ELECTROCHEMICAL STUDIES OF THE INHIBITING EFFICIENCY OF ANTICORROSION COATINGS

Kodirov N.U
Academy of the Ministry of Emergency Situations

Beknazarov Kh.S
Doctor of Technical Sciences, Professor, Angreen University. Tashkent

Ibragimov B.T.

Abstract: In this article, the polarization curves of anti-corrosion coatings are studied. Corrosion analysis of bare and coated substrates was performed using a CS-350 potentiostat system connected to corrosion analysis software. Polarization measurements were carried out potentiostatically at room temperature using an Ag/AgCl/Cl- (0.222 V) reference electrode and a platinum electrode. Potentiodynamic measurements were performed in the range from -2000 to 2000 mV vs. Ag/AgCl/Cl at a rate of 5 mV/s. Before the measurements, the electrodes were kept in the working solutions for at least 30 minutes to reach the steady state potential.

Introduction

The mechanism of inhibition of anti-corrosion coatings is based on the prevention or complete cessation of corrosion of the anti-corrosion coating obtained in certain concentrations by passivating the surface of metal and metal structures by various physical and chemical mechanisms [1,2]. Electrochemical impedance spectroscopy and potentiodynamic scanning show that the protective barrier properties of PFCB coatings against corrosion attack are almost equal to those of polyvinylidene fluoride (PVDF) coatings (Figure 5) [4-7].
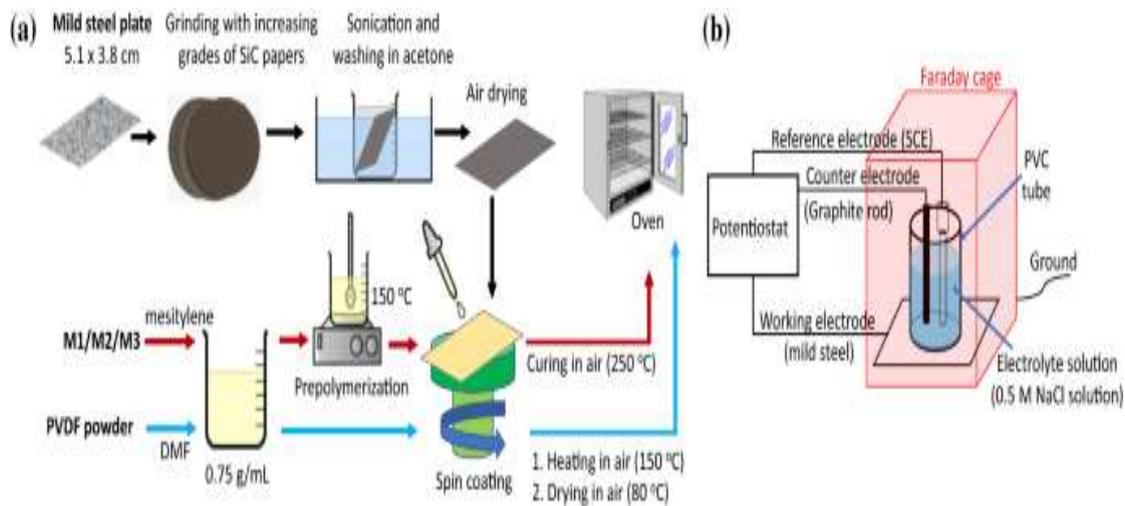
Figure 1. a Schematic of the preparation of coated metal substrates. b Installation of a three-electrode cell wrapped in a Faraday cage

Combined with high thermal resistance, PFCBs can lead to new corrosion-resistant coatings in marine, oil and gas, and other applications[8,9].

