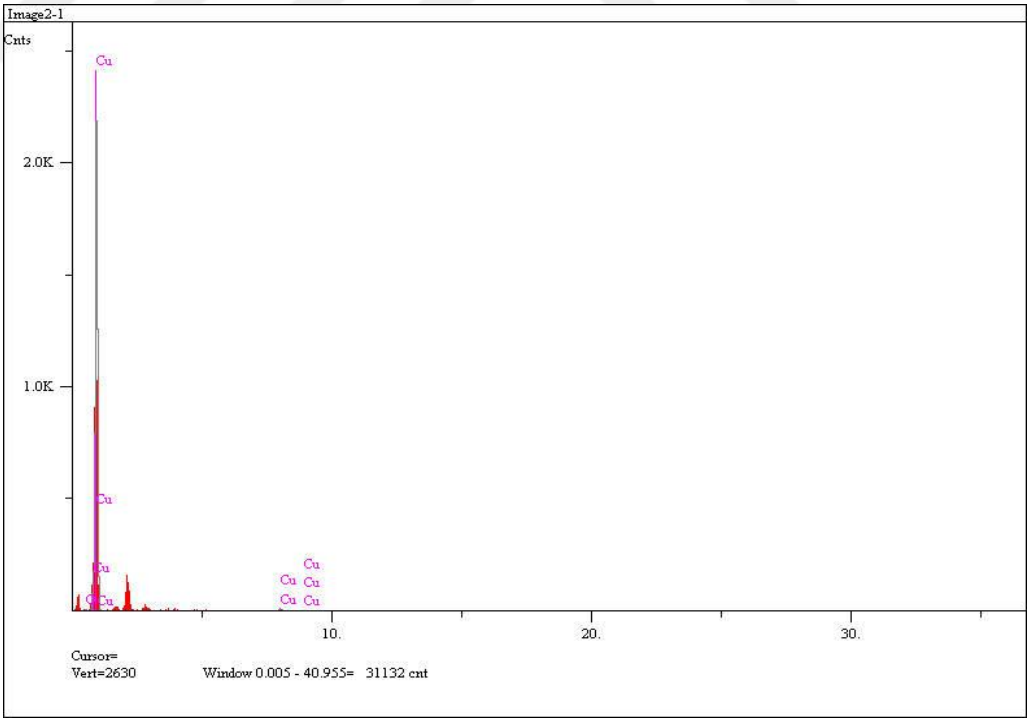


Figure 4.13 SEM-EDX graphs which is obtained by using EMIC with 320 grit size sandpaper at 150 minutes. The deposit amount is 4.46µm.

Component	Mole Conc.	Conc.		
Cu	50.424	80.157	wt.%	
O	49.576	19.843	wt.%	
	100.000	100.000	wt.%	Total

Elt.	Line	Intensity (c/s)	Error 2-sig	Conc		
O	Ka	0.60	0.154	19.843	wt.%	
Cu	Ka	1.65	0.257	80.157	wt.%	
				100.000	wt.%	Total

kV	20.0
Takeoff Angle	35.0°
Elapsed Livetime	100.0

Figure 4.14 SEM-EDX analysis results of sample which is obtained by using EMIC with 320 grit size sandpaper at 150 minutes. The Cu deposit amount is 4.46µm and 80wt%.

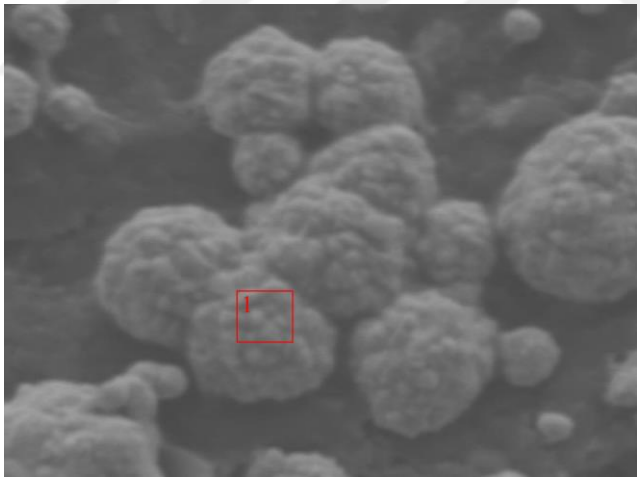


Figure 4.15 SEM-EDX analysis of sample which is obtained by using EMIC with 320 grit size sandpaper at 150 minutes. The deposit amount is 4.46µm.

4.2 Electroless Nickel Plating with EMIC

In the study, the electroless nickel plating were performed with EMIC used as catalyst. The effect of ionic liquid, 400-800 sandpaper sizes and 30-60-90 min. plating times were investigated for the amount of deposit. The plating bath temperature was taken as constant at 70^0C. The plating bath pH was adjusted to 8-9. The samples were analyzed by Fischerscope X-Ray XDL-B System. The results of experiments were shown in Figures 4.16a – 4.17c.

The experimental procedure was given in the Part 3.2.2.

According to the X-ray analyses, the effect of time on amount of deposit was shown in Figures 4.16a - 4.16b.

