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INVESTIGATION OF THE OPERATING CONDITIONS ON ELECTROLESS NICKEL PLATING OVER ABS PLASTIC

ABSTRACT

The aim of this study is to investigate the operating conditions of without electrical current usage nickel plating over ABS plastic and determining the best plating conditions. Experimental study consists of four parts as; preparation of materials, etching, coating and analysis. The effects of temperature and pH of the plating bath, plating time and grinding paper size were investigated on nickel plating. Experiments were carried out in the plating bath with 120, 240 and 320 grit size sandpapers, at 85-90-95^{0}C plating temperatures, at 7-9-11 pH and 15-30-45 minutes of deposition times. The results of the experimental studies analyzed by using X-Ray XDL-B System, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). Due to the results of the experiments and analysis, the electroless nickel plating on ABS plastic was a success.

Keywords: Electroless Plating, ABS Plastic, Nickel Plating, Plating baths, SEM&XRD

1. INTRODUCTION

Electroless nickel (EN) plating is a process for depositing a nickel alloy from aqueous solutions onto a substrate without the use of electric current. It differs, therefore, from electroplating which depends on an external source of direct current to reduce nickel ions in the electrolyte to nickel metal on the substrate. Electroless nickel plating is a chemical process which reduces nickel ions in solution to nickel metal by chemical reduction [1, 2, 3 and 4]. The most common reducing agent used is sodium hypophosphite. Alternatives are sodium borohydride and dimethylamine borane but they are used much less frequently. It is estimated that sodium hypophosphite is used in more than 99% of all electroless nickel plating and this publication refers only to the use of this reducing agent [5 and 6]. ABS, acrylonitrile-butadienestyrene, has found the widest acceptance in the plating industry. ABS is a terpolymer thermoplastic that has an acrylonitrile-styrene matrix with butadiene rubber uniformly distributed in it. This quality makes it unique for plating, as the butadiene can be selectively etched out of the matrix, leaving microscopic holes that are used as bonding sites by the electroless plate. Other factors influencing the choice are: low cost, low coefficient of thermal expansion, ease of molding, good metal adhesion to the substrate, good appearance after plate [7]. Plating is a thin layer of metal that has been added to the outside of a material. It is a surface covering process by which a metal is deposited on a conductive surface. Plating is used to: Harden objects, Decorate objects, Inhibit corrosion, Improve solderability/weatherability,

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Reduce friction, Improve paint adhesion, Alter conductivity, Improve IR reflectivity, provide radiation shielding. There are two types of plating: electroplating and electroless plating [8]. Electroless nickel plating is an auto-catalytic reaction used to deposit a coating of nickel on a substrate. Unlike electroplating, it is not necessary to pass an electric current through the solution to form a deposit. This plating technique is used to prevent corrosion and wear. EN techniques can also be used to manufacture composite coatings by suspending powder in the bath [9]. The most common form of electroless nickel plating produces a nickel phosphorus alloy coating. The phosphorus content in electroless nickel coatings can range from 2% to 13%. It is commonly used in engineering coating applications where wear resistance, hardness and corrosion protection are required. Applications include oil field valves, rotors, drive shafts, paper handling equipment, fuel rails, and optical surfaces for diamond turning, door knobs, kitchen utensils, bathroom fixtures, electrical/mechanical tools and office equipment [10].

2. RESEARCH SIGNIFICANCE

In this study electroless nickel plating on ABS plastic was achieved at different plating times, temperatures, pH and thickness. On the contrary of the traditional processes with chromic and sulphuric acids, pretreatment of the materials, the etching and the plating processes were performed with environmentally friendly chemicals and techniques. Significance of this project is to investigate the operating conditions of electroless nickel plating over ABS plastic and determining the best plating conditions.