Pure tetragonal 10-20 nm zirconia-based Ni-P composite coating was obtained by Shibli S and other researchers. The physico-chemical and electrochemical properties of the coating, including corrosion resistance, were studied. The Ni-P-nano-tetragonal zirconium coating is partially crystalline and has a face-centered cubic phase. Ni-P-nano-tetragonal zirconium coatings show a cathodic shift of depletion circuit potential (OCP) in the range of - 0.340 to - 0.520 V. This indicates the high absorption efficiency of the zirconium coating [10].
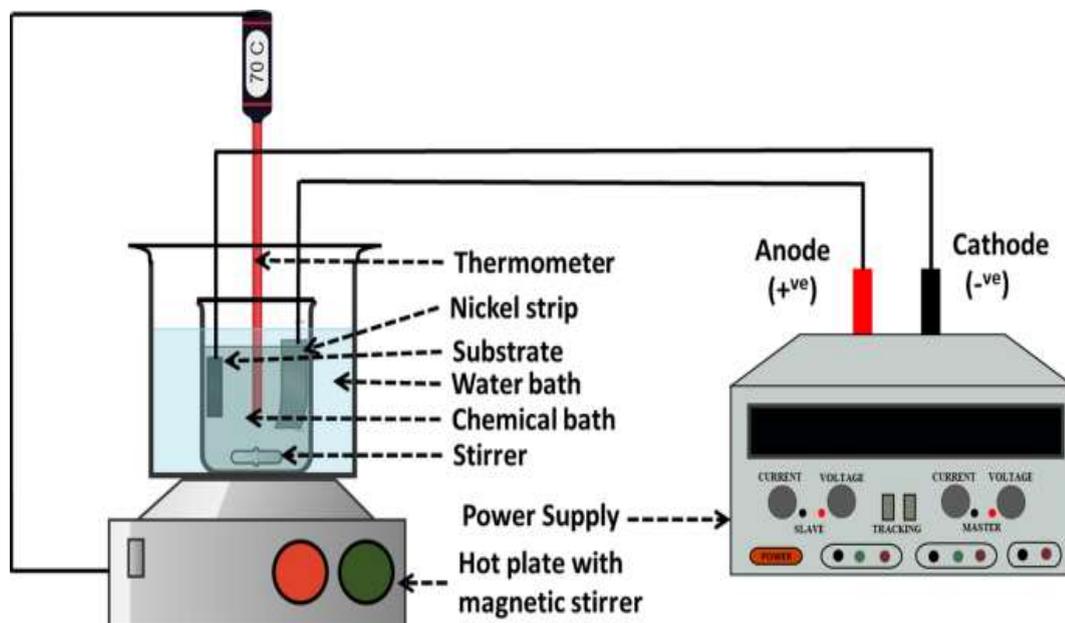

Figure 15. Schematic diagram of the electrodeposition process for the development of Ni-P-TiC composite coatings.

Favorable structural, mechanical and anti-corrosion properties of Ni-P-TiC composite coatings indicate their use in many industrial fields [11].

Methods

In this study, the effect of titanium carbide (TiC) particle concentration on the structural, mechanical and electrochemical properties of Ni-P composite coatings was studied. Different

amounts of TiC particles (0, 0.5, 1.0, 1.5, and 2.0 g L-1) were co-electrodeposited in Ni-P matrix under optimized conditions and then characterized using different methods. Structural analysis of prepared coatings shows uniform, compact and molecularly structured coatings without significant defects. According to the results of the study, the maximum hardness was reached at a concentration of 1.5 g L-1, but increasing the amount of TiC particles from a concentration of 1.5 g L-1 leads to a decrease in hardness, which is related to their accumulation in the Ni-P matrix[12].

Experimental part

In order to study the effectiveness of this hybrid anti-corrosion coating, practical experiments were carried out in hermetically sealed containers with a capacity of 500 ml.

Each of the coated and uncoated samples was covered with a waterproof tape to prevent corrosion, leaving a space of 1 cm × 1 cm. This makes it possible to measure the corrosion rate on specific surfaces. Corrosion analysis of bare and coated substrates was performed using a CS350 potentiostat system connected to corrosion analysis software. Polarization measurements were carried out potentiostatically at room temperature using an Ag/AgCl/Cl- (0.222 V) reference electrode and a platinum electrode. Potentiodynamic measurements were performed in the range from -2000 to 2000 mV with respect to Ag/AgCl/Clat at a rate of 5 mV/s. Before the measurements, the electrodes were kept in the working solutions for at least 30 minutes to reach the steady state potential.

