An Electro less Plating – A Review Paper

Yagnesh B Chauhan[1]
[1]Assistant Professor
[1]Department of Mechanical Engineering
[1]G.E.C. Dahod

Abstract— Electro less plating has become an established industrial technique and gained increasing importance at present. By such means not only pure metals but also alloys can be deposited on ferrous and non-ferrous materials to improve their surface characteristics. By using appropriate pee- plate treatment methods, a wide range of plastics and ceramics can also be plated by electro less methods. These processes have particular advantages in the field where galvanic processes can only be used at great expense or where they fail completely. Electro less nickel plating on steel is carried out by a chemical reaction and without the use of an external source of electricity. In electro less nickel plating, nickel chloride will come as a metallic salt and is reduced by using Sodium hypophosphite as the reducing agent to nickel metal, which then is deposited on the steel.

Key words: Electro less plating, nickel chloride, Sodium hypophosphite

I. INTRODUCTION

Electroless plating is an auto-catalytic process where the substrate develops a potential when it is dipped in electroless solution called bath which contains a source metal of metallic ions, reducing agent, stabilizer and others. Due to the developed potential, both positive and negative ions are attracted towards the substrate surface and release their energy through charge transfer process.

Each process parameter has its specific role on the process and influences the process response variables. Temperature initiates the reaction mechanism which controls the ionization process in the solution and charge transfer process from source to substrate. In addition to this, the substrate is activated before dipping into the electroless bath and sensitized to initiate the charge transfer process. Actually in electroless metal deposition process, no external current supply is required to deposit material on a substrate.

Electro less deposition has the advantages of simplicity and feasibility over other processes. The amorphous boron is introduced to improve the adherence between coating and the substrate besides improving properties, like wear resistance, hardness, corrosion resistance and surface roughness.

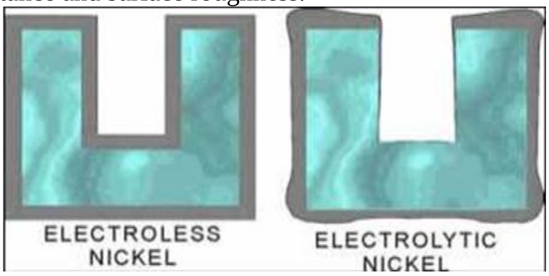


Fig. 1: Comparison between electoless and electroplating surfaces

The applications of electroless nickel have been reported in many industries, like petroleum, chemical, plastics, optics, aerospace, nuclear, electronic devices, computer, and printing because of its excellent corrosion and wear resistance properties.

The true electroless or "chemical" metal deposition processes are those capable of being used in place of Electro deposited coatings in that they permit a continuous metal deposition. Such deposits form only on certain catalytically active surfaces (auto catalytic deposition). The electrons needed to reduced the metal ions are provided by the reducing agents R^{n+} which surrender z electrons, themselves being oxidized to $R^{(n+z)}$. The equations for this are.

II. LITERATURE REVIEW

Mordechay Schlesinger and Milan Paunovic[1] Electroless (autocatalytic) plating involves the presence of a chemical reducing agent in solution to reduce metallic ions to the metal state. The name electroless is somewhat misleading, however. There are no external electrodes present, but there is electric current (charge transfer) involved. Instead of an anode, the metal is supplied by the metal salt; replenishment is achieved by adding either salt or an external loop with an anode of the corresponding metal that has higher efficiency than the cathode. There is therefore, instead of a cathode to reduce the metal, a substrate serving as the cathode, while the electrons are provided by a reducing agent. The process takes place only on catalytic surfaces rather than throughout the solution (if the process is not properly controlled, the reduction can take place throughout the solution, possibly on particles of dust or of catalytic metals, with undesirable results).

