E3S Web of Conferences **401**, 05054 (2023)
CONMECHYDRO - 2023
https://doi.org/10.1051/e3sconf/202340105054

Anode behavior of aluminum alloy AB1 with magnesium

M. Z. Kurbonova[1*], *I. A.* Emomov[2], *N. T.* Rakhimova[1], *I. N.* Ganiev[3], *D. A.* Kurbonova[4], and *U. M.* Norkulov[4]

[1]Tajik National University, Dushanbe, Tajikistan
[2]Dangara State University, Tajikistan
[3]Tajik Technical University named after M. S. Osimi, Tajikistan
[4]Samarkand State University, Samarkand, Uzbekistan

Abstract. In modern technology, the main advantages of aluminum alloys as structural materials are lightness, pliability to stamping, corrosion resistance (in air, aluminum is instantly covered with a strong film of Al_2O_3, which prevents its further oxidation), high thermal conductivity, and non-toxicity of its compounds. These properties have made aluminum alloys the main raw material in the aviation and aerospace industries and, more recently, as a composite material. Regarding specific strength (the ratio of ultimate strength to density), aluminum alloys are significantly superior to steel.

Therefore, in the article, the electrochemical properties of the aluminum alloy AB1 with magnesium in the NaCl electrolyte medium were studied by the potentiodynamic method with a potential sweep rate of 2 mV / s. It is shown that alloying the AB1 alloy with magnesium up to 1.0 wt.% Increases its anodic stability by 30% in the NaCl electrolyte environment. It was found that with an increase in the concentration of chloride - ion, the corrosion rate of alloys increases, and the potentials of free corrosion, pitting formation, and repassivation of alloys decrease. An increase in the content of the alloying component shifts the indicated potentials to the positive region.

1 Introduction

Aluminum and its alloys are widely used as a construction material. The main advantages of aluminum as a construction material are lightness, ductility, corrosion resistance (in the air, aluminum is instantly covered by a solid film Al_2O_3, which prevents further oxidation), high thermal conductivity, nonpoisonous nature of its compounds. These properties have made aluminum a major raw material in the aviation and aerospace industries and, recently, as a composite material [1-4].

Deformable structural aluminum alloys are mainly aluminum alloys with four components: Cu, Mg, Zn, and Si, to which Li and Ag have been added relatively recently [5-9]. All of the above components were chosen for one reason - they have the greatest solubility in solid aluminum compared to other known elements, which decreases sharply

---

[*] Corresponding author: m_kurbonova@mail.ru

with decreasing temperature, resulting in the cooling of alloys with these components from the solid solution of intermetallic phases, and when heated - dissolved. This phase transformation (the only one in solid aluminum alloys) has opened the possibility of strongly influencing the structure and properties of the alloys through heat treatment [3].

Aluminum and its alloys are highly manufacturable, well deformable, and it is easy to obtain complex shapes of aluminum-made objects. Aluminum and a number of its alloys have fairly high corrosion resistance. It is inferior only to silver, copper, and gold in electrical conductivity [4-6].

In publicly available scientific literature, there is no information about the physicochemical properties of aluminum-beryllium alloy AB1 alloyed with magnesium.

2 Results of experimental studies and Discussion

The quality of a material is determined mainly by its properties, chemical composition, and structure. Moreover, material properties depend on the structure, which, in turn, depends on the chemical composition. Therefore, a material's properties, composition, and structure can be determined in quality assessment [7].

The most important corrosion characteristic of metals and alloys, which can be used both to predict their corrosion resistance and to choose the method of protection under given conditions, is the dependence of dissolution rate on the potential. Evaluating the role of the electrode potential in the behavior of the metal (alloy), in passivation, and in the passive state is possible by the potentiodynamic method.

The aluminum alloy AB1 (Al+1 wt.% Be) with a magnesium content of 0.05, 0.1, 0.5, and 1.0 wt.% was obtained for the study. The composition of the alloys was controlled by qualitative and quantitative analysis.

The obtained alloys were cast in graphite molding bars with a diameter of 8 mm and a length of 140 mm. Non-working part of the samples was insulated with resin (a mixture of 50% rosin and 50% paraffin). The working surface was the end of the electrode. Before dipping the sample into the working solution, its end part was cleaned with sandpaper, polished, degreased, thoroughly washed with alcohol, and then dipped into the NaCl electrolyte solution. The temperature of the solution in the cell was kept constant (20 ^{0}C) using MLSH-8 thermostat.