The inhibition efficiency of vermiculite-based anti-corrosion coating was studied and analyzed using potentiodynamic polarization.

By calculating corrosion rate (μcorr, mm/year) and enhanced protection efficiency (PEF %). Y_{corr} is calculated according to the following formula:

$$v_{corr}(\text{mm/year}) = \frac{I_{corr}(\text{A cm}^{-2}) \cdot M(\text{g})}{D(\text{g cm}^{-3}) \cdot V} \times 3270$$

Samples with high concentration of vermiculite showed high polarization resistance.

Here, I_{corr} is the corrosion current density (A cm^{-2}), M is the molecular mass, D is the density of carbon steel (g cm^{-3}), V is the valence (the number of electrons lost during the corrosion process.) and 3270 is a constant. PEF% can be estimated using the following formula:

$$P_{EF}\% = \frac{I_{corr}^0 - I_{corr}^c}{I_{corr}^0} \times 100$$

Here, I_{0corr} is the corrosion current density of uncoated steel (A cm^{-2}) and Ic is the corrosion current density of coated steel (A cm^{-2}). Rp values can be calculated from the potentiodynamic polarization plots according to the Stern-Geary equation:

$$R_p = \frac{\beta_a \beta_c}{2.303(\beta_a + \beta_c)I_{corr}}$$

where I_{corr} is the corrosion current density and ba and b_c are the anodic and cathodic slopes, respectively ($\Delta E/\Delta \log I$).

Results and Discussion

Different amounts of vermiculite were added to this hybrid anti-corrosion coating, and their level of steel protection was studied below.
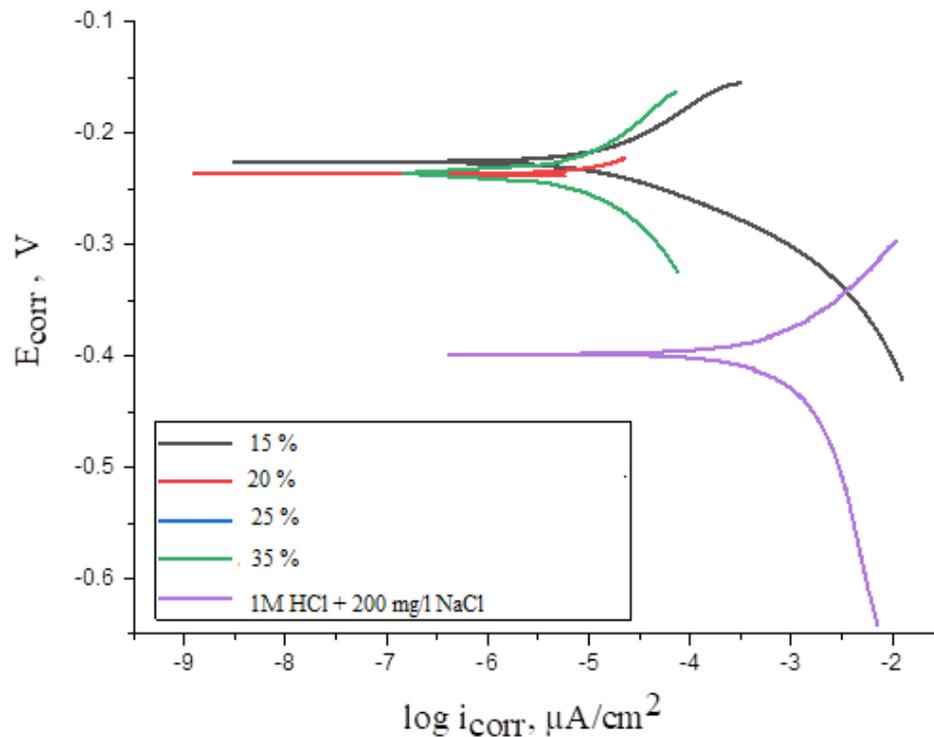
Figure 3.1. Polarization curves of coating containing 25% and 35% vermiculite mineral in 1M HCl + 200 mg/l NaCl medium for 2 hours.

Table-3.1.

