CORROSION BEHAVIOR OF Ni-P COATED STEEL STRIPS

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ABSTRACT

In addition to high hardness, Ni-P coatings obtained by the electroless method are widely used due to their high corrosion resistance. The corrosion resistance depends on the content of phosphorus in the coating. Various phosphorus contents result from changes in pH in the process of obtaining layers. The layers obtained in different working conditions were tested for electrochemical corrosion. Tests were conducted on a potentiostat PGP 201. There were plotted and analyzed the anodic polarization Tafel curves for different phosphorus contents, pH conditions and time-exposure in the coating bath. Analyzing the anodic polarization curves it is noticed that low phosphorus sample shows an almost continuous corrosion process while samples with high phosphorus content have slow corrosion in the 3.5% NaCl testing medium.

KEYWORDS: coating, electroless method, corrosion

1. Introduction

Ni-P chemical coatings are obtained by means of autocatalytic method using a nickel salt (sulphate or chloride) and a reductant (sodium hypophosphite) [1, 2]. Protective layers of Ni-P have many features such as hardness and high wear resistance, corrosion resistance, acceptable ductility [3, 4]. One of the most common reasons for using chemical coatings of Ni-P in functional applications is their excellent resistance to corrosion.

As shown in Figure 1, 30% of these types of coating applications refer to their increased resistance to corrosion [5].

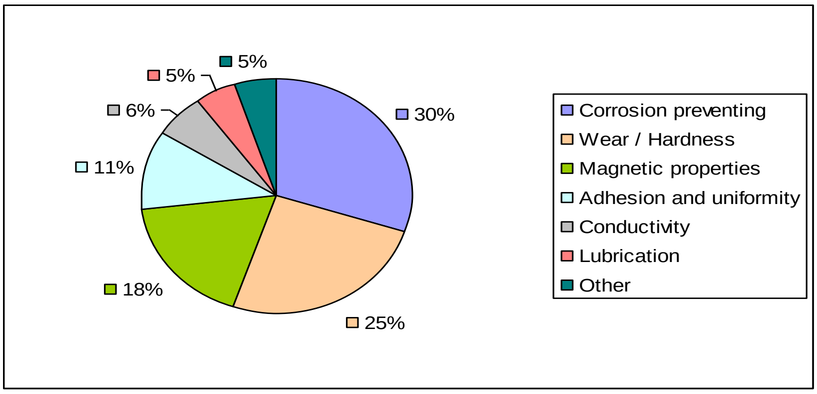

Fig. 1. *Ni-P layer applications* [5]

Compared to electrochemical coatings [6], deposits obtained by the chemical method are usually less porous and more resistant to corrosion (to equal thickness).

In warm highly alkaline solutions, low phosphorus coatings are more resistant to corrosion than those with high content of phosphorus [7]. However, alloys having high content of phosphorous provides increased corrosion resistance in most corrosive environments [8].

The high corrosion resistance of Ni-P coatings is due to the formation of a nickel coating which acts as a barrier to oxygen diffusion onto the metal surface. In general, the corrosion resistance of the Ni-

P coatings is improved by increasing the content of P so that the layers with high phosphorus content and amorphous structures feature a very high resistance to corrosion [9].

2. Experimental research

Corrosion tests were conducted using PGP 201 potentiostat connected to an electrochemical three-electrode cell: working electrode – sample being tested on the surface of which measures were made, counter - electrode of platinum and the saturated calomel electrode, Hg/Hg_2Cl_2, as reference electrode (SCE = + 241 mV/ENH). The system was connected to a computer with VOLTAMASTER 4 software for data analysis. The samples to be tested (working electrode) were isolated on one side prior to immersion into the test solution, i.e. 3.5% NaCl solution.

The corrosion test of each sample begin by monitoring the corrosion potential (open circuit potential – OCP) until this has reached the stationary value.

For potentiodynamic polarization tests, the scanning speed of 2 mV/s was used.

Plotting and interpretation of the Tafel curves give information on the corrosion current density, polarization resistance and the corrosion rate of the systems tested.

Figure 2 illustrates the polarization curves for three coating layers of different phosphorous contents. The Tafel parameters listed in Table 1 show close corrosion behavior for the samples code P1 and P3, P2 having the best resistance to corrosion.

