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Effect of Nickel Pulse Electroplating Parameters on ST12 Steel

[1]Hassan Nosrati, [1]Seyed hadi Tabaian, [1]Hamid Reza Baharvandi,
[2]Mohammad Nemati and [3]Ahmad Samariha

[1]Composite Center, Faculty of Materials & Manufacturing Processes,
Malek-e-Ashtar University of Technology, Lavizan, Tehran, Iran
[2]Department of Wood and Paper, Science and Research Branch, Islamic Azad University, Tehran, Iran
[3]Young Researchers Club, Science and Research Branch, Islamic Azad University, Tehran, Iran

Abstract: Nickel coatings benefit from their high corrosion resistance and low porosity content. However, improving these properties seems to be necessary for special purposes which can be achieved through pulse plating. The most important parameters to enhance surface quality of Nickel pulse plating on ST12 steel have been discussed in this research. Morphology of the coatings have been investigated by metallographic and AFM experiments. Reported morphology of the coating for all cases was even except for that of direct current (DC).

Key words: Nickel · Pulse · Electroplatin

INTRODUCTION

Voltage and current between the two electrodes interchange quickly in pulse plating [1-3]. These are separated using zero current in some pulses having equal amplitude, time duration and polarity. Each pulse includes ON-time (T_{ON}) whenever voltage and current exist in the circuit and OFF-time (T_{OFF}) whenever zero current is in the circuit.

By controlling the amplitude of pulses and their relevant factors, composition of the produced coating and its thickness can be controlled at atomic level [4-7]. Pulses are categorized in different groups according to the wave shape, some of which are: cathodic or anodic pulse with a no current time, direct current with increasing frequency, diphase pulse, pulse on pulse, cathodic pulse accompanied by anodic pulse [8].

The most common type of pulse plating is replacing the poles or changing cathodic pole with anodic pole [9]. The desired structure and acceptable porosity would b achieved in pulse plating by modification of the pulse parameters [10-16].

For the nickel coating, a more desired shape can be earned with advantageous mechanical properties and resistance against corrosion by altering the pulse parameters [17, 18].

The current research has utilized anodic-cathodic pulse plating. Various parameters have been investigated in order to study the differences between direct plating and pulse plating some of which were number of pulses, time of pulses and voltages of forward and backward.

Experimental: For preparing samples of the plating process, ST12 steel was used according to DIN standards with chemical composition summarized in tanle1 below.

Samples with dimensions of 3×5cm were cut in 1mm thickness to conduct experiments in different conditions. These samples were then polished and sanded to attain the required surface characteristics. The surface was finally coated after being pickled and degreased.

A potentiostat apparatuses was used for creating the plating current in addition to control voltage and amperage. It was equipped with a reference electrode in KCl solution and it was controlled by GPES software. A 500ml cylindrical container was employed as the plating bath which was placed on a magnetic heater to be heated and stirred as well.

Table 1: Chemical composition of the steel used in this research based on DIN standard

Grade	C%	P%	S%	Mn%
ST12	0.12	0.045	0.045	0.6

Corresponding Author: Hassan Nosrati, Composite Center, Faculty of Materials & Manufacturing Processes,
Malek-e-Ashtar University of Technology, Lavizan, Tehran, Iran.

Table 2: Conditions and results of plating process

Sample	Initial Weight (gr)	Final Weight (gr)	Initial Total Voltage (v)	Apparatuses Voltage (v)	Pulse Voltage (v)	Bath Temperature (°C)	Number of Pulses	Direct Time (s)	Reverse Time (s)	Direct Voltage (v)	Reverse Voltage (v)
1	16.55	16.57	0.65	-0.25	-	45	-	1800	-	0.9	-
2	16.12	16.15	0.34	-0.30	-	45	-	3600	-	0.87	-
3	16.38	16.42	0.36	-0.30	0.5	45	50	150	10	0.85	-0.8
4	16.36	16.62	0.19	-0.45	0.55	50	35	250	15	0.9	-0.9
5	17.64	17.69	0.35	-0.35	0.55	50	35	250	10	0.9	-0.77
6	17.70	17.88	0.48	-0.45	0.65	50	35	250	20	0.95	-0.9
7	17.84	17.91	0.48	-0.45	0.75	55-50	35	250	25	1.2	-0.9
8	17.77	17.79	0.50	-0.30	0.75	55-50	12	250	25	5.9	-1.2

One of the most common plating baths for nickel (Watts Bath) was used for experiments. For this purpose, 150gr nickel sulfamate was mixed with 20gr boric acid and 20gr nickel chloride; then distilled water was added to set the total volume to 500ml. Temperature of the solution was raised to 100°C to homogenize the solution. Afterwards, the temperature was decreased to 40-50°C with 3ml of organic and bright materials being added to the solution.