3. EXPERIMENTAL STUDY

Experimental study consists of four parts as; preparation of materials, etching, coating and analysis. The effects of temperature and pH of the electroless nickel plating bath, plating time and grinding paper size were investigated on nickel plating. Experiments were carried out in the nickel plating bath with 120, 240 and 320 grit size sandpapers, at different temperatures as 85-90-95^{0}C, at different pH values of 7-9-11 and 15-30-45 minutes of deposition time.

3.1. Experimental Procedure

- Initially, 20mmx35mmx1.5mm ABS plastic samples are grounded with the 120-240-320 grit sandpaper size.
- The samples are placed in a 65^{0}C oven maintained for 4 to 5h.
- The samples are taken from oven and placed in a 10g/L NaOH alcoholic solution.
- This NaOH alcoholic solution is placed into in a 35-40^{0}C water bath for 30 min.
- The samples are placed in an aqueous solution with a certain ratio of nitric acid, hydrogen peroxide and NH_4F.
- It is exposed with a supersonic wave for 30min [6].
- The resultant samples are washed with deionized water.
- The electroless plating bath is prepared according to concentrations of chemicals.
- Initial pH and temperature are recorded.
- The solution is heated until reached the experimental temperature.

- When bubleing is observed time is recorded and ABS samples are immersed into the bath.
- pH of the bath is adjusted with NaOH solution according to experimental pH values.
- Samples are taken at 15-30-45 minutes.
- Temperature and pH values are recorded at specified times.
- At the end of the experiment ABS samples are washed with distilled water.
- ABS samples are dried in the oven.

3.2. Analysis of the Experimental Results

Fischerscope X-Ray XDL-B System was used to determine the deposition amounts of the samples. According to the results obtained from X-ray analysis, the samples that gave the best plating results were analyzed using XDR and SEM to determine the crystallinity of a compound and to investigate the surface morphology of the samples, respectively.

4. FINDINGS AND DISCUSSION

In this project, the electroless nickel plating on ABS plastic was studied. The effects of temperature, pH, sandpaper size and plating time were investigated for the amount of deposit. There a lot of plating baths in the literature [11-13]. The composition of the electroless nickel plating bath solution was given in Table 1.

Table 1. Composition of the electroless plating bath

Chemical	Formula	Concentration(g/L)
Nickel Sulfate	$NiSO_4$	40
Sodium Hypophosphite Monohydrate	$NaH_2PO_2 \cdot H_2O$	20
Tri Sodium Citrate Dihydrate	$C_6H_5Na_3O_3 \cdot 2H_2O$	100
Ammonium Chloride	NH_4Cl	50

After electroless nikel was plated over the ABS plastic samples, it is decided to measure the plating amount of Nickel over the samples. For this purpose, Fischerscope X-Ray XDL-B System was used to determine the deposition amounts of the samples. Results obtained from X-Ray analysis are evaluated and thickness versus time graphs are plotted at different grinding sandpaper sizes (120, 240 and 320 grit) for 85-90-95^{0}C. It is seen from the Figures 1, 2 and 3 that, the amount of deposits increases with increasing plating bath temperatures and plating times as expected. According to the literature [14], it can be concluded that thickness of plated samples increases with increasing time and increasing plating bath temperature.

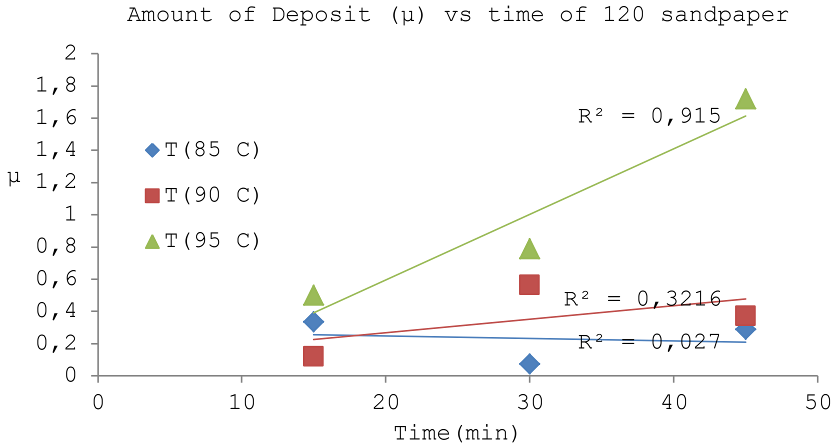


Figure 1. Amount of Deposit (µ) vs plating time for specimen grounded with 120 grit sandpaper