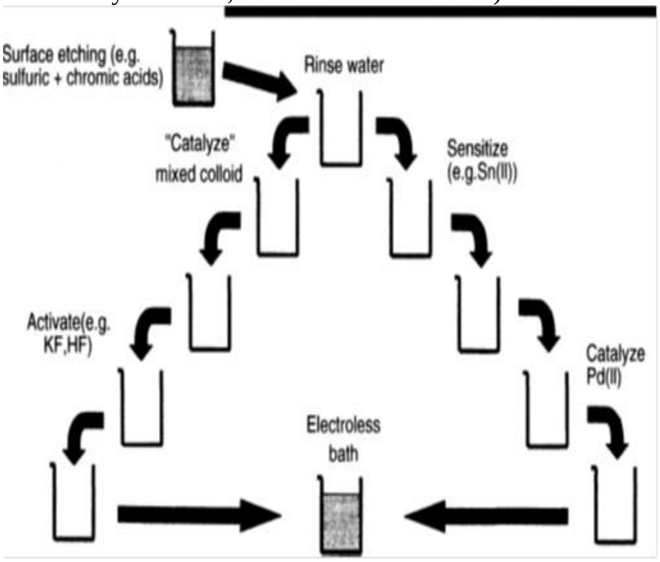


Fig. 2: Schematic representation of the electroless deposition process.

Mallory and Hajdu[2] studied the effect of bath pH and recorded this type results shown in figure.

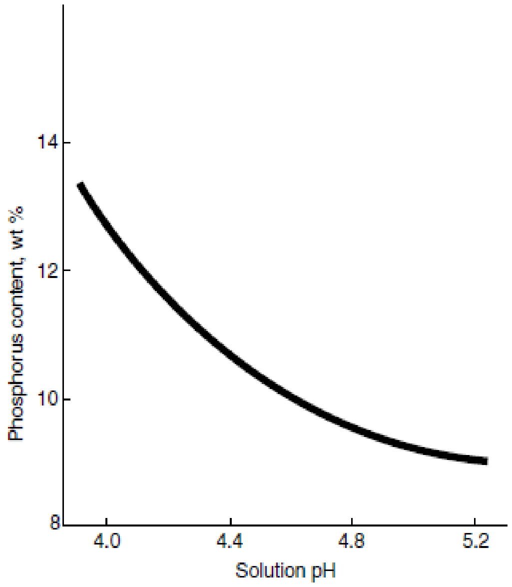


Fig. 3: Effect of pHon phosphorous content.

I.E.Ayoub[3] has studied on Electroless Ni-P Plating on Stainless Steel and concluded the following points.[1]

(1) Ni-P coating can be successfully plated on the surface of stainless steel. The coating was compact, uniform and showed mixture microstructure of amorphous and microcrystalline with phosphorus contents of 8.57 wt.%.
(2) The corrosion resistance of Ni-P on stainless is greatly improved by heat-treatment which were tested by the immersion experiment and the potentiodynamic polarization experiment in 3 % NaCl solution.
(3) The micro hardness of the coating was increasing with increased the heat treatment temperature for a constant time (1hr), maximum hardness was achieved at 400°C.

Juan Hajdu[4] has developed Surface Preparation For Electroless Nickel Plating in which the masking is used in surface preparation.

A. Masking:

Many parts may require only partial coverage with electroless nickel, and portions of the substrate must be protected by masking. Many stop-off materials (tapes and coatings) used for electroplating can be applied for masking parts for electroless plating. Since most electroless nickel solutions operate at high temperatures, and the parts may stay in the bath for a long time, the masking materials should be tested thoroughly before using them on expensive parts.

Masking materials may also release organic or metallic contaminants that may harm the nickel deposits. A problem commonly encountered when plating small areas in large parts is how to adjust the plating process to very low surface-to-volume ratios.

All electroless plating solutions will perform best above minimum loading levels, which may be difficult to reach with masked parts.

Sijie Wang & Wei Zhang[5] studied the influence of heat treatment for coating of nickel plating on hollow glass beads by electoless plating process. The microstructure and component of Ni-plated GBs surface were studied by scanning electron microscopy and energy dispersive spectrometer; heat insulation and reflectivity were detected by heat insulation instrument (home-made) and vector network analyzer. The results show coatings prepared by electroless plating were uniform, the nickel element in the coating was higher than 95.71% (mass fraction); with heat treatment, the surface roughness of coating was greater apparently.