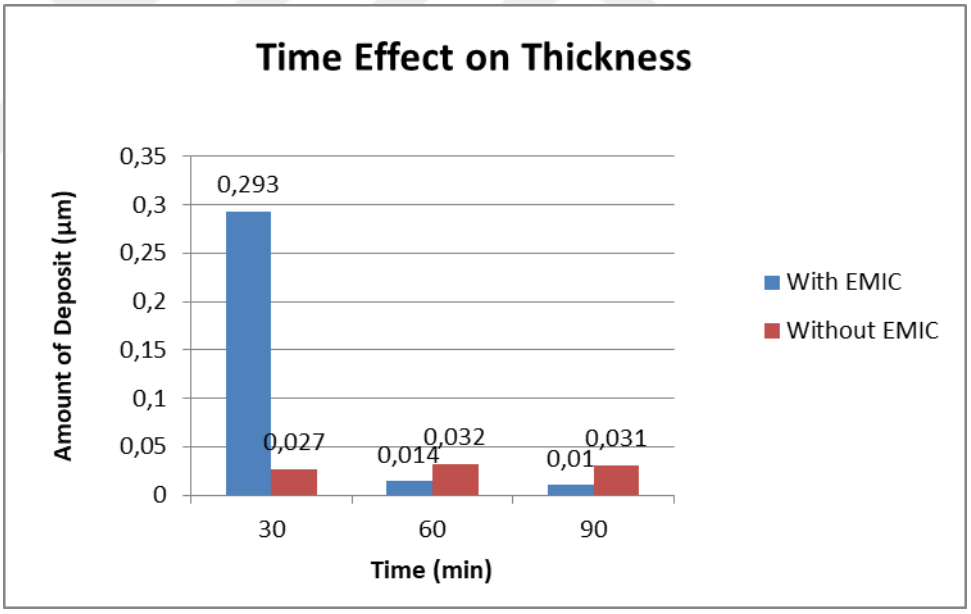


Figure 4.16a Time effect on amount of deposit for 400 grit size sandpaper

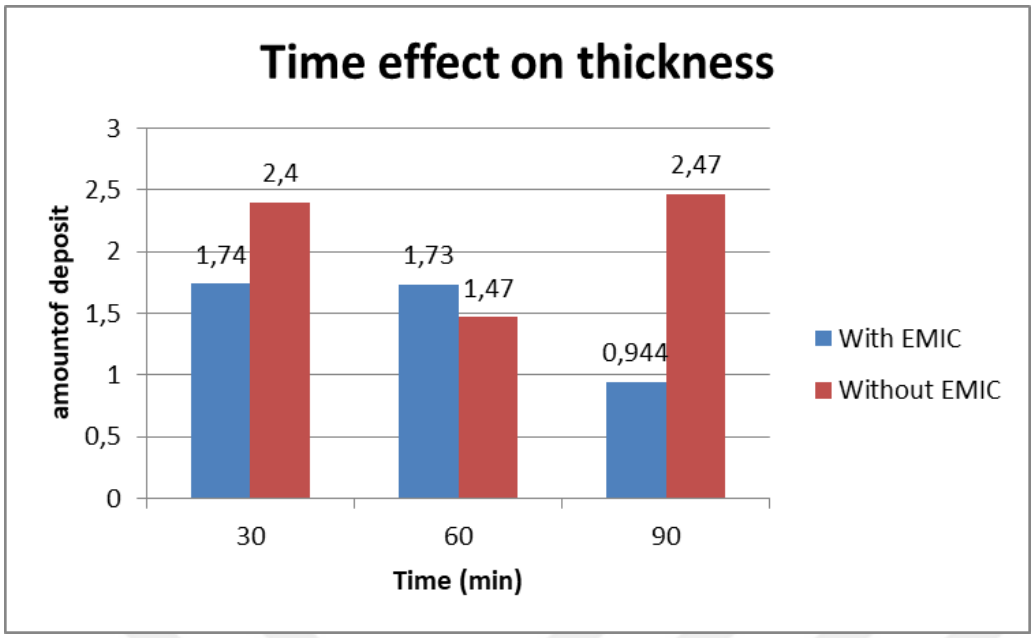


Figure 4.16b Time effect on amount of deposit for 800 grit size sandpaper.

The dependence of plating time on the amount of deposit was investigated for ionic liquid and without ionic liquid (Figures 4.16a - 4.16b). The maximum amount of the deposit was about 1.74 µm and 1.73 for 30 and 60 min for EMIC. And the amount of deposit increased with increasing plating time of the substrate at 70^0C constant temperature for without EMIC. The maximum amount of the deposit is found as 2.47 µm for 90 min without using EMIC.

The best plating time according to 400 (0,293µm) and 800 (1,74 µm) grit size sandpapers for EMIC could be taken 30 minutes. When the time increased the deposit amount was decreased. The maximum amount of the deposit was about 0,032 µm and 0,031 for 60 and 90 min for 400 grit size and without EMIC. The best plating time according to 400 (0,031µm) and 800 (2,47µm) grit size sandpapers for without EMIC could be taken as 90 minutes.

The effect of sandpaper size on amount of deposit was shown in Figures 4.17a - 4.17c.

