



OBTAINING OF COMPOSITE ANTI-CORROSION COATINGS BASED ON VERMICULITE MINERALS

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ABSTRACT

The article synthesized new hybrid anti-corrosion coatings based on vermiculite and a polymer composite. It was found that the surface of the composite coating was completely homogeneous and transparent, without any cracks or phase separations in the matrix volume.

Introduction. Due to various economic and environmental considerations, the protection of metals and alloys from corrosion is of great importance in modern metalworking industries [1]. The most valuable and successful method of preventing corrosion and scratching of metals is to apply an outer layer of polymer coating to the metal substrate. Polymer coatings have been widely used as a barrier layer between aggressive ions and the metal surface to prevent corrosion [2, 3]. Unfortunately, most of these organic substances are imported from abroad. To solve these problems, available substances were used, which have many advantages, including ease of preparation, low cost and availability of substances, as well as local products manufactured by Navoiazot JSC. There are many types of corrosion inhibitors that have been used as anticorrosion agents against US corrosion in acidic environments and gave high inhibition efficiency due to the ease of

adsorption on the steel surface, where there is more than one place, which facilitates the adsorption process [4–7]. The addition of polymeric chemical compounds to a corrosion solution to reduce corrosion (HCl, H₂SO₄, H₃PO₄ and HNO₃) is referred to as a corrosion inhibitor by forming a protective layer on the surface of the steel, and this form of corrosion protection is called inhibition [8]. We have developed a new hybrid composition in which vermiculites were successfully used as fillers on various metal substrates with organic coatings [9,10]. It is known that vermiculite is a widespread natural mineral used to improve the chemical resistance and mechanical strength of ash coatings. Vermiculite has excellent antibacterial effect, anti-corrosion properties, high strength, high wear and heat resistance, good hardness. Such exceptional properties open up wide opportunities for industrial use, since vermiculite is environmentally friendly due to its non-toxicity.



In this study, we report the synthesis of hybrid composite coatings of vermiculite with organic compounds. In addition, the characteristics of the applied coatings were evaluated using a scratch resistance test. The vermiculite-containing coating showed better corrosion resistance with improved scratch resistance, which is an important parameter to consider in multi-purpose applications.

2. Objects and methods of research

2.1. Vermiculite of the Tebinbulak deposit was used as a natural mineral.

A scratch test was performed to evaluate the hardness of the sample and scratch resistance. HUATECH scratch tester. A coated sample with a dry film thickness, which is measured in the range of 25-30 μm , stabilizes the instrument and adds the instrument weight of 50 g to the coating mass. The resin used in this study was ED-20 epoxy. The amount of crosslinker used for each cell was fixed at 0.05 g and all coatings were applied at 120 μm wet film thickness on a 15 x 10 x 0.06 cm steel substrate. All samples were kept at ambient temperature for 2 h after application, then dried at 80°C for 60 min.

Electrochemical measurements were carried out under extreme environmental conditions, including exposure to an aqueous solution of sodium chloride (5% NaCl) in air. Each sample was sealed with waterproof tape to prevent premature corrosion along the edges of the substrate. A 1cm \times 1cm area at the center of each sample was exposed to the solution during the test. Corrosion analysis of bare and coated substrates was performed using a CS350 potentiostat system connected to corrosion analysis software. Polarization measurements were made potentiostatically at room temperature

using an Ag/AgCl/Cl⁻ (0.222 V) reference electrode and a platinum electrode. Potentiodynamic measurements were carried out in the range from -2000 to 2000 mV relative to Ag/AgCl/Clat at a rate of 5 mV/s. Before measurements, the electrodes were kept in working solutions for at least 30 min to reach a steady potential.

RESULTS AND ITS DISCUSSION

Scratch resistance was carried out to test the scratch resistance of the obtained coatings. The results showed that the presence of vermiculite improves the mechanical properties of the coating by improving its compactness. In addition, peel testing and scratch resistance analysis were used to predict the mechanical properties of the coatings. The mechanical properties of the deposited coatings were affected by both internal (loading rate, scratching rate, machine calibration, indenter tip) and external (hardness, modulus of elasticity, fracture toughness of the coating and substrate) factors. Surface preparation and parameters such as surface roughness and friction coefficient also determine the behavior of coatings [11,12].

The scratch test results show the effect of the vermiculite weight ratio on the polymer matrix. The value of hardness increases with increasing mass fraction of vermiculite. The mono-layer vermiculite coating provides good adhesion and less porosity, thereby showing improved corrosion resistance.

Samples with a higher concentration of vermiculite showed higher polarization resistance, which increases the level of the contact surface between the components of vermiculite and the composite material with high strength, hardness and



toughness. These properties are associated with the hardness of vermiculite particles compared to the polymer, as well as with the influence of the interface between the matrices and high adhesion between them. The good distribution of the filler is associated with a reduced density of cross-links in the polymer, which contributes to the dispersion of particles between polymer bonds and an increase in hardness. The increase in compressive strength by increasing the weight ratio to 0.0015 is the result of the high strength of vermiculite, which is uniformly transferred to the host matrix. The very high level of contact between the resin matrix and the particles facilitates the transfer of physical stress. The particles are uniformly dispersed in the matrix, so they reduce the mobility of polymer chains by occupying the gaps between them, thereby increasing the resistance of the matrix to deformation and crack growth.