Electrochemical research of aluminum alloy AB1 with magnesium was performed on potentiostat PI-50-1.1 in potentiodynamic mode with the rate of the sweep of potential 2mV/s, using programmer PR-8 and recorder LKD-4 by the methods described in works. This work used a three-electrode electrochemical cell, which allows to study the dependence of the process speed (the value of current) on the potential of only one of the electrodes, which is called the working electrode. The reference electrode was a silver chloride electrode, and the auxiliary electrode was a platinum electrode.

Estimation of corrosion resistance of the alloys was carried out according to complete potentiodynamic curves obtained by the methods described in papers [9] which calculated the potentials of free corrosion ($E_{free.cor.}$), pitting formation ($E_{p.f.}$) and repassivation (rep.), values which are shown in table and on fig. 1 and 2.

In electrochemical research, samples were potentiodynamically polarized in the positive direction from the potential established at immersion (steady-state potential or potential of corrosion) to a sharp increase of current due to pitting (fig. 1, curve I). The samples were then polarized in the opposite direction to a potential of -1200 mV (Fig. 1, curves II and III), resulting in alkalization at the electrode layer of the sample surface. Finally, the samples were polarized again in the positive direction (Fig. 1, curve IV).

The corrosion current, as the main electrochemical characteristic of the corrosion process, was calculated using the cathodic curve, taking into account the angle coefficient bk = 0.12 V, since in neutral media, the process of pitting corrosion of aluminum and its alloys is controlled by the cathodic reaction of oxygen ionization.

The corrosion rate was determined using the formula: K = i-corr. - k,

where k is the electrochemical equivalent, the numerical value of which for aluminum is 0.335 g/A-h.

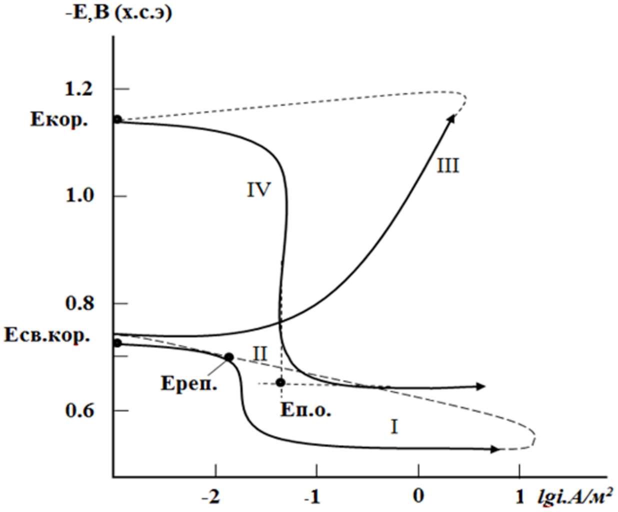

Fig. 1. Full polarization (2mV/s) curve of aluminum alloy AB1, in electrolyte medium of 3% NaCl

The samples were kept in 0.03, 0.3, and 3% NaCl electrolytes until a constant potential was reached before the potential sweep. Based on the potential dependence (E, mV) on time (t, min.), the values of free corrosion potential were determined. Time dependences of the potential of free corrosion of aluminum alloy AB1, alloyed with magnesium in the environment of NaCl electrolyte which are shown in Fig. 2. We can see that during the first hour of exposure in sodium chloride solution, the potential of free corrosion becomes constant. The values of electrode potentials do not change during longer exposure (1-3 days).