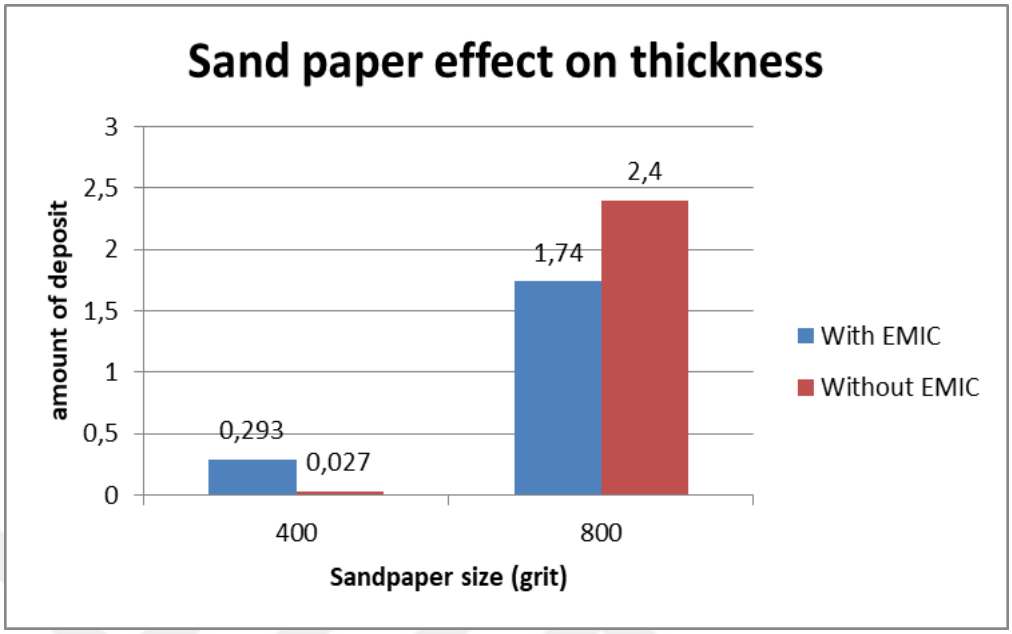


Figure 4.17a Amount of deposit versus sandpaper for 30 minutes.

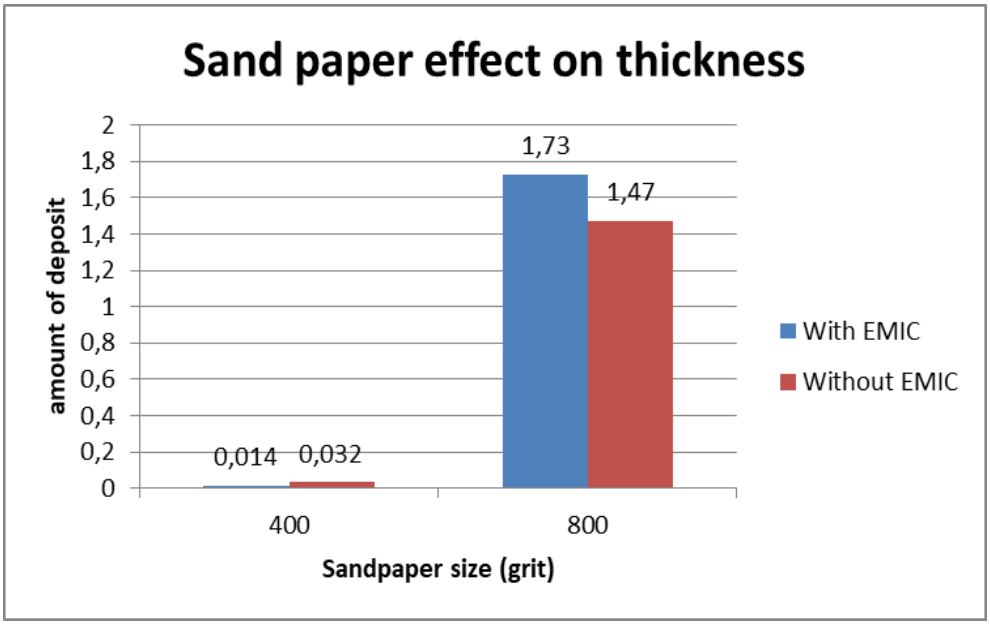


Figure 4.17b Amount of deposit versus sandpaper size for 60 minutes.

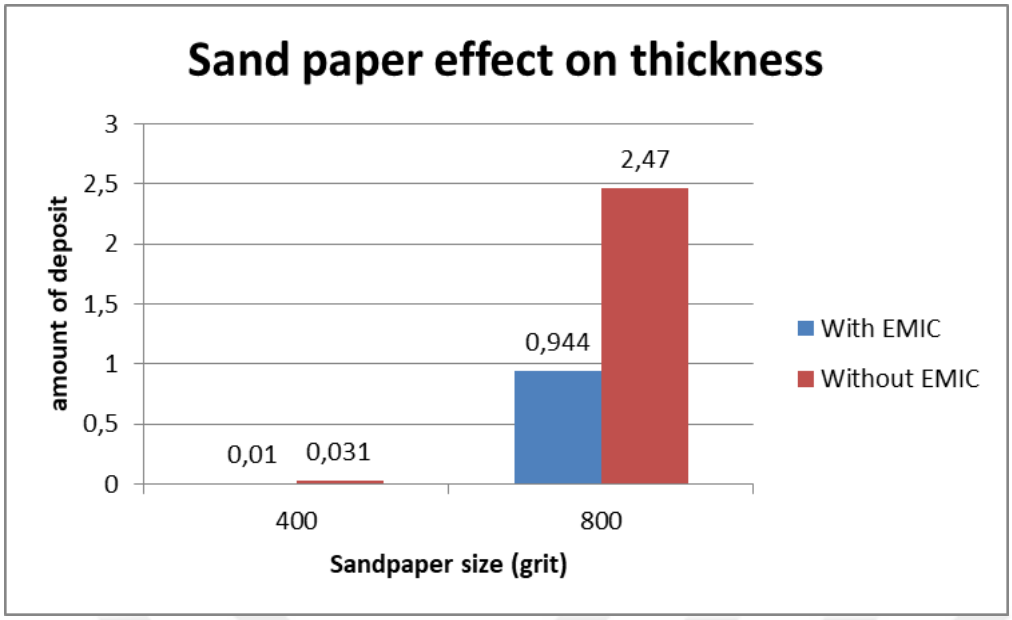


Figure 4.17c Amount of deposit versus sandpaper size for 90 minutes.