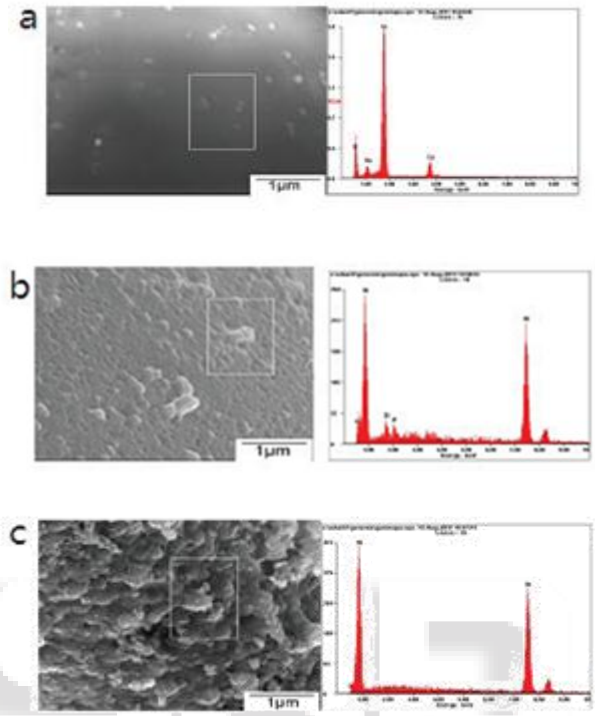


Fig. 4: SEM images and EDS of GBs/Ni-plated GBs/ Ni-plated GBs with heat treatmen (a) Before plating; (b) After plating (c) The coating with heat treatment

Ashish Kumar Singh, Vishnu Kant Bajpai and Chetan Singh Solanki [6] carried out electroless palting on c-Si solar cell.

In c-Si solar cell front contact metallization, nickel-copper electroplating scheme is found to be economical compared to other available techniques. In this metallization process, nickel seed layer deposition is looking simple but very important step in terms of its grain size, minimum thickness reaching the continuity of the film and its uniformity. Thin, uniform and continuous nickel seed layer helps in reducing the metal-semiconductor contact resistance as well as prevent junction shunting during silicide formation at the metal-semiconductor interface. Although, there are different process parameters affecting the morphology of the nickel film in electroless chemical bath deposition, but due to the photovoltaic effect of the p-n junction of the solar cell, the ambient light affects the nickel deposition process. The effect of light on electroless nickel (EN) deposition has been studied in this work. For this purpose the experiments have been performed in different lighting conditions like: dark, ambient, varying intensity UV-VIS light. Also, the nickel depositions have been done for different periods of time from very small period like 30s to longer periods like: 1 min, 2 min, 3 min and 4 min to see the effect at the initial stage of depositions as well as for prolonged deposition. Alkaline bath (pH ~7.5) was selected for EN-deposition and other experimental condi tions were kept same for all theexperiments. EN- deposition under dark is found to be the most suitable for nickel-copper metallization process.

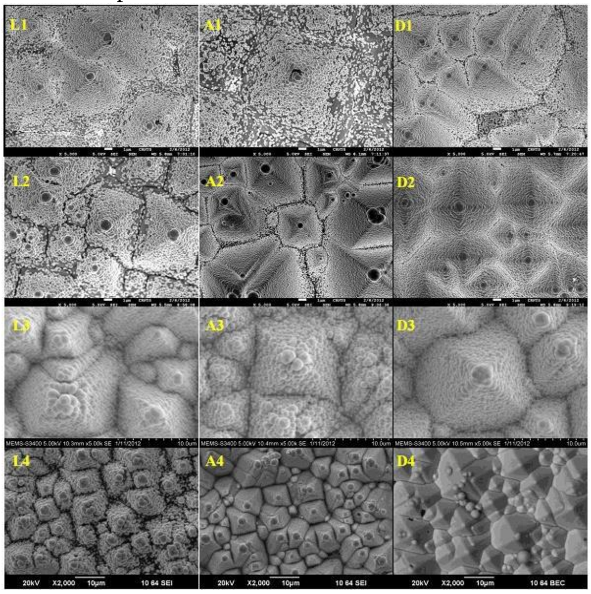
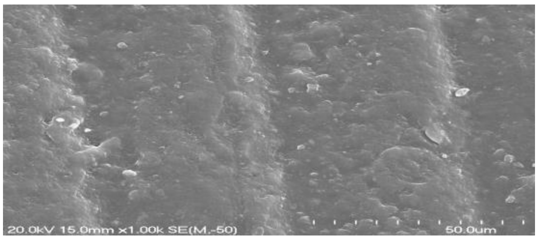