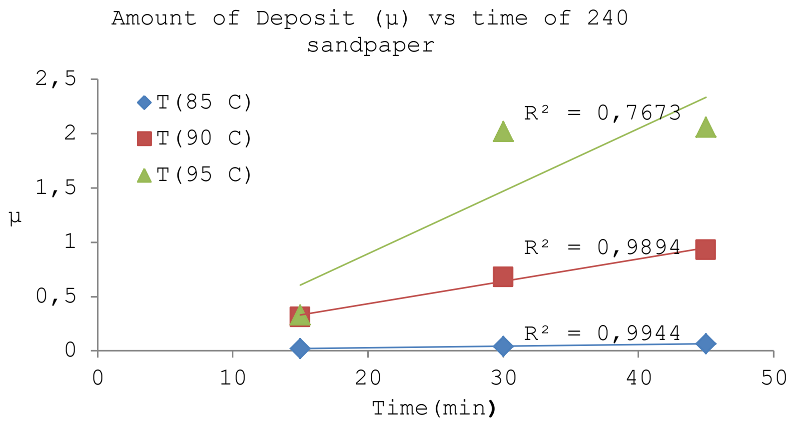


Figure 2. Amount of Deposit (µ) vs plating time for specimen grounded with 240 grit sandpaper

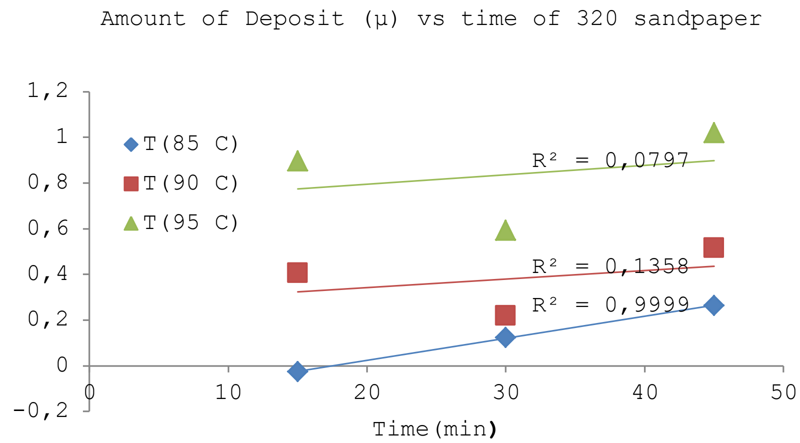


Figure 3. Amount of Deposit (µ) vs plating time for specimen grounded with 320 grit sandpaper

Amount of deposit versus pH graphs are plotted to see the effect of solution pH on the plating rate of electroless nickel deposits (Figure 4). It is observed from this figure that, the amount of deposit decreases with increasing pH values. This means that without any type of buffering, as deposition progresses, the pH value in a bath is expected to become lower. This is reflected in a gradual lowering of the deposition rate as well.

