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# Influence of the electrolysis mode on corrosion resistance of metallic coatings

**S Yu Kireev, Yu P Perelygin and S N Kireeva**

Penza State University, Faculty of Machine Building and Transport  
40, Krasnaya street, Penza, Russia

E-mail: Sergey58\_79@mail.ru

**Abstract.** Research has been carried out to determine the dependence of corrosion resistance of galvanic zinc and nickel coatings, formed from acid electrolytes with addition of lactic acid, on the electrolysis mode. It is shown that the galvanostatic mode of pulse electrolysis makes it possible to obtain coatings having improved corrosion resistance in the moisture chamber and neutral salt spray. Corrosion resistance of coatings was assessed by changing of the transient electrical resistivity values before and after accelerated corrosion tests. Coatings formed using potentiostatic pulses of rectangular shape are of higher corrosion resistance, which is explained by the positive effect of pulse electrolysis modes on the morphological features of galvanic sludge, and is confirmed by the results of atomic force microscope (AFM) studies.

## 1. Introduction

The formation of coatings on the surface of metal products is a very common technological process both in engineering and in the instrument-making industry. Modification of the surface layer of the product allows solving several problems, including giving special properties and increasing corrosion resistance [1, 2].

The technology of electrochemical formation of coatings by metals and alloys makes it possible to obtain relatively thin, firmly entangled with the basis coatings on the metal surface. This technology allows controlling the composition and properties of coatings, due to change in the composition of electrolyte and electrolysis modes. Non-stationary electrolysis (magnetohydrodynamic processing of a solution, application of ultrasound, cathode vibration, and alternating current) greatly extends the process control capabilities, since there are additional independent parameters [3].

Recently, the technology of forming multilayered metal coatings has become increasingly popular. There is evidence that multilayer composites have an improved set of performance characteristics compared to monomaterials of equal thickness [4, 5]. Thus, the study of the relationship between the physical and mechanical, technological, performance characteristics of coatings, and electrolysis modes is an actual problem. The purpose of this work is to study the influence of galvanostatic and potentiostatic modes of electrolysis on the corrosion resistance of galvanic coatings.

## 2. Research Methodology

Electrodeposition was carried out in thermostated cells filled with electrolytes, for the preparation of which laboratory reagent grade and distilled water were used. The coating mass was determined with the help of analytical balance AND HR-200 with an accuracy of 0.0001 g.



The stabilized source B5-45 was used as a source of direct current; pulse generator G5-60 was used to obtain galvanostatic pulses of a rectangular shape; potentiostat IPC-Pro was used to obtain potentiostatic pulses of a rectangular shape. To ensure the potentiostatic mode of pulse electrolysis, we have developed a design of the laboratory cell and the research methodology, ensuring reproducibility of the obtained results due to the identical arrangement of the electrodes during the experiments.

Electrodeposition of zinc and nickel coatings was carried out on copper (C00) and steel (St3) basis in various modes of electrolytes, the composition of which is given in [6, 7]. Corrosion resistance of coatings was determined in a moisture chamber and neutral salt spray [8].

### 3. Results and Discussion

Table 1 shows the research results of the corrosion resistance of nickel and zinc coatings obtained under various electrolysis modes: stationary electrolysis (S), galvanostatic (G), and potentiostatic pulse (P) modes.

The time before the appearance of corrosion products and the coefficient  $K$ , calculated by the following formula, were used as the criteria for corrosion resistance:

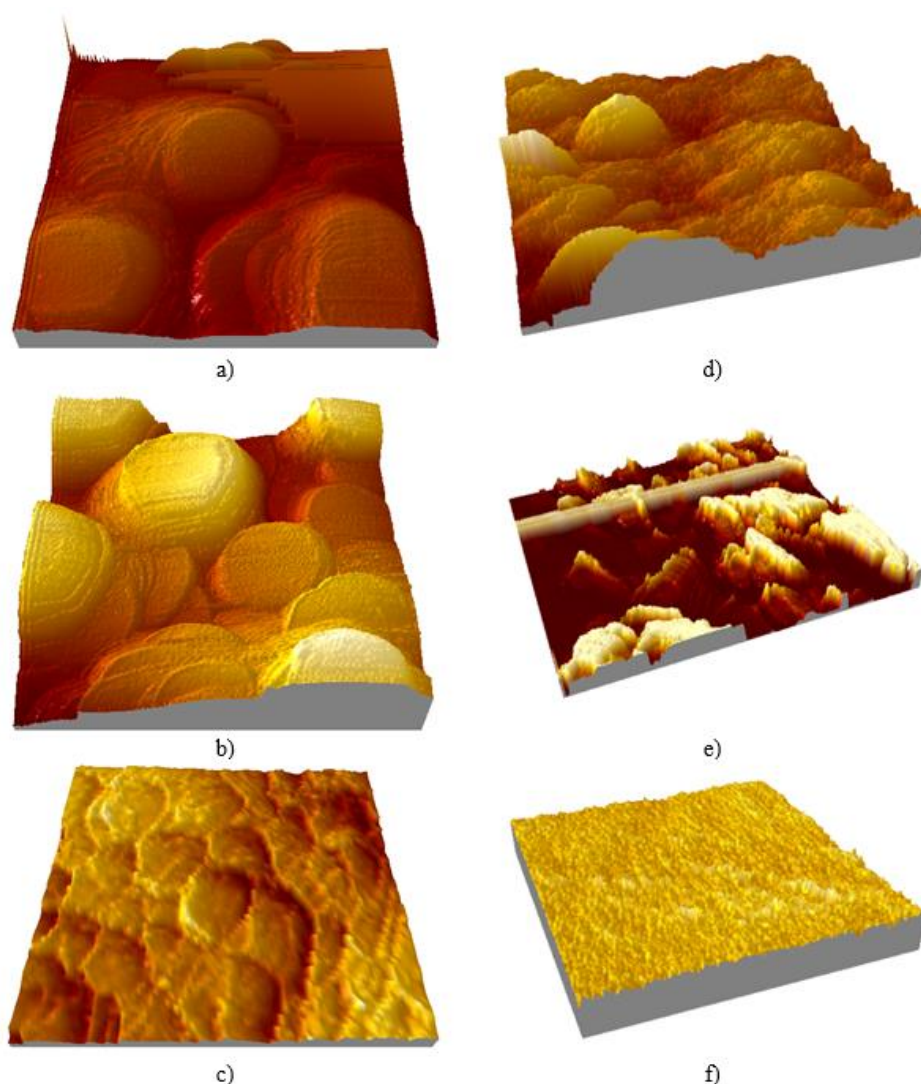
$$K = \frac{R_{trans} - R_{trans}^0}{R_{trans}^0},$$

where  $R_{trans}^0$  is the transient electrical resistivity of the coating before corrosion tests;  $R_{trans}$  is the transient electrical resistivity of the coating after corrosion tests. The larger  $K$  is, the more the surface of the sample was subjected to corrosive changes, and, consequently, the corrosion resistance is lower.

**Table 1.** Research results of the dependence of the corrosion index on the coating material, the base material, and the electrolysis mode under the influence of neutral salt spray and moisture.

Coating material	Electrolysis mode	Base material	Corrosion index ( $K$ ) at loading on a contact pair			
			in the moisture chamber		in the neutral salt spray chamber	
			0.5 H	1.0 H	0.5 H	1.0 H
Zn	S	Cu	2.23	2.05	—	—
Zn	P	Cu	0.68	0.56	0.74	0.86
Zn	P	St3	0.09	0.05	0.26	0.14
Ni	S	Cu	1.33	1.68	—	—
Ni	G	Cu	0.39	0.36	—	—
Ni	P	Cu	0.31	0.33	0.50	0.67
Ni	P	St3	0.14	0.17	0.36	0.25

Analyzing the results, we have come to the conclusion that pulse modes of electrolysis, especially potentiostatic pulse mode, allow forming the most corrosion-resistant coatings. This is explained by the favorable influence of the pulse current on the morphological features of the coatings, namely: decrease of porosity, increase in uniformity, and fine crystallinity. It is confirmed by the research results of the influence of the electrolysis mode on the morphological features of coatings by scanning atomic force microscopy method (figure 1).



**Figure 1.** AFM images of the surface of samples coated with nickel ( $2.5 \times 2.5 \mu\text{m}$ ) (a, b, c) and zinc ( $10 \times 10 \mu\text{m}$ ) (d, e, f) for stationary (a, d), galvanostatic (b, e), and potentiostatic (c, f) pulse electrolysis modes (current density  $1 \text{ A/dm}^2$ ).

#### 4. Conclusions

The research carried out has allowed establishing the relationship between electrolysis mode and corrosion resistance of coatings. Corrosion resistance of nickel coatings obtained in the galvanostatic pulse mode is 3.4-4.7 times higher than in the stationary electrolysis mode.

The potentiostatic pulse mode has the greatest influence on the properties of coatings. So, the corrosion resistance of nickel and zinc coatings formed in this mode exceeds this indicator for stationary mode in 4.3-5.1 and 3.3-3.7 times, respectively.

It has been proved that the use of pulse current promotes the formation of metal and alloy coatings characterized by increased uniformity and nonporosity at a smaller thickness.

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