Fig. 5: SEM images (top view) showing variation in surface morphology of electroless nickel deposition due to effect of light

(L1) 2150 Lux, 60s, 5 kX; (A1) 510 Lux, 60s, 5 kX; (D1) dark, 60s, 5 kX; (L2) 1820 Lux, 120s, 5 kX; (A2) 450 Lux, 120s, 5 kX; (D2) dark, 120s, 5 kX; (L3) 1880 Lux, 180s, 5 kX; (A3) 480 Lux, 180s, 5 kX; (D3) dark, 180s, 5 kX; (L4) 1870 Lux, 240s, 2 kX; (A4) 500 Lux, 240s, 2 kX; (D4) dark, 240s, 2 kX; Other bath conditions were kept similar (bath-3, pH~ 7.5, 85±1ºC). Light intensity (luminosity) was measured at the surface of EN-bath.

J.C. Rajaguru, C. Au, M. Duke[7] presented an investigation of electroless nickel plating on PerFactoryTM rapid prototype model built on PerFactoryTM R05 material. PerFactoryTM R05 is acrylic based photo sensitive resin. It is a popular material in rapid prototyping using PerFactoryTM method which employs addictive manufacturing technique to build prototypes for visual inspection, assembly etc. Metallization of such a prototype can extend the application envelop of the rapid prototyping technique as they can be used in many functional applications. Unlike the electroless nickel plating on metal substrate, the process on acrylic resin substrate is not auto-catalytic. Hence, etching and activation are necessary for initiating the process. The final coating is then investigated using scanning electron microscope (SEM) together with energy dispersive spectroscopy (EDS) and x-ray diffraction (XRD) analysis to identify the morphology and structure of the coating. The SEM & EDS analysis on surface and chemical composition of model surface after each preliminary surface treatment are also presented. Finally the layer is tested on Vickers micro hardness tester.



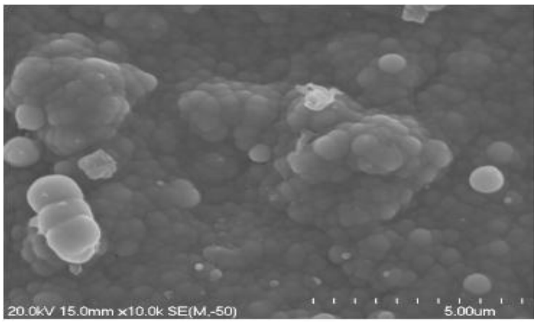


Fig. 6: The surface morphologies of original PerFactoryTM model surface, and surface after electroless nickel plating

Surface hardness of the nickel coating is measured using Vickers micro hardness tester, Leco LM700. Data are collected for the load range from 10 gf to 1000 gf for both nickel coating and the uncoated PerFactoryTM model using Vickers diamond indenter at 10 second dwelling time. Data are tabulated after getting the average of five readings for each loading condition in both cases. Fig. shows the Vickers hardness comparison. According to the hardness data, the nickel coated surface has higher hardness value than the uncoated surface for the loading range from 1000 gf to 200 gf. The highest recorded Vickers hardness is 14.7 HV at 500 gf loading which is 83% higher than without coating hardness value of 8 HV500 gf.

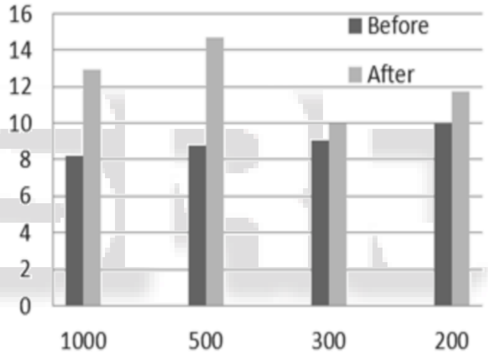


Fig. 7: Vickers Hardness value (HV) versus loading (gf): a) before, b) after the coating

Electroless plating is employed successfully to coat a layer of nickel-phosphorous alloy on the urface of an acrylic resin built PerFactoryTM rapid prototype sample. Etching the surface before the activation has a significant effect on surface and creates anchor point for final layer. The morphology study using SEM investigation is performed and surface morphology shows the homogeneous layer of nickel-phosphorous coating. Furthermore, new nickel coating improves the surface hardness of PerFactoryTM model as much as 83%. However, further investigation is required to obtain mechanical and thermal properties of the layer for its functional applications.