Corrosion parameters of uncoated and coated steel in different concentrations of 1M HCl + 200 mg/l NaCl

	R p (kΩ cm^2)	I corr (μA cm^{-2})	E corr (mV)	ν corr (mm/yar)	P EF (%)
Without coatings	-	-	-	-	-
10	1.53	20.66	−856	24.01×10^{-2}	–
15	4.24	13.76	−722	15.99×10^{-2}	33.4
20	6.33	9.34	−691	10.85×10^{-2}	54.8
25	66.9	0.85	−667	2.08×10^{-2}	95.9
35	36.7	1.79	−544	0.99×10^{-2}	82.6

From the table above, we can see that the results of electrochemical corrosion protection of the coatings obtained on the basis of vermiculite added in different mass weights are presented. It follows that when the amount of vermiculite in the coating increases by a certain percentage, its level of protection increases. It can be seen that the resistance at 15% is 4.24 (protection level is 33.4%), 20% is 6.33 (protection level is 54.8%), at 25% (protection level is 95.9%) is 66.9 and at 35% is 36.7 (the level of protection was 82.6%). As a result, 25% returned the maximum level of protection, and when it was increased to 35%, the level of protection decreased.

Conclusion

The inhibition efficiency of the anti-corrosion coating was determined by the electrochemical method. This experiment studied polarization curves in 1M HCl + 200 mg/l NaCl medium.

References

[1]   Wang G, Yang J (2010) Influences of binder on fire protection and anticorrosion properties of intumescent fire resistive coating for steel structure. Surf Coat Technol 204(8):1186–1192

[2]   Posner R, Ozcan O, Grundmeier G (2013) Water and ions at polymer/metal interfaces. In: da Silva LFM, Sato C (eds) Design of adhesive joints under humid conditions. Springer, Hamburg, pp 22–52

[3]   Schriver M, Regan W, Gannett WJ et al (2013) Graphene as a long-term metal oxidation barrier: worse than nothing. ACS Nano 7(7):5763–5768

[4]   Sharma, A., Sharma, S. Graphene-based polymer coatings for preventing marine corrosion: a review. *J Coat Technol Res* **20**, 413–432 (2023).

[5]   Krishnamurthy, A., Gadhamshetty, V., Mukherjee, R. *et al.* Superiority of Graphene over Polymer Coatings for Prevention of Microbially Induced Corrosion. *Sci Rep* **5**, 13858 (2015).

[6]   Hasanov, R., Bilgiç, S. & Gece, G. Experimental and theoretical studies on the corrosion properties of some conducting polymer coatings. *J Solid State Electrochem* **15**, 1063–1070 (2011).

[7]   Zhang, L., Wang, W., Wu, H. *et al.* Corrosion-resistant composite coatings based on a graphene oxide–metal oxide/urushiol formaldehyde polymer system. *J Coat Technol Res* **18**, 1209–1225 (2021).

[8]   Nomozov A K, Beknazarov Kh S, Khodjamkulov S Z, Misirov Z Kh. Salsola Oppositifolia acid extract as a green corrosion inhibitor for carbon steel. Indian J Chem *Tech*. 2023; 30(6)**:** 872-877. https://doi.org/10.56042/ijct.v30i6.6553.

[9]   Muratov B.A, Turaev Kh. Kh, Umbarov I.A, Kasimov Sh.A, Nomozov A.K, "Studying of Complexes of Zn(II) and Co(II) with Acyclovir (2-amino-9-((2-hydroxyethoxy)methyl)-1,9-dihydro-6H-purine-6-OH),"*Int. J of Eng. Trends and Tech.* 2024; 72(1): 202-208. https://doi.org/10.14445/22315381/IJETT-V72I1P120.

[10] Shaymardanova M A, Mirzakulov Kh Ch, Melikulova G, Khodjamkulov S Z, Nomozov A K, Shaymardanova Kh.S. Study of process of obtaining monopotassium phosphate based on monosodium phosphate and potassium chloride. Chemical Problems. 2023; 3 (21): 279-293. https://doi.org/10.32737/2221-8688-2023-3-279-293.