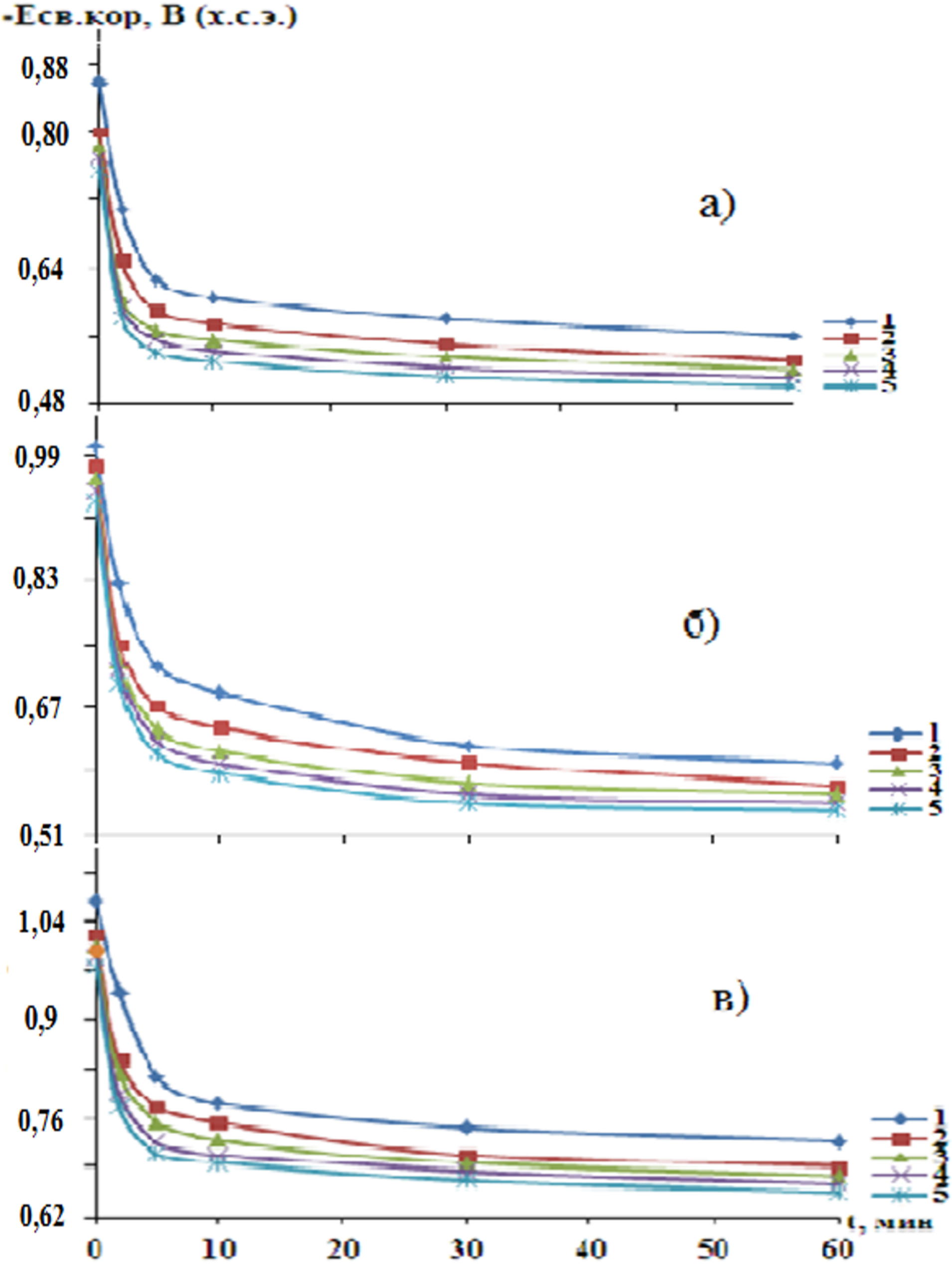

Fig. 2. Time dependence of free corrosion potential (Eb.cor, V), aluminum alloy AB (1), containing magnesium, wt%: 0.05 (2); 0.1 (3); 0.5 (4); 1.0 (5), in electrolyte environment 0.03 (a), 0.3 (b) and 3 (c)%NaCl

Figure 2 shows that the initial aluminum alloy AB1 and the magnesium alloy are characterized by a shift of the free-corrosion potential in the positive area in time. The alloys were polarized after the steady-state potential was established.