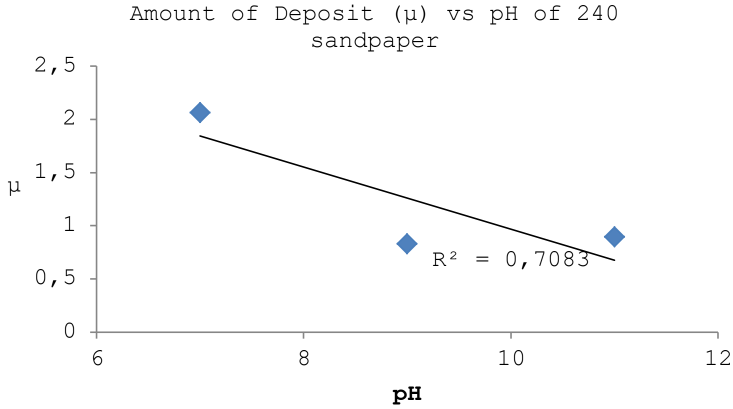


Figure 4. Amount of Deposit (µ) vs pH for specimen grounded with 240 grit sandpaper

Intensity versus 2θ graph is plotted according to X-Ray Diffraction analysis results for the best operating conditions. Broad peaks at 2Theta=20° and 2Theta=45° in the Figure 5 suggest an amorphous structure of the nickel coating on the sample and thus the as plated layer is ductile. So it is clear that the layer structure is not pure crystal and further heat treatment can be employed to transfer amorphous structure into crystalline structure [15]. According to JCPDS database, the peak representing at 45° corresponds to stable phase of nickel (JSPDS 04-0850) and that of at 20° corresponds to meta stable phase of nickel(JSPDS 18-0883).

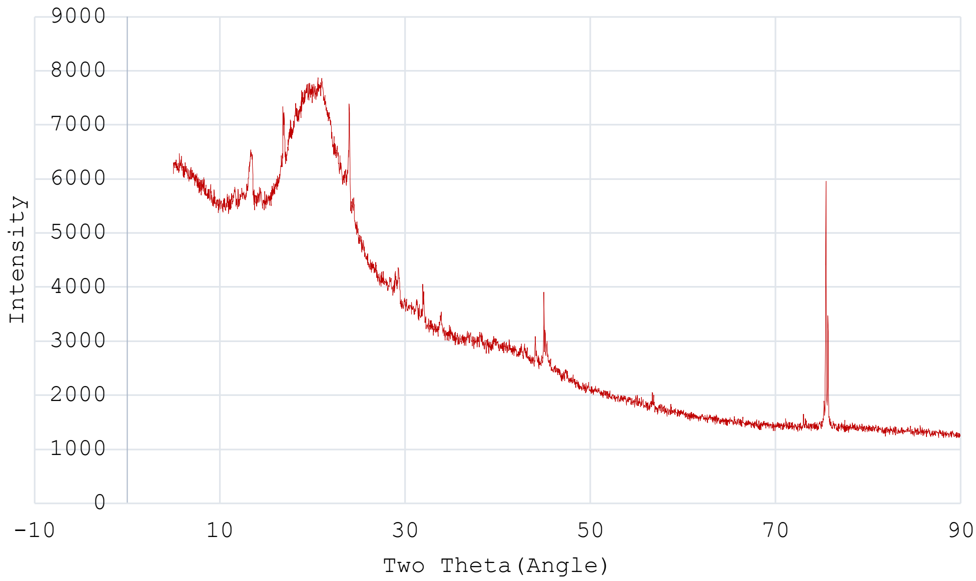
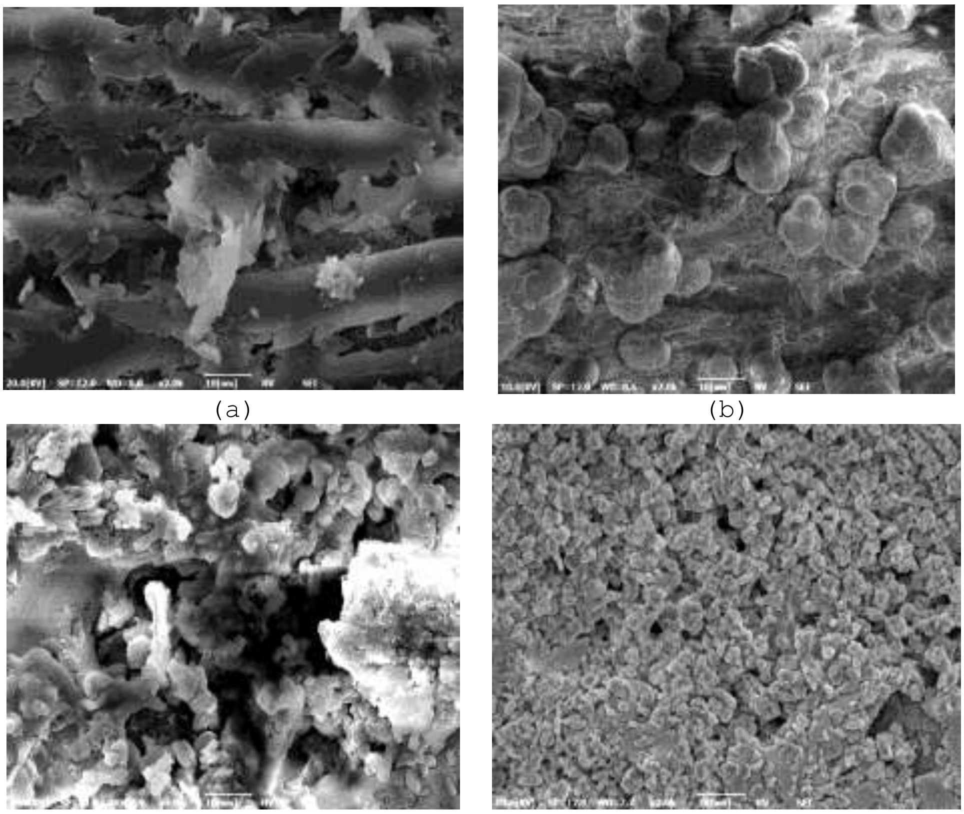