Results obtained from X-Ray analysis were evaluated and thickness versus sandpaper size graphs were plotted (Figures 4.17a – 4.17c). When the sandpaper size was increased the deposit amount increased. So sandpaper size had positive effect on the deposit amount.

It was shown from Figures 4.17a-4.17c that, the thickness of the nickel film increases when sandpaper size increases by using EMIC. The maximum amount of the deposit was about 1.74 μm for 800 grit of sand paper. In addition to this, sandpaper size increases, the thickness of the nickel film increases without EMIC.

According to the results from X-Ray analysis of samples, the best result at 400 grit size sandpaper for deposit amount was 0,293 μm with EMIC at 30 minutes (Figure 4.16a). EMIC was decreasing the operating time. The reaction rate was relatively more stable with EMIC at the 30-60-90 min operating times at 800 grit size sandpaper (Figure 4.16b) and the nickel distribution of the surface was homogenous than without EMIC. So EMIC had positive effect on the nickel plating.

According to X-Ray analysis, the best plated samples were selected for XRD analysis. These results were obtained from samples grounded with 800 grit

sandpaper with EMIC according to the different plating times. The plating times were taken 30, 60, 90 minutes. The XRD graphs showed that, only nickel was obtained in the layer as expected in the literature (Figure 4.18a - 4.18b - 4.18c) (Tang et al, 2009).

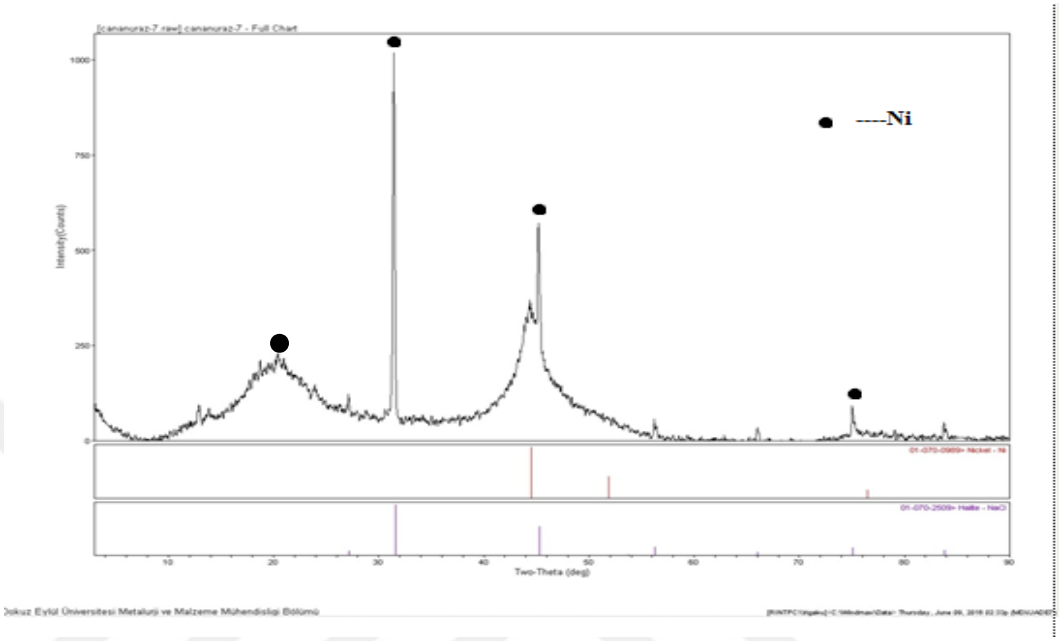


Figure 4.18a XRD Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 30 minutes.

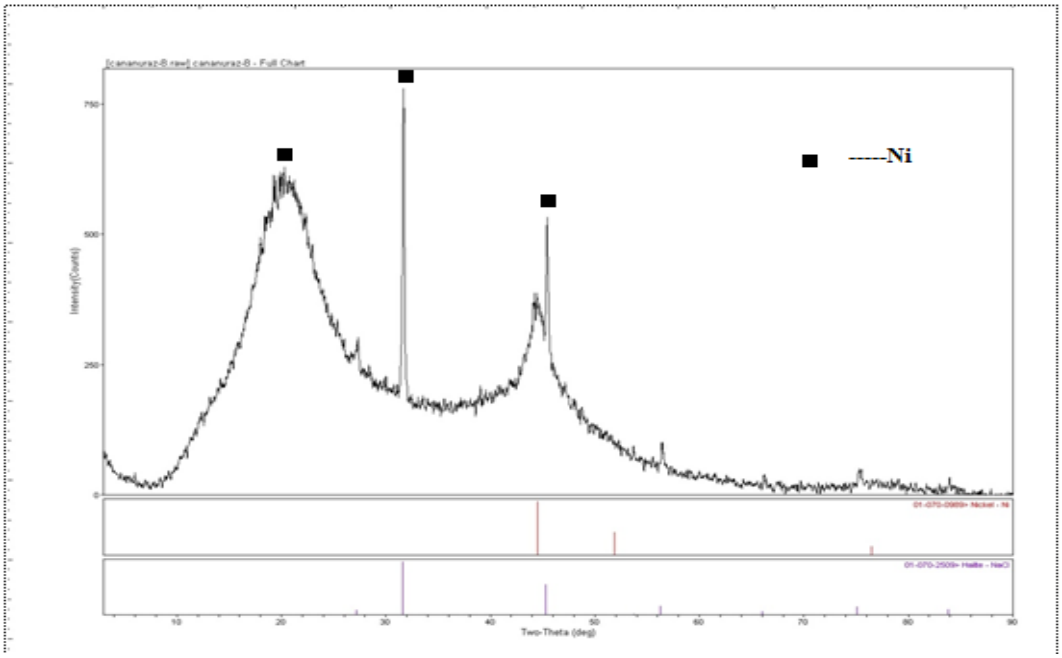


Figure 4.18b XRD Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 60 minutes.