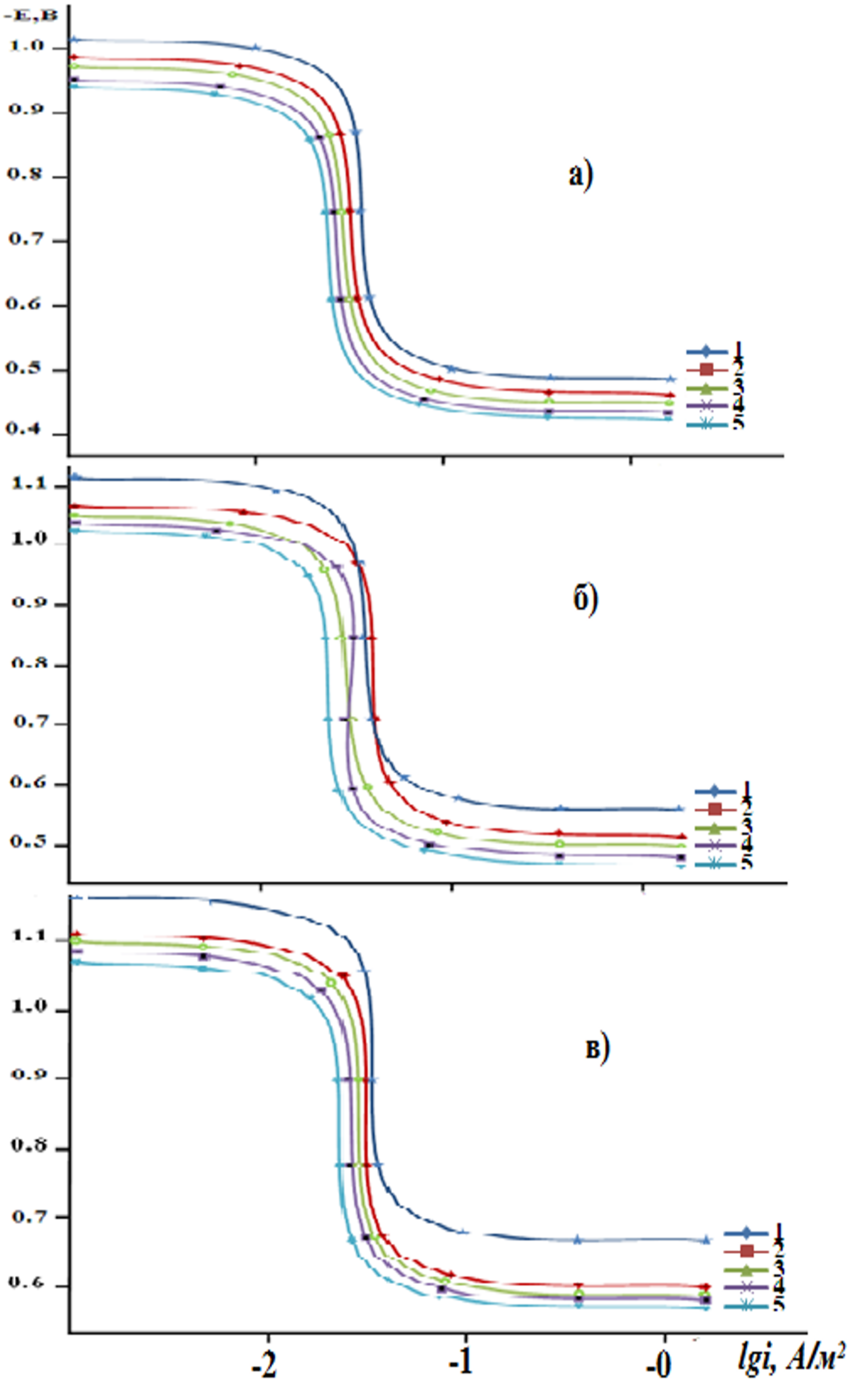

Fig. 3. Potentiodynamic anodic polarization (2mV / s) curves of AB (1) aluminum alloy containing magnesium, wt%: 0.05 (2); 0.1 (3); 0.5 (4); 1.0 (5), in electrolyte environment 0.03 (a), 0.3 (b) and 3 (c)%NaCl

As shown in Fig. 3, the potentiodynamic anodic polarization curves also confirm the above patterns.

Table 1. Corrosion-electrochemical characteristics of aluminum alloy AB (1) with magnesium in electrolyte environment NaCl

Medium, NaCl mass%	Magnesium content in alloy, mass %	Electrochemical potentials, mV (s.c.e.)				Corrosion rate	
		$-E_{fri,kor.}$	$-E_{kor..}$	$-E_{p.p.}$	$-E_{rep.}$	I_{kor}•10^2, A/m^2	K•10^3, g/m^2·hour
0.03	0.0	0.560	1.010	0.490	0.540	0.031	10.38
	0.05	0.549	0.990	0.465	0.501	0.028	9.38
	0.1	0.538	0.972	0.450	0.490	0.025	8.37
	0.5	0.528	0.955	0.436	0.478	0.023	7.70
	1.0	0.519	0.940	0.425	0.470	0.021	7.03
0.3	0.0	0.600	1.114	0.560	0.580	0.036	12.06
	0.05	0.570	1.070	0.516	0.555	0.033	11.05
	0.1	0.560	1.055	0.500	0.540	0.031	10.38
	0.5	0.549	1.042	0.485	0.525	0.029	09.71
	1.0	0.540	1.030	0.470	0.510	0.027	09.04
3.0	0.0	0.728	1.160	0.670	0.700	0.042	14.07
	0.05	0.690	1.112	0.614	0.630	0.039	13.06
	0.1	0.678	1.100	0.600	0.620	0.037	12.39
	0.5	0.667	1.085	0.582	0.610	0.035	11.72
	1.0	0.656	1.070	0.570	0.601	0.033	11.05

