EFFECT OF DEPOSITION TEMPERATURE ON CORROSION RESISTANCE OF NANO-CEC

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ABSTRACT

An electrolyte for chromium based nano-composite electrolytic coatings (nano-CEC) obtaining has been developed. Nano-CEC was applied on steel of the St 3 brand with constant exposure to ultrasound, electrolyte temperature 50–60°C, current density 7kA/m^2 for 1 and 2 hours from two variants of chromium-plating electrolytes, differing in the fact that one electrolyte contained strontium sulfate, in the other – without it. Quantitative assessment of the corrosion resistance of nano - CEC deposited on steel St.3, was estimated by the gravimetric method with an accuracy of 0.1 mg by comparison with the anticorrosion resistance of St.3 steel without coating. For corrosion testing of samples with nano-CEC, we developed and created a stand that allows you to simultaneously test 8 samples in a stream of corrosive medium pumped by a peristaltic pump with a speed in the range of 10-60 rpm. Distilled water and a solution of sodium chloride in concentrations of 5, 10, 20% were used as an aggressive medium. The tests were carried out at a flow rate of corrosive medium 40 rpm and temperatures of 19-23, 30, and 40 ° C. A test bench for corrosion resistance has been developed and created, which allows: to carry out tests in various corrosive environments at temperatures from room temperature to 60-70 ° C; to carry out tests at different modes of exposure of the corrosive medium to the test parts using a peristaltic pump, which allows changing the flow rate from zero to 60 rpm; simultaneously test 8 samples, which increases the reliability of the results.

Key words: nano-composition coatings, corrosion resistance, amine media, protective properties, carbon steel

INTRODUCTION

Electrolytic chromium, in comparison with other electrodepositable metals, is the most corrosion-resistant, wear-resistant and has high hardness. Despite this, it is not protected against corrosion due to porosity. Deposition of composite electrolytic coatings (CEC) using appropriate dispersed particles can improve the anti-corrosion properties of electrolytic chromium [1-7]. The protective ability of the cover depends on the amount of the dispersed phase in the metal matrix. We assume that in addition to the amount of the dispersed phase, the degree of dispersion of the second phase also affects the corrosion resistance. We assume that in addition to the amount of the dispersed phase, the degree of dispersion of the second phase also influences the corrosion resistance. It is known that chromium-based nano-CEC have very high anti-corrosion properties in water-oil media, and particles with dimensions d≤10nm have high activity against the chromium matrix [8-11], which is manifested in their intensive co-precipitation with chromium ions in the process of metal electro-crystallization [12-15]. In this regard, we have conducted studies of the effect of dispersed particles of the "Aerosil-300" brand of nano dimensions on the corrosion resistance of CEC in solutions of sodium chloride.

MATERIALS AND EXPERIMENTAL PROCEDURE

In order to clarify the effect of temperature and ultrasonic field on the corrosion resistance of the CEC, we were provided with three options that are inevitably associated with the deposition technology of any CEC. The fact is that in order to obtain both CEC and Nano- CEC there should be a sedimentation field of electrolyte - suspension, a nourishing process of CEC deposition - dispersed parts regardless of the method of creating the sedimentation space of electrolyte - suspension: bags, airborne or ultrasonic, as in our case.

The most likely are three options for electrodeposition:

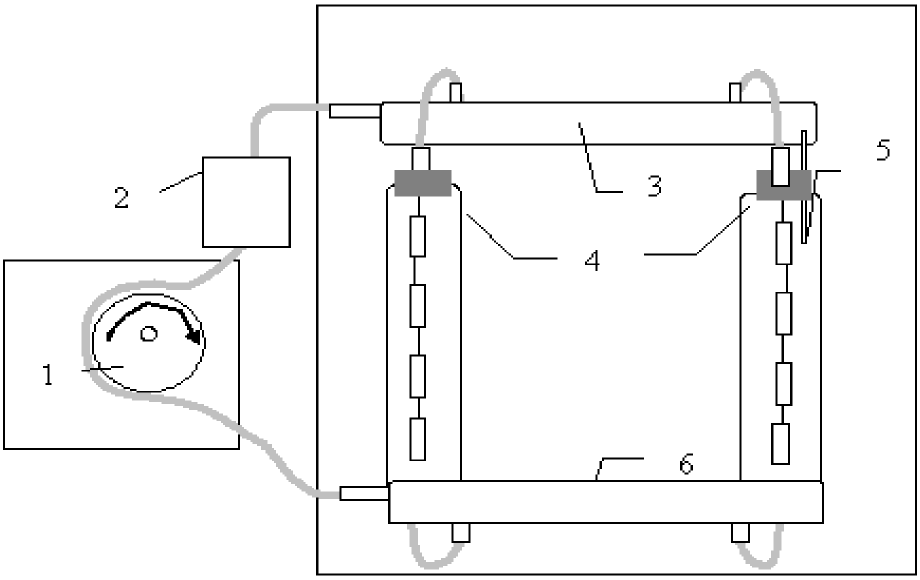
- in a quiet sedimentation field, not disturbed by any external influences, including ultrasound;
- in a sedimentation field periodically disturbed by an external influence, for example, by ultrasound;
- in the sedimentation field, which is under constant external influence, in our case - by ultrasound.