All chemicals used in the experiments were procured from industrial grades, while pure nickel balls inside steel net were used as anode electrode.

Some 24 samples were exposed to direct and pulse plating (for the purpose of comparison) in different conditions. Characteristics of 8 major samples have been listed in table 2. The samples were finally weighted and studied by metallographic observations.

RESULTS AND DISCUSSION

Table 2 illustrates characteristics of 8 coated samples. During all steps of plating, pH content of the electrolyte solution was kept constant at 2.5 while dedicated area for coating for all samples was 3×1.5cm (4.5cm^2). Each sample was coated for three times in order to keep the other parameters unchanged for comparison. For example, sample6 was coated three times each one with almost different conditions.

In samples 1 and 2, plating has been accomplished in direct state which demonstrates lower quality as compared with other samples.

Hydrogen gas is released in cathode for voltages higher than 1v which causes delays in reduction of the plating metal or even expose it with some difficulties. If gas is released to a great extent, it can form bubbles or pitting on the surface. These problems could be solved in pulse plating since the place of bubbles will be removed which is known as the most significant advantages of pulse plating over direct plating. Concentration polarization will be increased with time in direct plating which can sometimes inhibit the plating process completely. Figures 1 and 2 compare metallographic images taken for samle2 (direct plating) and sample7 (pulse plating).

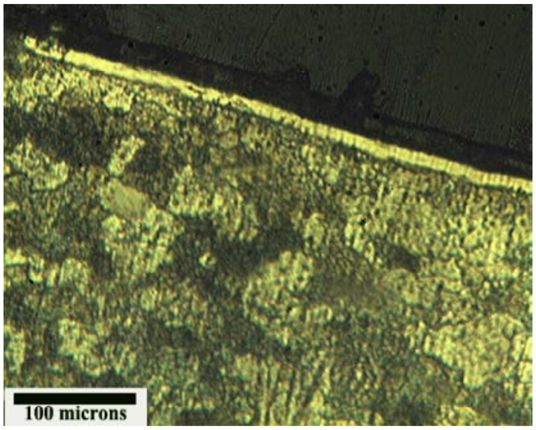

Fig. 1: Metallographic micrographs of sample2 with the existing voids on its surface (etched in Marble solution)

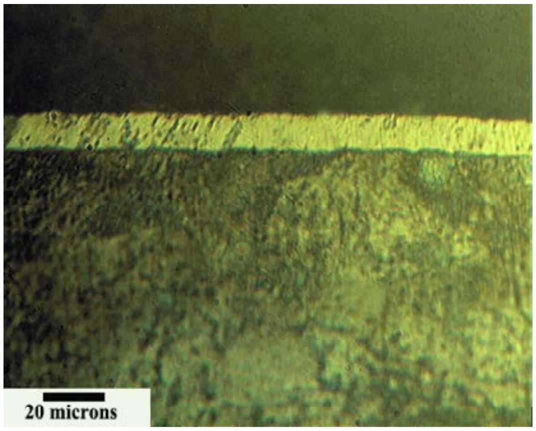

Fig. 2: Metallographic micrographs of sample7 (etched in Marble solution)

Table 3: Forward voltages and changes in weight/total time

Sample	Forward Voltage (v)	ΔM/Δt
3	0.3	5×10^{-6}
4	0.45	2.8×10^{-5}
5	0.35	5.5×10^{-6}

Table 4: Backward voltages and changes in weight/total time

Sample	Backward Voltage (v)	ΔM/Δt
4	0.55	2.8×10^{-5}
6	0.65	1.9×10^{-5}
7	0.75	7.3×10^{-6}

Table 5: Temperature and changes in weight/total time

Sample	Bath Temperature (°C)	ΔM/Δt
6	50	1.9×10^{-5}
7	52	7.3×10^{-6}
8	55	6.1×10^{-5}

Table 6: Total backward time and changes in weight/total time

Sample	Backward Time (s)	ΔM/Δt
4	15	2.8×10^{-5}
6	20	1.9×10^{-5}
7	25	7.3×10^{-6}

Effect of Variable Forward Voltage on Constant Backward Voltage: Regarding samples 3, 4 and 5, when all conditions are almost constant and same for the samples, table 3 will demonstrate that increasing the forward voltage will raise weight changes as well. However, this weight change will be interrupted or even mitigated in voltages close to hydrogen releasing.