Table 1 shows the main corrosion and electrochemical characteristics of aluminum alloy AB1 with magnesium additives in the electrolyte NaCl. The values of free corrosion and pitting potentials were determined under the same measuring conditions. The potential of free corrosion shifts to a more positive region for the alloy AB1 with magnesium additives from 0.05 to 1.0 wt.% in the electrolyte NaCl medium (table).

Increasing magnesium concentration increases the repassivation potential from -0.700 to -0.601V and the pitting potential from -0.670V to -0.570V, in 3.0% NaCl electrolyte medium. The corrosion resistance of the alloys increases with the growth of these parameters. The aluminum-beryllium alloy containing 1.0 wt% magnesium is characterized by a minimum corrosion current density of 0.033A/m^2, in an electrolyte medium of 3.0% NaCl. The corrosion rate of this alloy differs from the initial one by more than 37%.

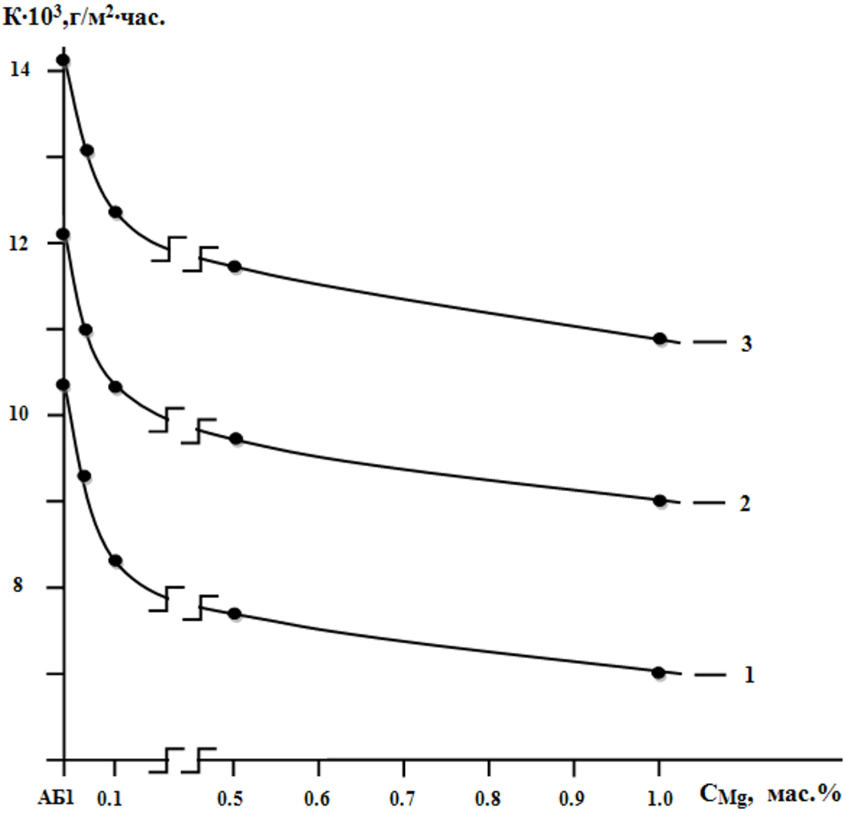

Fig. 4. Corrosion rate dependence of aluminum alloy AB1, with magnesium, in electrolyte environment 0.03 (1); 0.3 (2); 3.0% (3) NaCl