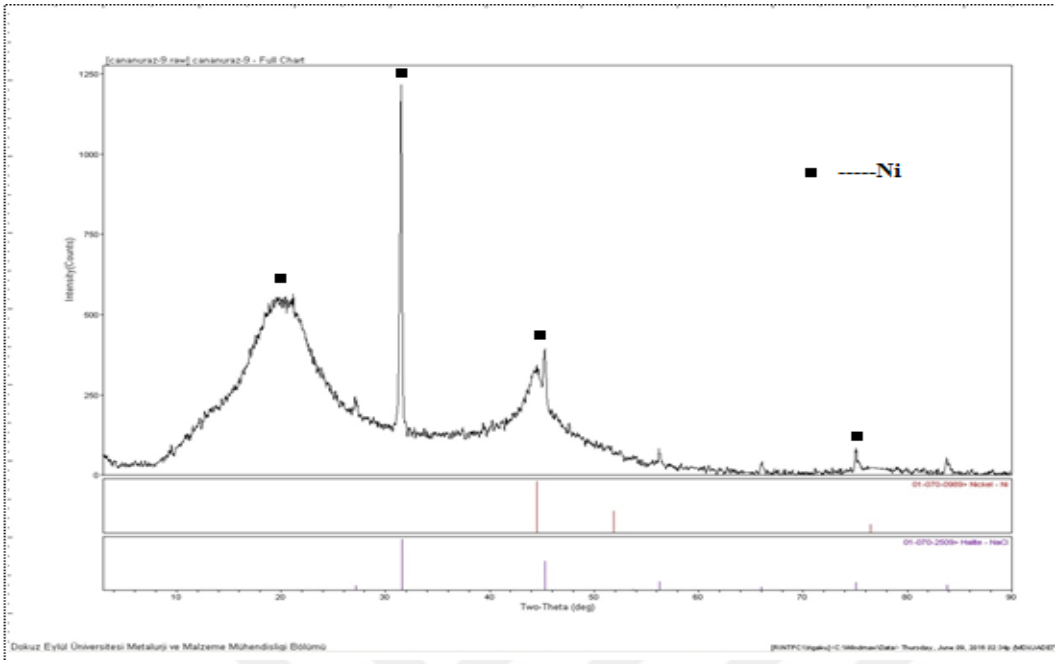


Figure 4.18c XRD Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 90 minutes.

The microstructures of the coatings were shown in the SEM images given in Figures 4.19a - 4.20. These images were obtained by using EMIC and 800 grit size sand paper at 30 (1,74µm) and 60 (1,73µm) minutes.

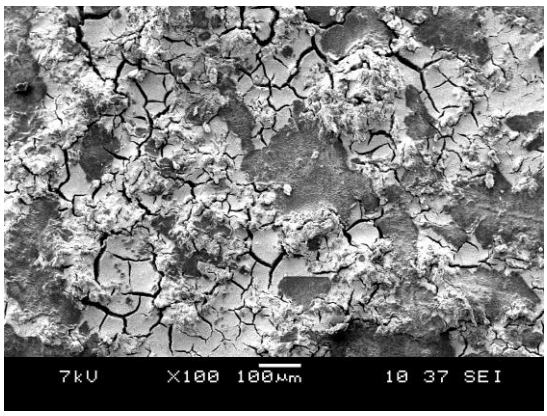


Figure 4.19a 100 X SEM Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 30 minutes.

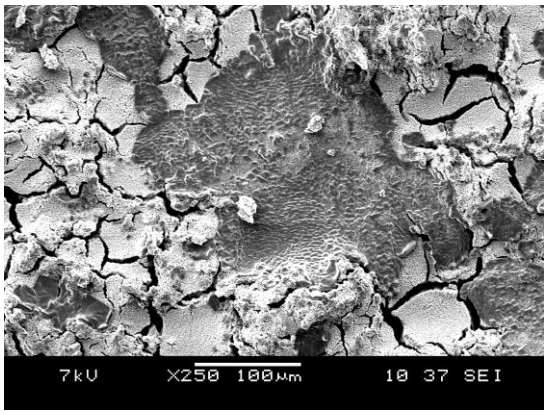


Figure 4.19b 250 X SEM Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 30 minutes

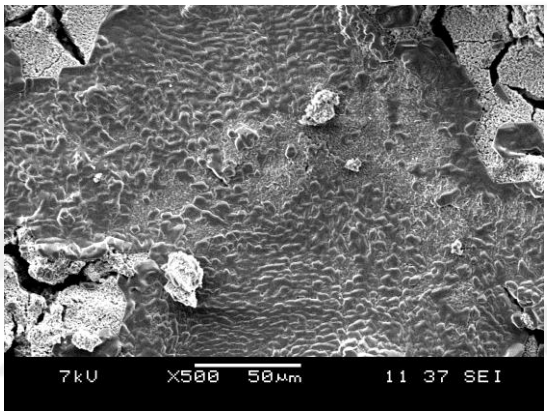


Figure 4.19c 500 X SEM Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 30 minutes.