Effect of Variable Backward Voltage on Constant Forward Voltage: When the current is reversed, Ni will leave the previous cathode (currently anode) and this phenomenon would be more pronounced whatever voltage is increased further. This case experiences interruptions again in voltages close to hydrogen releasing (Table4).

Effect of Variable Temperature on Constant Pulse Ratio: By increasing the temperature, the weight will be decreased to some extent due to polarization and then, further increase in the temperature will lead to higher weights (Table5).

Effect of Changes in Total Backward Time on Constant Forward Time: By increasing the total backward time, the weight changes will be decreased since this can reduce total plating time (Table6).

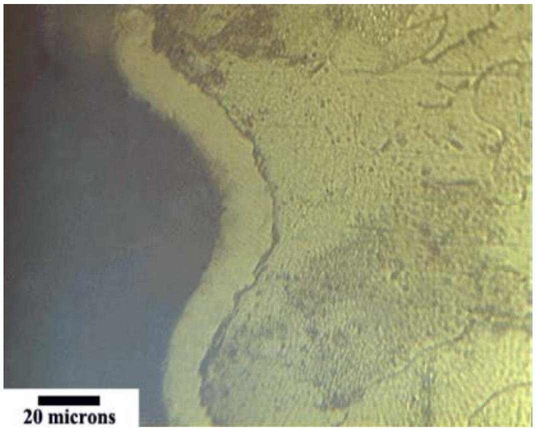

Fig. 3: Metallographic image of sample8 after bending test (etched in Marble solution)

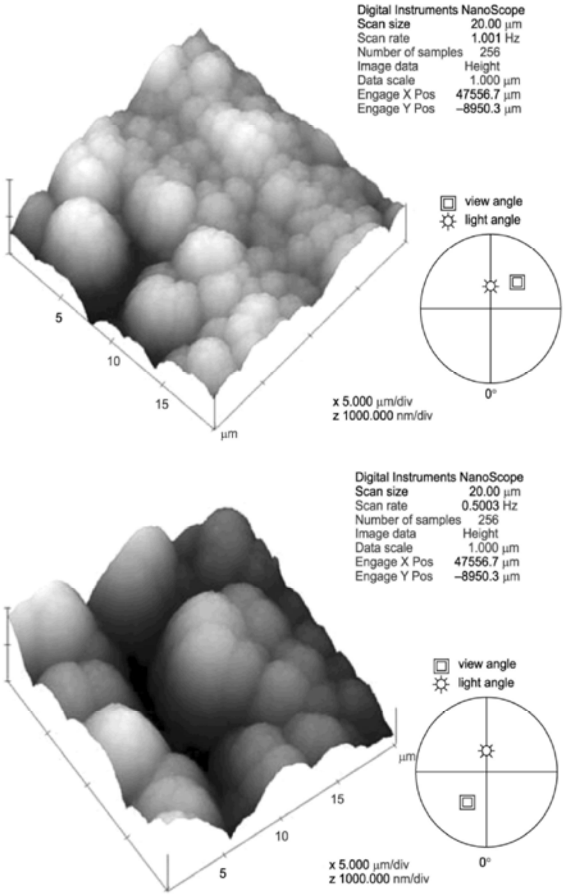

Fig. 4: AFM micrograph for sample2 (upper) and sample7 (lower)

Effect of Number of Pulses: In constant total time, smaller weight changes could be expected for greater number of pulses, because more pulses will in fact increase the total backward time.

In order to study adhesion of the pulse coatings, sample8 was examined by bending test. Taking into account the metallographic section of the sample, it can be observed that high adhesion strength has been achieved (Figure3).

AFM Analysis: Figure4 indicates that the surface obtained from pulse plating (lower) was much smoother than the one obtained by direct plating (upper).

CONCLUSIONS

Pulse plating produces smoother, more perfect and low deficiency surface in comparison with direct plating. Pulse plating benefits from some interesting properties such as less limitation in voltage and ability to remove deficiencies.

Increased voltage and total forward time will intensify weight changes, whereas increased voltage and total backward time will reduce weight changes. Raising the temperature within standard range for coating will increase weight changes while more pulses would lead to less weight changes.

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