Since the coatings obtained in the mode of brilliant hard chrome plating have the greatest demand, electrodeposition of nano - CEC was carried out at a temperatures of 50-60° C, current density 7 kA / m^2. For electrodeposition we used two variants of chromium-plating electrolytes, differing in the fact that one electrolyte contained strontium sulfate, in the other – without it (Table 1).

Table 1 – Electrolyte composition (g/dm^3)

A_1	A_2
CrO_3 – 250 H_2SO_4 – 2,5 C – 25	CrO_3 – 250; $SrSO_4$ – 7; C – 25.

Quantitative assessment of the corrosion resistance of nano - CEC deposited on steel St.3, was estimated by the gravimetric method with an accuracy of 0.1 mg by comparison with the anticorrosion resistance of St.3 steel without coating. For corrosion testing of samples with nano-CEC, we developed and created a stand that allows you to simultaneously test 8 samples in a stream of corrosive medium pumped by a peristaltic pump with a speed in the range of 10-60 rpm. Distilled water and a solution of sodium chloride in concentrations of 5, 10, 20% were used as an aggressive medium. Scheme of the test bench for corrosion is shown on Figure 1.



1 - peristaltic pump; 2 - broiler to maintain the set temperature of the corrosive environment; 3 - distributor; 4 - columns for placement of the tested samples; 5 - thermometer to monitor the temperature of the corrosive environment; 6 – buffer

Figure 1 - Scheme of test bench for corrosion

Principle of operation of stand and test conditions are clear from the diagram. Table 2 shows the results of corrosion resistance testing of chromium - silicon dioxide nano – CEC which deposited on St 3 steel samples from an electrolyte with strontium sulfate at a temperature of 50 ° C, current density of 7 kA / m^2 for 1 hour.

Table 3 shows the results of testing the corrosion resistance of nano – CEC chromium – silicon dioxide deposited on samples of steel St.3 from electrolyte without strontium at a current density of 7 kA / m2 for 1 hour at 50 and 60 ° C. As can be seen from the obtained results, applied nano - CEP increases the corrosion resistance of steel Art. 3 to 29.5 times, which is almost 1.5 times less than that of nano - CEP from electrolyte with strontium. Comparison of the results of tables 2 and 3 indicate that nano - CEP obtained from electrolyte without strontium have a lower protective ability than nano - CEC from electrolyte with strontium. For this reason, more detailed studies of nano - CEC from electrolyte without strontium were carried out for thicker nano - CEC, obtained by electrodeposition within 2 hours. The results of these studies are shown in table 4.

Table 2 - Results of corrosion resistance study of nano–CEC chromium - silicon dioxide from electrolyte with strontium

The composition of the aggressive environment	Temperature of aggressive environment, ^0C	Corrosion rate, $10^{-3}kg/m^2hour$	Increasing of corrosion resistance, time
Distilled water	21,5	0,0258	42,6
	30	0,0279	45,8
	40	0,0316	44,6
5% solution NaCl	21,5	0,0362	37,3
	30	0,0372	47,8
	40	0,0428	43,9
10% solution NaCl	21,5	0,0451	42,8
	30	0,0456	45,8
	40	0,0458	45,6
20% solution NaCl	21,5	0,0529	41,7
	30	0,0553	38,8
	40	0,0570	39,6

Table 3 - Results of corrosion resistance testing of nano - CEC chromium - silicon dioxide, obtained from an electrolyte without strontium for 1 hour

The composition of the aggressive environment	Temperature of aggressive environment, ^0C	Corrosion rate, $10^{-3}kg/m^2hour$	Increasing of corrosion resistance, time	The composition of the aggressive environment
5% solution NaCl	50	21,5	0,0586	28,0
	50	30	0,0603	29,5
	60	21,5	0,0525	25,7

Table 4. Results of corrosion resistance testing of nano - CEC chromium - silicon dioxide, obtained from electrolyte without strontium within 2 hours

The composition of the aggressive environment	Temperature of aggressive environment, ^0C	Corrosion rate, $10^{-3}kg/m^2hour$	Increasing of corrosion resistance, time	The composition of the aggressive environment
5% solution NaCl	50	19-20	0,0158	69,5
5% solution NaCl	60	19-20	0,0172	63,9

From the data of table 4 it follows that the increase in the duration of nano - CEC deposition in electrolyte without strontium outlines the tendency of a significant increase in corrosion resistance (up to 69.5 times). A comparison of the data in Tables 3 and 4 shows that an increase in the duration of nano - CEC deposition from 1 hour to 2 hours significantly increases the anticorrosion resistance of nano - CEC obtained from electrolyte without strontium.