Figure 5. XRD pattern of electroless deposition of Ni layer with 240 grit size sandpaper at 30 min., at 90^{0}C and at pH 9

SEM analysis of unplated ABS samples and nickel plated samples were performed to investigate the surface morphology of the samples (Figure 6a, Figure 6b, Figure 6c, and Figure 6d).

The plating thicknesses of the samples are 0.329, 2.02 and 2.06 µm at 15, 30 and 45 minutes plating times, respectively. It is shown from Figure 6a, Figure 6b, Figure 6c, and Figure 6d that a crystalline material is deposited on the surface of the substrate by using 240 grit sand paper at solution pH 7 and at 45 minutes. It is proved that electroless nickel plating took place. The elemental mapping result by SEM-EDX also indicated that the plating film consisted of nickel only, and the nickel was homogeneously distributed on the surface of the film [16].



(a) (b) (c) (d)

Figure 6. SEM Analyses of a)unplated b) plated at 15 min c)plated at 30 min d) plated at 45 min using 240 grit sandpaper at pH 7-8 and at 95°C

5. CONCLUSIONS

In this experimental study, the operating conditions and the best plating conditions of electroless nickel plating over ABS plastic were investigated. The investigated parameters were the thickness of plate, plating time, sandpaper size effect, plating bath temperature and pH. From the results of this experimental study, the following conclusions can be drawn:

- It is succeeded to plate the ABS plastic with dense, smooth, and pure nickel.
- The maximum amount of the deposit was achieved for the sample grounded with 240 grit sandpaper and at 95^0C plating bath temperature, at solution pH 7 and 45 minutes of electroless nickel plating time.
- XRD results indicated that the deposited film was nickel. The plating film consisted of Nickel only, and the metal was homogeneously distributed on the surface of the film.
- On the contrary of the traditional processes with chromic and sulphuric acids, the pretreatment, the etching and the plating processes were performed with environmentally friendly chemicals

and technique. In this way, both it will be provided a significant benefit to public health, and it will be brought innovation to the metal plating industry with the unhazardous process.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

FINANCIAL DISCLOSURE

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

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