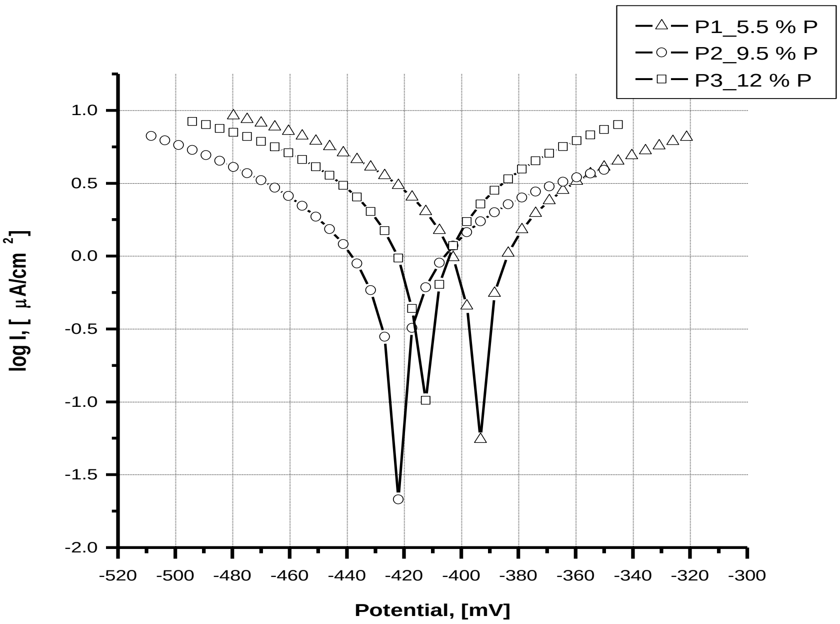

Fig. 2. *Comparative polarization potentiodynamic curves for Ni-P coatings with different phosphorous contents (in 3.5% NaCl solution)*

Table 1. *Results from the potentiodynamic polarisation curves for Ni-P coatings with different phosphorous contents*

Sample	Potential [mV]	Rp [kohm cm^2]	I cor [μA/cm^2]	βa [mV/decade]	βc [mV/decade]	V cor [μm/an]
P1 _ 5.5 % P	-393.4	10.15	2.40	127	-144.5	24.73
P2 _ 9.5 % P	-422.5	16.07	1.35	124.2	-121.5	13.96
P3 _ 12 % P	-413.3	8.96	1.30	127.6	-140.0	23.66

For Ni-P coatings, the lowest corrosion rate in NaCl 3.5% (13.96 μm/year) was obtained with the Ni coating having 9.5% P content and the highest value of the corrosion rate (24.73 μm/year for the Ni coating with low P content (5.5% P).

Since the duration of the coating process affects the layer thickness and this further influences the corrosion resistance, the corrosion behavior was tested on the samples obtained at different times of immersion for obtaining coatings.

Results are shown in Table 2 and Figure 3.

The lowest corrosion rate in NaCl 3.5% (14.35 μm/year) was obtained for the Ni coating achieved in 20 minutes and the highest corrosion rate (83.73 μm/year) for the Ni coating obtained in 10 minutes.

It can be seen that with increasing the time of exposure in the chemical deposition bath, corrosion rate decreases with increasing layer thickness.

Table 2. *Results from the potentiodynamic polarisation curves for Ni-P coatings obtained at different times of immersion*

Sample	Potential [mV]	Rp [kohm cm^2]	i cor [μA/cm^2]	**β**a [mV/decade]	**β**a [mV/decade]	V cor [μm/an]
P4_10 minutes	-521.7	2.28	8.1459	68.7	267.8	83.72
P5_15 minutes	-454.4	2.76	6.9861	77.8	199.9	71.80
P6_20 minutes	-392.1	12.22	1.3964	104.8	105.1	14.35

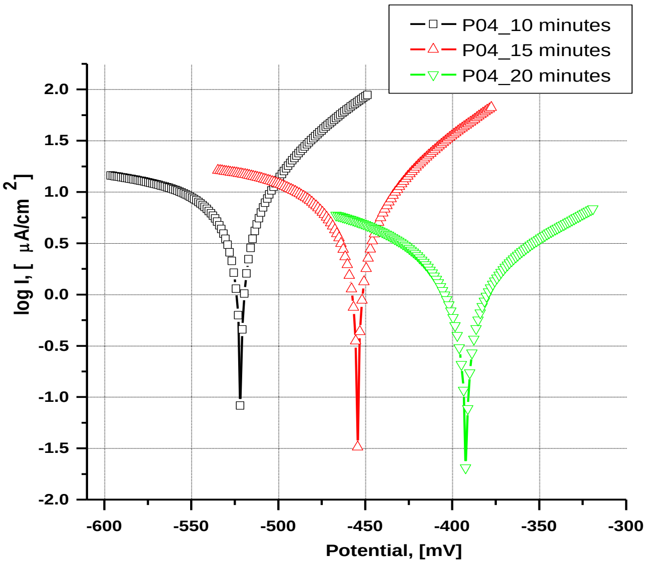

Fig. 3. *Comparative polarization potentiodynamic curves for Ni-P coatings obtained at different times of immersion (in 3.5% NaCl solution)*

Since at different pH of the nickel plating bath different chemical compositions of Ni-P coatings are obtained, the corrosion behavior was analyzed on samples obtained with different values of pH, maintaining the other parameters constant, respectively duration (10 minutes) and temperature (83 °C).

The best corrosion behavior as resulting from the polarization curves (Figure 4) is to be found with the samples obtained at pH = 5. At this pH value, high phosphorous content is achieved that enriches the nickel, thus increasing the coating corrosion resistance. Also at pH = 5 under the same conditions of temperature and time, thicker layers are obtained as compared to those at pH = 4 and pH = 3.5, respectively.

Table 3 illustrates the Tafel parameters achieved for these samples.