Olawale Olarewaju Ajibola, Daniel T. Oloruntoba, and Benjamin O. Adewuyil [8] examined effects of hard surface polishing grits and activation on electroless-nickel (EN) plating on cast aluminium alloy substrates in sodium hypophosphite baths. As-received aluminium alloy sample sourced from automobile hydraulic brake master cylinder piston was melted in electric furnace and sand cast into rod. The cast samples were polished using different grits (60 μm– 1200 μm) before plating.

The effects on adhesion, appearance, and quantity of EN deposits on substrates were studied. Observation shows that the quantity of EN deposit is partly dependent on the alloy type and roughness of the surface of the substrates, whereas the adhesion and brightness are not solely controlled by the degree of surface polishing. The best yield in terms of adhesion and appearance was obtained from the activation in zincate and palladium chloride solutions. Higher plating rates (g/mm2/min) of $3.01E-05$, $2.41E-05$, and $2.90E-05$ were obtained from chromate, zincate, and chloride than $8.49E-06$, $8.86E-06$, and $1.69E-05$ as obtained from HCl etched, NaOH, and H2O activated surfaces, respectively.

EN has been deposited on the cast Al alloy substrates in sodiumhypophosphite bath.With the variation in the surface finishing, it was observed that the quantity of EN deposition is partly dependent on the type and roughness of the surface of the aluminium alloy substrates, whereas the adhesion and brightness are not solely controlled by the surface polishing grits. There are instances where low polishing grit produced better and more tenacious coating than the higher polishing grit. The best yield in terms of the plating quality (adhesion and appearance) was obtained from the activation in zincate and palladium chloride solutions. Higher plating rates (g/mm2/min) of $3.01E-05$, $2.41E-05$, and $2.90E-05$ were obtained from chromate, zincate, and chloride than $8.49E-06$, $8.86E-06$, and $1.69E-05$ as obtained from HCl etched, NaOH, and H2O activated surfaces, respectively. Zincating on cast Al alloy substrate prior to EN-plating as it has been reported to be result oriented and, hence, encouraged for better adhesion.

Prasanna Gadhari, and Prasanta Sahoo[9] investigate the influence of coating process parameters on the microhardness of electroless Ni–P–Al2O3 composite coating with the help ofTaguchi analysis. Four parameters, namely, concentration of nickel sulphateas a nickel source, concentration of sodium hypophosphite as a reducing agent, concentration of Al2O3 particles as concentration of second phase particles, and annealing temperature, are considered and fitted into an*L27* orthogonal array to find out the optimized condition for improvedhardness of the coating. The optimized condition is found to yield about 20.47% improvement in hardness of the coating comparedto the initial condition. The significance of the process parameters and their interactions on the hardness of electroless Ni–P–Al2O3 composite coating isstudied with the help of analysis of variance, which revealed that annealing temperature and concentration of second phase particles (Al2O3 particles) have significant influence on the hardness characteristics of electroless Ni–P–Al2O3 composite coating.

B. Advantages:

1) Major Advantages:

- Electroless solutions produce coatings with a very high degree of uniformity.
- Ideal for complex shapes.
- Only if the plating solution can contact area being plated.
- Electroless plating is ideal for the salvage of mis-machined parts & recycling worn components.

2) Other Advantages:

EN is the preferred choice among functional coatings for irregularly shaped, highly detailed part geometries because of its completely uniform deposit thickness and close dimensional tolerance capabilities.

3) Uniform Coverage:

- Complete uniform coverage to holes, deep recesses, inside diameters, and components
- with complex geometries.
- Many post-plate machining and finishing operations can be eliminated, resulting in significant cost savings and increased profitability.
- Critical tolerances can be maintained.