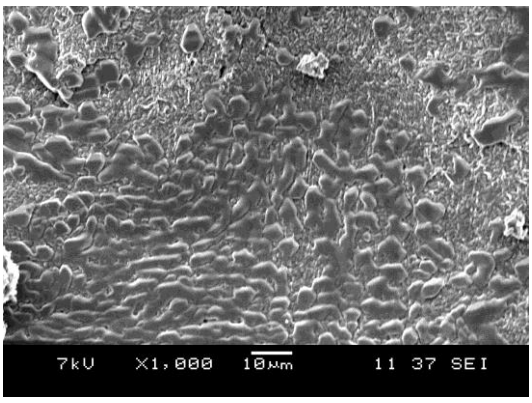


Figure 4.19d 1000 X SEM Analysis of sample which is obtained by using EMIC with 800 grit size sandpaper at 30 minutes.

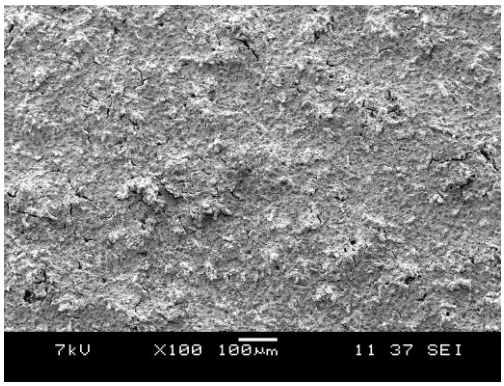


Figure 4.20 100 X SEM Analysis of sample which isobtained by using EMIC with 800 grit size sandpaper at 60 minutes.

According to the SEM analysis, it was shown from Figures 4.19a-4.20 that a crystalline material was deposited on the surface of the substrate and it was proved that electroless plating took place on the surface.

5. CONCLUSION

The aim of this thesis was to investigate and to develop of electroless plating catalyst and activation solution in the electroplating industry. Traditional copper and nickel plating steps are consisting of etching with chromic and sulphuric acids, metallization with hydrochloric acid, palladium and tin, accelerate with accelerator chemicals. This chemicals are hazardous both environment and human.

For this purpose, electroless baths were prepared by using environmentally friendly chemicals (EMIC & DCA) instead of the plating operation with hazardous chromic and sulphuric acids, palladium…etc. chemicals. Etching of the ABS was provided by sandpaper. On the contrary of the conventional sensitization and activation steps, palladium-free surface activation process was used to activate ABS plastic. After nickel plating, the pretreated plastic surface obtained uniformly distributed coating.

It is succeeded in demonstrating the electroless plating of dense, smooth, and pure metal for copper and nickel. XRD results indicated that the deposited film was copper for copper experiment and nickel for nickel experiment. At the Appendix Part A, the thickness calculation example for nickel according to Figure 4.18a can be seen. The elemental mapping results of SEM-EDX indicated that the plating film consisted of related metal only, and it was homogeneously distributed on the surface of the film.

In the literature, there was found no electroless copper or nickel plating on ABS plastic study with RTIL. There is a new study for the plating sector. The experimental data were share at 12th National Chemical Engineering Congress (UKMK 2016). At that time the article related copper plating was written with the name of ‘’Electroless Cu Plating on ABS Plastic by Using Environmentally Friendly Chemicals’’ and applied to Dokuz Eylul University, Faculty of Engineering, Journal of Science and Engineering. Additionally, Tubitak 1002 Project was approved with the Project number 216M372.

There were two types of experiments. First one was copper plating with RTIL. The catalytic effects of RTILs were investigated and EMIC was found more suitable RTIL for metal plating operation. Second one is nickel plating with EMIC. When EMIC was found more suitable, the nickel plating experiments were performed with EMIC. The experiments were showed that the ionic liquid has positive effect of the copper and nickel plating process.

6. RECOMMENDATIONS

As future study, glass, PVC, ABS/PC, aluminum and ceramic materials could be performed for all two plating method instead of ABS.

Copper and nickel were used as metal layer. Other metals such as zinc could be used.

At the etching state, different materials such that fiberglass, alumina powder…etc. could be used instead of sandpaper

Shape of sample could be changed and analyzed according to see the shape effect of ABS plastic.

pH and chemicals of bath could be changed and performed (Schlesinger and Paunovic, 2010, Table 18.6).

Feasibility study and cost analysis could be applied for pilot plant study.

REFERENCES

Adams, M. E., Buckley, D.J., Colborn, ,R.E., 1993, 'Acrylonitrile-butadiene-styrene Polymers', (https://books.google.com.tr/books?id=CVPkVaAR1xwC&pg=PA19&hl=tr&source=gbs_selected_pages&cad=2#v=onepage&q&f=false, (Access Date:26.03.2017)

Ang, L.L., Hor, T. S. A., Xu, G. Q., Tung, C. H., Zhao, S.P., Wang, J. L.S., 2000, " Decoration of Activated Carbon Nanotubes with Copper and Nickel", Carbon, 38, 363-372

Beşergil, B., 'Endüstri Polimerleri', http://www.bayar.edu.tr/besergil/endustri_polimerleri.pdf, (Access Date: 02.04.2017)

Boreas Kimya, ABS Kaplama, http://www.boreaskimya.com/urunler/plastik-kaplama/abs-kaplama, (Access Date: 23.09.2017)

Caturla, F., Molina, F., Molina-Sabio, M., Rodriguez-Reinoso, F., Esteban, A., 1995, "Electroless Plating of Graphite with Copper and Nickel", Journal of Electrochemical Science, 142, 4084-4091.

Crawford, R.J., 1998, 'Plastics Engineering', 3rd edition, Oxford, Butterworth-Heinemann Publishing, 505p.