CONCLUSION

1 Two electrolyte variants have been developed for the nano-CEC deposition of, chromium-silicon dioxide, characterized in that one contains strontium sulphate and the other does not.
2 A test bench for corrosion resistance has been developed and created, which allows:
- conduct tests in various corrosive environments at temperatures from room temperature to 60-70 ° C;
- to carry out tests at different modes of exposure of the corrosive medium to the test parts using a peristaltic pump, which allows changing the flow rate from zero to 60 rpm;
- simultaneously test 8 samples, which increases the reliability of the results.

3 Quantitative assessment of the corrosion rate was carried out by a gravimetric method.
4 Nano-CEP obtained from both electrolyte variants increase the corrosion resistance of steel Art. 3 in NaCl solutions up to 45-69 times depending on the thickness of the nano-CEP, the temperature of the corrosive medium, the presence or absence of strontium sulfate.

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REFERENCES

[1] Yar-Mukhamedova, G.Sh. Influence of thermal treatment on corrosion resistance of chromium and nickel composite coatings // Materials Science, 36, №6, P. 922-924,2000.

[2] Yar-Mukhamedova, G.Sh. Investigation of corrosion resistance of metallic composite thin-film systems before and after thermal treatment by the "corrodkote" method // Materials Science. Vol.37, №1. - Pp.140-143. 2001.

[3] Yar-Mukhamedova, G.Sh. Internal adsorption of admixtures in precipitates of metals // Materials Science. Vol.35(4), p.599-600. 1999.

[4] Yar-Mukhamedova, G.Sh. A mathematical model of formation of the structure of composite films by the cut-off method // Materials Science. Vol.36, No 4, p. 598-601.2000.

[5] Muradov, A., Mukashev, K. et al. Impact of silver metallization and electron irradiation on the mechanical deformation of polyimide films //Technical Physics, vol. 62 / issue 11, pp 1692-1697, 2017.

[6] Mussabek, G., Sagyndykov, A. et.al. Modern state of composite coatings formation problem // 17th Int.l Multidisc. Sc Geoconf. SGEM 2017. 17 (61), 2017, Pp 233-240. 130800Fan.

[7] Muradov, A., Mukashev, K. et al. Mathematical model of composite materials formation // 17th Int.l Multidisc. Sc Geoconf. SGEM 2017. 17 (61), 2017, Pp 201-208. 130800

[8] Yar-Mukhamedova, G.Sh. Investigation of the texture of composite electrodeposited chromium-carbon coatings // Materials Science. Vol. 36, №5, 2000.- Pp.752-754.

[9] Aldabergenova, T.M., Kislitsin, S.B. et al. Effect of low-energy alpha-particles irradiation on surface structure and physical-mechanical properties of high-purity tungsten // AIP Conference Proceedings. 2016.

[10] Yar-Mukhamedova, G., Yar-Mukhamedov, E. Investigation of corrosion resistance of chrome based nano-composition coatings in the conditions of oil production // 12nd Int.l Multidisc. Sc Geoconf. SGEM 2012. 12 (56), 2012.

[11] Darisheva, A.M., Moldabaev, M., Karimova, I.S. The physical bases of electrolytic formation of chromium-silicon dioxide nanocomposite systems in electrolytic coatings // 12nd Int.l Multidisc. Sc Geoconf. SGEM 2012. 12 (56), 2012.

[12] Karakurkchi, A., Sakhnenko, N., Atchibayev, R. Research on the improvement of mixed titania and Co(Mn) oxide nano-composite coatings. IOP Conference Series: Materials Science and Engineering. P. 69-74. 2018.

[13] Yar-Mukhamedova, G.Sh., Sakhnenko, N.D., Ved, M.V. Surface analysis of Fe-Co-Mo electrolytic coatings // IOP Conference Series: Materials Science and Engineering. 213 (1) 012019.(2019).

[14] Ved', M., Sakhnenko, N., Yermolenko, I. Composition and corrosion behavior of iron-cobalt-tungsten.// Eurasian Chemico-Technological Journal. Vol.20, №3.- Pp. 145-152. (2018).

[15] Boranbayev, M., Yar-Mukhamedova, G. et al. Phase transition of hexagonal be nanocrystal into cubic superlattice under x-ray radiation. // 18th Int.l Multidisc. Sc Geoconf. SGEM. 18(6.1), c. 393-400, 2018.