Table 3. *Results from the potentiodynamic polarisation curves for Ni-P coatings obtained at different pH values*

Sample	Potential [mV]	Rp [kohm cm^2]	i cor [μA/cm^2]	βa [mV/decade]	βc [mV/decade]	V cor [μm/an]
P7_ pH ≈5	-357.7	10.86	1.26	86.4	90.7	12.96
P8_ pH ≈4	-347.4	9.09	1.69	99.2	98.9	17.40
P9_ pH ≈3.5	-367.4	16.73	1.39	169.1	119.6	14.37

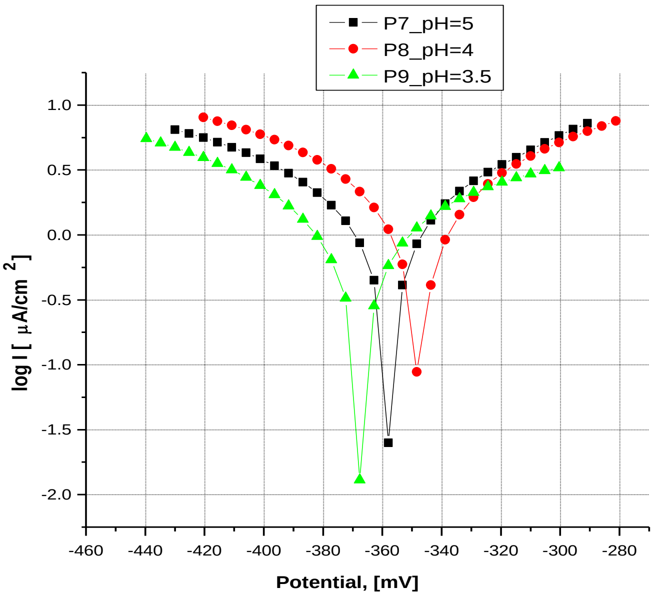

Fig. 4. *Comparative polarization potentiodynamic curves for Ni-P coatings obtained at different pH values (in 3.5% NaCl solution)*

In order to explain the corrosion behavior of the samples analyzed, it is of interest to study and account for their anodic polarization curves.

Figure 5 shows the anodic polarization curve of the Ni-P layer obtained at different pH's which gives them different contents of P, the concentration of this element being greater as the pH is lower. We can say that P5 sample has the highest phosphorus content and P10 sample the lowest. By analyzing the curves in Figure 5 it is observed that the sample with a low content of phosphorus (pH = 6) features an almost continuous process of corrosion and high phosphorus-containing samples obtained at lower pH have a slow corrosion, the evolution of oxygen depolarization being virtually constant at P7 sample.

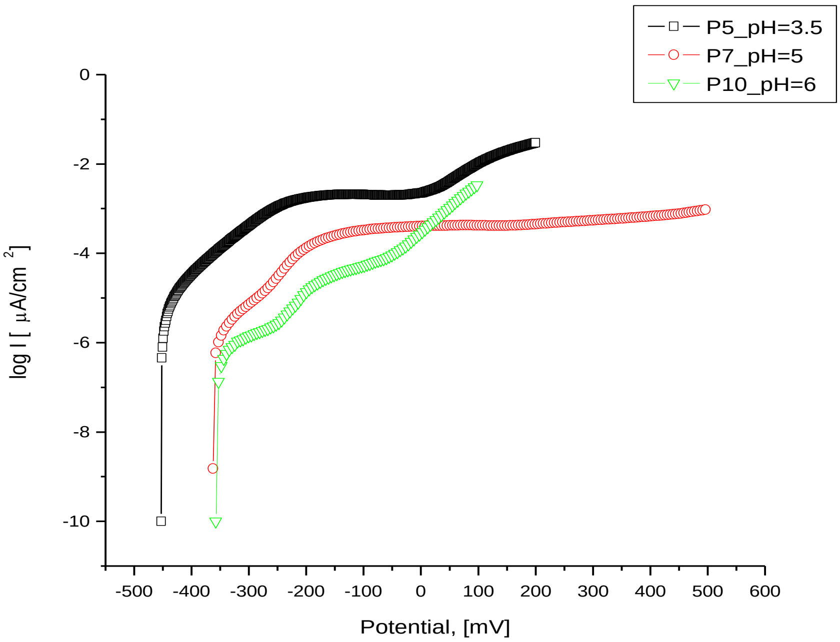

Fig. 5. *The anodic polarization curve of the Ni-P layer obtained at different pH values (in 3.5% NaCl solution)*

3. Conclusions

The Ni-P layers can be distinguished in terms of their resistance to corrosion based on the content of phosphorus as given by the pH of the nickel plating bath and the coating thickness which varies with the duration of immersion, the temperature and pH of the nickel-plating bath.

The best corrosion behavior is obtained for the Ni-P layers with 9.5% phosphorus obtained at a pH of 5 to a minimum immersion time of 10 minutes at 85 °C. The highest value of the corrosion rate (24.73 μm/year) resulted by coating with Ni and low P content (5.5%).

The anodic polarization curves indicate for the sample obtained at pH 5 a very slow evolution of the corrosion process as compared to the upward continuous evolution of the sample obtained at pH= 6 with a low content of phosphorus.

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