Air bubbles have been reduced by adding vermiculite and preventing cracking due to vacancies in the matrix. This decrease may be due to the accumulation of particles and the lack of resin materials to load the particles. Cracks can occur in places with high stress density due to poor distribution of reinforcement or lack of polymeric materials to connect with a large amount of reinforcement. Fillers effectively limit the accumulation of particles that usually occurs in the presence of vermiculite. With a further increase in the filler content, the hardness effect of the polymer/vermiculite systems slowly increases or may even decrease. This means that the technological method does not have a positive effect on particle aggregation. Although the adhesion of the filler to the matrix is improved, significant particle aggregation occurs at high filler concentrations[13,14].

Table 1

Corrosion rate of with uncoated and coated specimens

Properties	Hybrid coating	Polymer coating (no vermiculite)	Not coated sample
Protective properties, %	97,89	92,37	79,68

It is concluded that vermiculite delamination plays an important role, first of all, in surface roughness, which, in turn, affects adhesion by changing the characteristics of the coating-substrate

interface. For a sample containing 0.003 g of vermiculite in a mixture of composite resins, the highest scratch resistance was obtained with sufficient adhesion efficiency.

Table 2

Electrochemical protection of uncoated and coated samples

Sample	Time, h	Corrosion rate, mm/year	F
Without coating	24	956,54	2,61
	48	1226,32	2,78
	72	1415,63	3,22
	96	1654,78	3,32



Polymer coating (without vermiculite)	24	239,17	5,36
	48	79,81	4,94
	72	34,95	5,87
	96	30,68	6,51
Hybrid Coatings with Vermiculite	24	9,66	8,63
	48	4,84	9,12
	72	4,78	9,78
	96	3,32	10,49

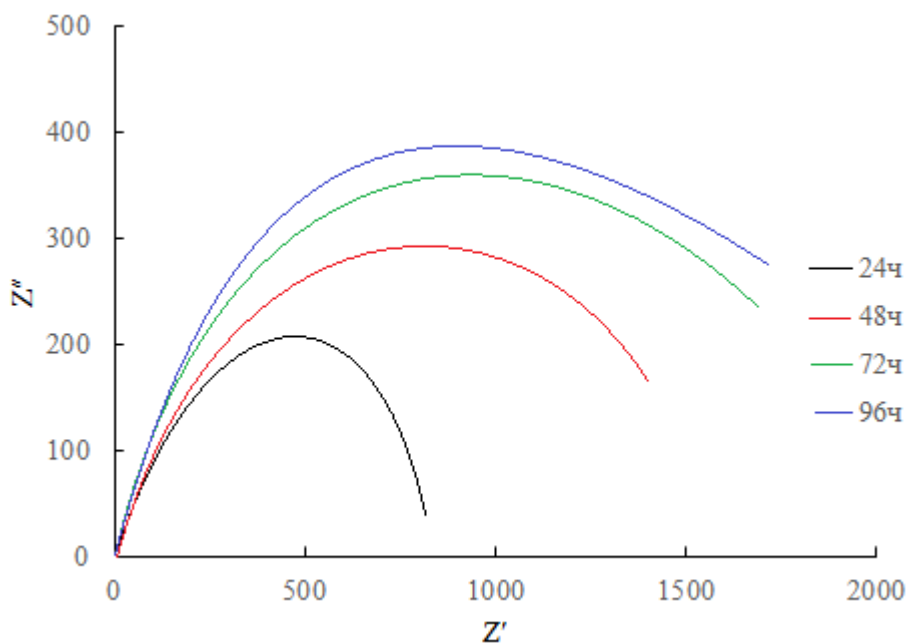


Fig. 1. Impedance spectra of a pure sample (without coating) after 4-day immersion in 0.5 M NaCl.

In the case of an uncoated sample, the data obtained from Fig. 3 shows that after 24 hours and 48 hours of immersion, the resistance decreased due to the degradation of the substrate and the onset of corrosion. After 72 hours and 96 hours of immersion, the surface resistance slightly increased due to the formation of corrosion products and plugging of pores by water and intrusive ions.

The Nyquist plot shows a single peak in the first 24 hours and a double peak in subsequent periods. Water from the environment penetrates the coating and reaches the joint surface, and corrosion begins. As a result, the durability of the

coating decreases over time due to the penetration of water and ions[15.16].

The corrosion rate of the clean sample, coated and hybrid composite coating indicates an increase in anti-corrosion properties in the sequence: uncoated > polymer coating > hybrid coating. The impedance values for the uncoated sample decrease, indicating that the coating is starting to flake off, which is likely to occur within the marked area as a result of corrosion attack at the coating/substrate interface.

Conclusion.

In this study, scratch-resistant and anti-corrosion hybrid composite coatings based



on vermiculite were synthesized using vermiculite. Vermiculite particles have a large aspect ratio and free space between the particles, which increases the surface hardness and elastic modulus and thus improves corrosion resistance. Increased

scratch resistance of polymer coatings was observed with the addition of vermiculite particles. Also, the surface of the composite coating was completely homogeneous and transparent, without any cracks or phase separations in the matrix volume.

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