Deng Ming-Jay, **I.-Wen Sun, Po-Yu Chen, Jeng-Kuei Chang,Wen-Ta Tsai**, 2008, "Electrodeposition behavior of nickel in the water- and air-stable 1-ethyl-3-methylimidazolium-dicyanamide **room**-temperature ionic liquid", Electrochimica Acta 53, 5812–5818

Endres, F., MacFarlane, D., Abbott, A., 2008, "Electrodeposition from Ionic Liquids", Wiley-VCH, Weinheim, Germany

Fukuhara, C., Ohkura, H., Gonohe, K., Igarashi, A, 2005, "Low-Temperature Water-Gas Shift Reaction of Plate-Type Copper-Based Catalysts on an Aluminum Plate Prepared by Electroless Plating", Applied Catalysis A: General, 279, 195–203

Galinski, M., Lewandowski, A., Stepniak, I., 2006, Ionic Liquid as Electrolytes, Journal of Electrochimica Acta, Volume 51,Pages 5567–5580

Johnson, K. E., 2007, The Electrochemical Society Interface, What's an Ionic Liquid?, https://www.electrochem.org/dl/interface/spr/spr07/spr07_p38.pdf, (Access Date: 30.04.2017)

REFERENCES (continued)

Kılıçarslan, A., Toptan, F., Kerti, I., 'Akımsız Nikel Kaplama Yöntemi ve Seramik Partiküllerine Uygulanması', Türk Mühendis ve Mimar Odaları Birliği Metalurji Mühendisleri Odası, http://www.metalurji.org.tr/dergi/dergi154/d154_3337.pdf (Access Date: 5.11.2016)

Koura, N., Nagase, H., Sato, A., Kumakura, S., Takeuchi, K., Ui, K., Tsuda, T., Loong, C. K., 2007. "Electroless Plating of Aluminum from a Room-Temperature Ionic Liquid Electrolyte", Journal of Electrochemical Society, 155, 155-157

Kulich, D. M., Gaggar, S. K., Lowry, V., Stepien R., 2001, **'**Encyclopedia of Polymer Science and Technology', http://onlinelibrary.wiley.com/doi/10.1002/0471440264.pst011/abstract?userIsAuthenticated=false&deniedAccessCustomisedMessage=, (Access Date:25.03.2017)

Linka, G.and Riedel, W., 1987, 'Galvanotechnik', 568p.

Liu, Z., Chen, Y., 1998, "Spectroscopic Studies on Tetragonal ZrO_2-Supported MoO_3 and NiO- MoO_3 Systems", Journal of Catalysis, 177, 314-324

Luo, L-M., Lu, Z., Huang, X., Tan, X., Ding, X., Cheng, J., Zhu, L., Wu, Y., 2014. "Electroless Copper Plating on PC Engineering Plastic with a Novel Palladium-Free Surface Activation Process", Surface & Coating Technology, 251, 69-73

Mallory, G.O., Hadju, J.B., 1990, 'Electroless Plating Fundametals & Applicaions', 1st edition, USA, William Andrew Publishing, 538p.

Marsh, K.N., Boxall, J.A., Lichtenthaler, R., 2004, Fluid Phase Equilibria, Volume 219, Pages 93-98

Mittal, V., 2015, Electroplating, https://chem.libretexts.org/Core/Analytical_Chemistry/Electrochemistry/Electrolytic_Cells/Electroplating, (Access Date:23.03.2017)

Murugesan,S. ve Linhardt, R.J., 2005, "Ionic liquids in carbohydrate chemistry-current trends and fture directions", Current Organic Synthesis, 2, 437-451.

Ngo, H.L., LeCompte, K., Hargens, L., McEwen, A.B., 2000, "Thermal properties of imidazolium ionic liquids",Thermochimica Acta, 357-358, 97-102.

Osborne, K, Electroplating, New Zealand Institute of Chemistry, https://nzic.org.nz/ChemProcesses/metals/8G.pdf, Access date:23.03.2017

REFERENCES (continued)

Pletcher, D. Walsh, F.C., 1990, 'Industrial Electrochemistry, 2nd edition, London, GB, Chapman & Hall, 654p.

Rajaguru, J.C., Au, C., Duke, M., 2012, 'Journal of Achievements in Materials Manufacturing Engineering', Vol55 Issue,2 pp.787

Rudnik,E., Kokoszka, K., Łapsa, J., 2008, "Comparative Studies on the Electroless Deposition of Ni-P, Co-P and Their Composites with SiC Particles", Surface & Coatings Technology, 202, 2584-2590

Schlesinger, M., Paunovic, M., 2010, 'Modern Electroplating', 5th edition, New Jersey John Wiley & Sons, Inc., 729p.

Song, L., Li, W., Wang, G., Zhang, M., Tao, K., 2007, "A New Route to Prepare Supported Nickel Phosphide/Silica-Alumina Hydrotreating Catalysts from Amorphous Alloys", Catalysis Today, 125, 137-14

Sudagar, J., Lian, J., Sha, W., 2013, 'Electroless nickel, alloy, composite and nano coatings - A critical review', Journal of Alloys and Compounds, Journal of Alloys and Compounds, Volume 571, 183-204

Tang, X., Bi, C., Han, C., Zhang, B., 2009, "A New Palladium Free Surface Activation Process for Ni Electroless Plating on ABS Plastic", Materials Letters, 63, 840-842

TutorVista, Electroplating, http://chemistry.tutorvista.com/physical-chemistry/electroplating.html, (Access Date:23.03.2017)

Wasserscheid, P., Keim, W., 2000, Ionic Liquids, http://www.organic-chemistry.org/topics/ionic-liquids.shtm (Access Date:30.04.2017)

Wikipedia, Electroplating, https://en.wikipedia.org/wiki/Electroplating#CITEREFDufour2006IX-1, (Access date:23.03.2017)