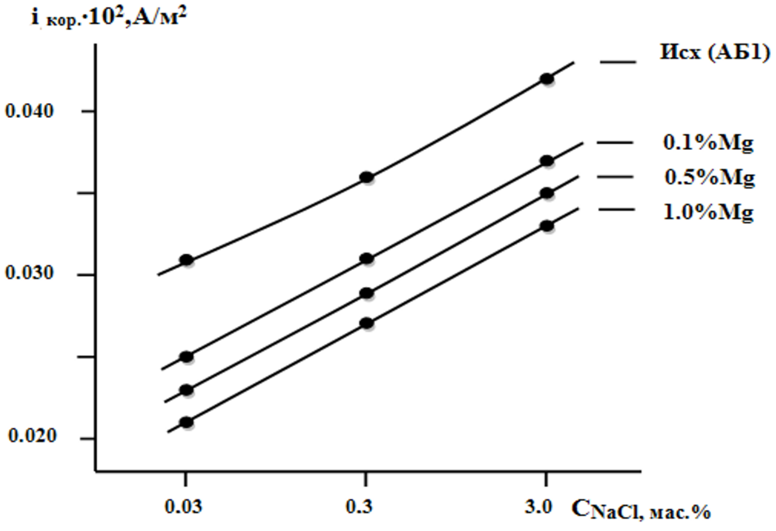

Fig. 5. Dependence of the current density of corrosion of the aluminum alloy AB1 with magnesium on the concentration of NaCl

Fig. 4 and 5 show the dependence of corrosion rate and corrosion current density of aluminum alloy AB1 with magnesium in the environment of the electrolyte NaCl.

3 Conclusions

Modern industry places ever higher demands on materials in their strength, wear resistance, corrosion resistance, and manufacturability. Therefore, using aluminum alloys alloyed with beryllium and magnesium is among the most promising directions. Research related to the search for new properties of aluminum-magnesium-based alloys and the possibilities of their application does not stop. Currently, the use of aluminum-based alloys with beryllium and magnesium in the creation of various parts and designs can reduce their weight by almost 30% and increase the ultimate strength by up to 300 MPa.

Thus, it has been established that the alloying of aluminum alloy AB1 with magnesium of up to 1.0 wt. % increases its anodic stability in the sodium chloride electrolyte environment. With increasing concentration of the alloying component, a change in the positive direction of the ordinate axis of the potentials of free corrosion, pitting, and repassivation is noted. With increasing chloride-ion concentration in electrolyte potentials of free corrosion, pitting and repassivation of alloys decrease corrosion rate increases.

References

1. Obidov Z.R., Ibrokhimov P.R., Rakhimov F.A., Ganiev I.N. Anodic behavior of Zn0.5Al alloy doped with molybdenum in acidic, neutral and alkaline media// Proceedings of universities. Applied chemistry and biotechnology. № 2(37). pp. 187-194. (2021).
2. Obidov Z. R., Amini R., Nazarov O. N., Jayloev J. Kh., Ganiev I. N. High temperature and electrochemical corrosion of Zn0.5Al alloy doped with calcium in various media. Russian Journal of Chemistry and Chemical Technology. Vol. 63(11). pp.21-26 (2020).
3. Padamata S. K., Yasinskiy A. S., and Polyakov P. V. Progress of inert anodes in aluminium industry. (2018).
4. Ganiev I. N., Rakhimova N. O., Kurbonova M. Z., Davlatzoda F. S., and Yakubov U. S. Effect of Titanium Additions on the Corrosion and Electrochemical Properties of Aluminum Alloy AB1. Inorganic Materials, Vol. 58(8), pp.893-897. (2022).
5. Niu Y., Cui R., He Y., and Yu Z. Wear and corrosion behavior of Mg–Gd–Y–Zr alloy treated by mixed molten-salt bath. Journal of alloys and compounds, Vol. 610, pp.294-300. (2014).
6. Mance A., Cerović D., and Mihajlović A. The effect of small additions of indium and thallium on the corrosion behaviour of aluminium in sea water. Journal of applied electrochemistry, Vol. 14(4), pp. 459-466. (1984).
7. Krasovskii M. O., Lavrenko V. O., and Kostenko L. M. Anodic behavior of Al–Bi and Al–Sb alloys in 3% NaCl solution. Powder Metallurgy and Metal Ceramics, Vol. 49, pp. 347-350. (2010).
8. Obidov Z. R., Amonova, A. V., and Ganiev I. N. Influence of the pH of the medium on the anodic behavior of scandium-doped Zn55Al alloy. Russian Journal of Non-Ferrous Metals, Vol. 54, pp.234-238. (2013).
9. Radzhabova S. G., Amini R. N., Ganiev I. N., and Obidov Z. R. Study of the Anodic Behavior of the Chromium-Doped Zn55Al Alloy in Corrosive Environments. Russian Journal of Applied Chemistry, Vol. 95(4), pp. 582-587. (2022).