4) Hardness And Wear Resistance:

- As deposited, Nickel Phosphorous hardness measures 47-63 HRC, depending upon the phosphorus content of the deposit
- Medium Phosphors as plated is approx 52HRC.
- High Phosphorous is approx 47HRC.
- Post-plating heat treatment can increase hardness to over 72 HRC.
- Exceptional wear and abrasion resistance properties allows it to replace more expensive alloy materials and hard chromium.

5) Excellent Adhesion:

- Deposit adhesion ranges from 40 to 60kpsi, which reduces chipping, flaking, and peeling under extreme conditions.
- Electroless Nickel deposits meet or exceed the stringent adhesion testing requirements outlined in ASTM B 571.

6) Lubricity And Release Qualities:

- Phosphorus in the Electroless Nickel alloy provides a natural lubricity which helps to minimize heat buildup and reduces scoring and galling.
- The coefficient of friction for EN vs. steel is about 0.13 under lubricated conditions and 0.4 under nonlubricated conditions, which is approximately 20% lower than chromium, one-half that of plain steel, and lower than aluminum or stainless steel.
- Electroless Nickel provides lubricity and functional release properties, making it an ideal plating for dies, gears, and molds. It can also be used as a costeffective measure to repair and
- salvage molds.

7) Composite Coatings:

- Electroless Nickel/Teflon Co-deposition deposits a durable, dry lubricating coating that combines the low coefficient of friction of PTFE (Teflon) in a strong, hard matrix of EN.
- Cost-effective alternative to expensive specialty alloys in applications that involve high speed/low load or slow speed/moderate load under dry lubrication.
- Unlike “topically-applied” PTFE coatings, distribution of PTFE particles is uniform throughout the entire thickness of the Electroless Nickel deposit. The surface is continually renewed throughout it’s service life to provide continued lubricity.

C. Applications:

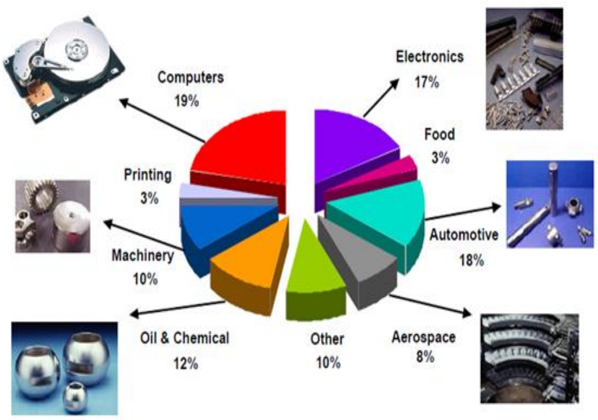


Fig. 8: Applications of Electoless plating in different industries

REFERENCES

[1] Modern Electroplating, Fifth Edition Edited by Mordechay Schlesinger and Milan Paunovic Copyright _ 2010 John Wiley & Sons, pp. 447-458
[2] G. O. Mallory and Juan B. Hajdu, Eds., Electroless Plating-Fundamentals and Applications, American Electroplaters and Surface Finishers Society, Chs. 1–11,
[3] I.E.Ayoub, Isotope and Radiation Research;Vol. 41(4s2); 2009; pp. 1551-1559
[4] Juan Hajdu, Metal Finishing, Volume 98, Issue 5, 2000, pp. 42-46
[5] Sijie Wang, Wei Zhang, Physics Procedia, 50, (2013), pp. 219 – 224
[6] Ashish Kumar Singh, Vishnu Kant Bajpai and Chetan Singh Solanki, Energy Procedia, 54, (2014),pp. 763 – 770
[7] J.C. Rajaguru, C. Au, M. Duke,Journal of Achievements in Materials and Manufacturing Engineering, 55/2, (2012),pp. 782-789
[8] Olawale Olarewaju Ajibola, Daniel T. Oloruntoba, and Benjamin O. Adewuyil, Journal of Coatings, Volume 2014, pp. 1-10
[9] Prasanna Gadhari*, Prasanta Sahoo, Procedia, Materials Science,6,(2014),pp.623–632