Wikipedia, Acrylonitrile Butadiene Styrene, https://en.wikipedia.org/wiki/Acrylonitrile_butadiene_styrene, (Access date:23.03.2017)

CURRICULUM VITAE

ŞENAY MACİT

Fırat Mah. 289 Sok. No:70 K:3 D:5 Buca\İZMİR

GSM : +90 537 945 65 52

E-mail*:* senayengin88@gmail.com

PERSONEL INFORMATION

Date of Birth	: 28.11.1988
Place of Birth	: Kırcaali \ Bulgaria
Citizenship	: T.C.
Marital Status	: Married
Smoking	: None
Driving Lisence	: B (2011)

EDUCATION

2013- 2017 **Graduate(Master)** Chemical Engineering Dep. of Ege University (ENG 100%)

2007 - 2012 **Undergraduate** Chemical Engineering Dep. of Ege University (ENG 100%)

2009 - 2013 **Undergraduate** Business Faculty of Anadolu University

2004 - 2007 **High Sch.** Buca Anatolian High School

1995 - 2004 **Primary Sch.** Buca Atatürk Primary School

EXPERIENCE / INTERNSHIP / PROJECTS

29.07.2016 - ...	TKF Metal Plating Corporation **(Experience)** Responsible of Production and Laboratory; Environmental Officer
17.02.2014 - 29.07.2016	TKF Metal Plating Corporation **(Experience)** Quality System Assurance Engineer: Responsible of quality assurance and occupational health & safety
15/09/2014 – 18/09/2016	Investigating and development of electroless plating catalyst and activation solution in electroplating industry **(Master Thesis)**

02/09/2013 - 10/02/2014	Ünlü Boya Sanayi ve Ticaret Ltd. Şti. **(Experience)** The job was related with research & development of the decorative paints. Also main part of the job was consisting of the problem solving about decorative paints.
30/01/2014 – 02/02/2014	İzmir-Konya Culture and Art Days **(Fair)*** Ünlü Boya Sanayi ve Ticaret Ltd. Şti. (İzmir International Fair)
07/11/2013 – 10/13/2013	İzmir-Sivas Culture and Art Days **(Fair)*** Ünlü Boya Sanayi ve Ticaret Ltd. Şti. (İzmir International Fair) *Authorized person
28/11/2011 - 18/05/2012	Degradation of Terephthalic Acid Containing Wastewaters by Photocatalytic Oxidation **(Diploma Project)**
15/08/2011 - 16/09/2011	Küçükbay Yağ Sanayi A.Ş. -Orkide- **(Training)**
24/08/2009 - 18/09/2009	Osmanlı Nafta Kimya Ltd. Şti.**(Training)**

CERTIFICATES / COURSES / SEMINARS:

23-26.07.16	12th National Chemical Engineering Congress (UKMK2016) (Presentation Topic: Investigating and development of electroless plating catalyst and activation solution in electroplating industry)
14-15.04.15	ISO TS 16949:2009 Internal Auditor Certificate
28.02.2015	MSA - Measurement System Analysis
21.02.2015	SPC - Statistical Process Control
17.01.2015	APQP - Advenced Product Quality Planning
17.01.2015	PPAP – Production Part Approval Process
27.12.2014	FMEA – Failure Mode Effect Analysis
20-21.12.14	ISO TS 16949:2009 Automotive Quality Management System (Tanju Kan, Automotive Sector Specialist, IAFT cert. No:5-ADP-12-05-1820)
03.2012 – 05.2012	KOSGEB Entrepreneur Education (60 h)
29-30.03.11	ISO Management Systems: TS EN ISO 9001:2008 Quality Man. TS EN ISO 140001:2004 Env. Man. TS EN ISO 18001:2007 SafetyMan. (Chamber of Chemical Engineering)
14.06.2011	KAIZEN (Elginkan Vakfı)
14.12.2009	Problem Solving Methods (Elginkan Vakfı)

SKILLS:

Language: English (Advanced), German (Beginner)

Computer: MS Office (World, Excel, Power Point,Outlook), İnternet, Visual Basic, İntellicad, Aspen Plus, Comsol Multiphysics

MEMBERSHIP / ACTIVITIES:

- Chamber of Chemical Engineering Member, since 2008
- Young Entrepreneur Society of Ege University (Active-Coordinator), 2009-2010
- Science and Technology Society of Ege University (EBİLTET), 2008-2009

REFERENCES:

⇒ Assist. Prof. Dr. Canan URAZ
(Chemical Engineering Department of Ege University)
Tel: (0232) 311 14 86
e-Mail: canan.uraz@ege.edu.tr

⇒ Chemical Engineer Merve ÇETİNKOL
(PGS Plating Co.)
Tel: 0532 630 05 80
e-Mail: mervecetinkol@pgsplastik.com

APPENDICES

APPENDIX A. XRD Result for Nickel Calculation

APPENDIX A. XRD RESULT FOR NICKEL CALCULATION

- The Bragg equation is:

$n\lambda = 2d\sin(\theta)$

Rearranging this equation for the unknown spacing d:

d = n x wavelength/2sin(θ).

2θ = 20 degrees, θ = 10 degrees, n =1, and wavelength = 1.540Å

So

d= 1 x 1.540/(2 x 0.174) = 4.43 Å

- The Scherrer Equation:

A more useful form can be written as

t, thickness = 0.9 λ/(B cos θ)

From XRD analysis result taken from EMUM

Kalpha= 1.54 ,

Kbeta= 1.392

λ = 1.54 nm, 2θ = 20º

θ = 10 º; cos (10) = 0.985

360 º = 2 x 3.142

B=1.392x 2 x 3.142/(360) = 0.024

t = 58.62 nm