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Scientific paper
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The influence of indium, gallium and bismuth on the corrosion behavior of alloys intended for protectors

This work was carried out of behavior of Al-Zn alloy systems in chloride solutions of different concentrations, with additional alloying indium, gallium and bismuth as micro alloying elements. In addition to these elements is done by the alloying with tin.

Thus obtained aluminum alloy with additional corrosion and electrochemical tests give a chance to produce their own sacrificial electrodes.

In preparing the concept on which this paper is based, started from the fact that there are a number of influential factors, starting from the chemical composition, methods of melting, alloying and casting methods that would allow obtaining high-quality alloy that can be effectively used as a protector.

***Keywords:** corrosion, protectors, alloys.*

INTRODUCTION

Protector electrode is applied in industry, infrastructure facilities, warehouses, shipyards, machinery operating in hostile environments, especially if they contain chlorides. The procedure protectorate care is based on the application of metal alloys electro negative as a protector (galvanic anodes or sacrificed anode).

Examination given in this paper has shown that it is very important to know how to obtain aluminum alloy, and its genetics, and its further treatment (thermal, mechanical).

On getting sacrificed alloy affects a number of factors, ranging from the choice of chemical composition, method of melting, alloying and casting methods that allow obtaining high-quality alloys.

Types of alloys obtained in our laboratory with additional corrosion and electrochemical tests give a chance to produce own sacrificial electrode with the addition of certain micro-alloying elements such as indium, gallium and bismuth.

Obtained by monitoring the behavior of alloys in aggressive solutions of different concentrations of NaCl will come to the conclusion of the above micro-alloying elements has a dominating influence on the corrosion characteristics of the investigated alloys.

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EXPERIMENTAL

Experimental investigations include three phases:

- preparing materials and casting of Al-alloy,
- testing the chemical composition and microstructure,
- examination of corrosion and electrochemical characteristics of Al-alloys in 0.51 M NaCl and 0.051 M at room temperature.

Chemical composition of the obtained alloys was investigated by the X-RAY quantometer, nondestructive method.

The microstructure of the investigated alloys was carried out on samples prepared for corrosion tests, in which micrographs were made before and after corrosion tests.

Corrosion testing of aluminum alloys of high activity (sacrificial electrodes) was performed on a computerized PAR device, a system with a saturated calomel electrode. Corrosion tests include the following methods:

- corrosion potential versus time,
- polarization resistance method
- potentiodynamic method.

RESULTS AND DISCUSSION

Results of chemical composition of Al-alloys obtained by the nondestructive method on X-RAY quantometer are given in Table 1.

Table 1 - Chemical composition of Al-alloys

Element	Alloy 1	Alloy 2	Alloy 3	Alloy 4
Zn	4.30	1.10	3.90	4.62
Sn	0.95	0.002	0.64	1.00
Bi	-	-	0.20	-
In	0.005	0.005	-	0.50
Ga	0.01	0.009	0.50	1.04
Fe	0.03	0.28	0.36	0.18
Si	0.10	0.11	0.11	0.10

Table 1 shows that in all obtained alloys zinc content varied from 1.10 to 4.62%, tin from 0.002 to1.0%, bismuth was present only in alloy 3 (0.20%). The content of indium in alloys 1 and 2 was0.005%, while in alloy 4 was 0.50%. As micro-alloying element gallium was added in all alloys, and the content ranged from 0.009% in the alloy 2 to1.04% in the alloy 4. As a constant admixture obtained in all alloys present as iron and silicon.

Results of corrosion tests in solutions of 0.51 M NaCl and 0.051M for all three test methods are given in Tables 2, 3 and 4.

Table 2 - Change in corrosion potential as a function of time (initial and final potential)

Alloy	0.51 M NaCl		0.051 M NaCl	
	E_{in} [mV]	E_{fin} [mV]	E_{in} [mV]	E_{fin} [mV]
1	-1159	-980	-1254	-918
2	-938	-903	-833	-734
3	-1380	-1324	-1340	-1263
4	-1439	-1512	-1419	-1440

Table 3 - Polarization resistance method

Alloy	0.51 M NaCl			0.051 M NaCl		
	e(j=0) [mV]	Rp [kΩ]	j_{corr} [μA/cm^2]	e(j=0) [mV]	Rp [kΩ]	j_{corr} [μA/cm^2]
1	-1021	1.1743	19.49	-1066	4.9318	4.4
2	-913	0.2782	78.03	-807.5	1.4984	14.49
3	-1362	0.1936	112.12	-1299	0.088	246.63
4	-1462	0.08622	251.6	-1429	0.1255	173.1

Tabela 4 - Potentiodynamic method

Alloy	0.51 M NaCl	0.051 M NaCl
	e(j=0) [mV]	e(j=0) [mV]
1	-1010	-903
2	-919	-780
3	-1332	-1230
4	-1507	-1420

Figures 1-6 show the histogram results of the corrosion potential, polarization resistance and corrosion current density in0.51 M and 0.051 M NaCl.

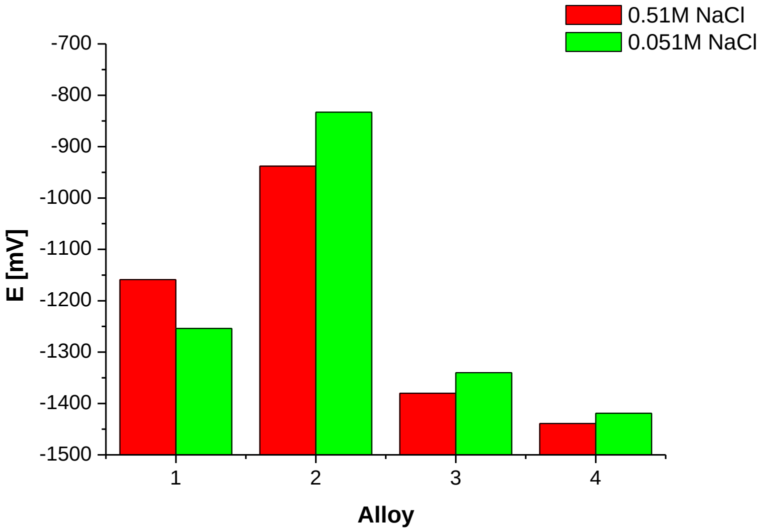

Figure 1 -Histogram of the initial corrosion potential

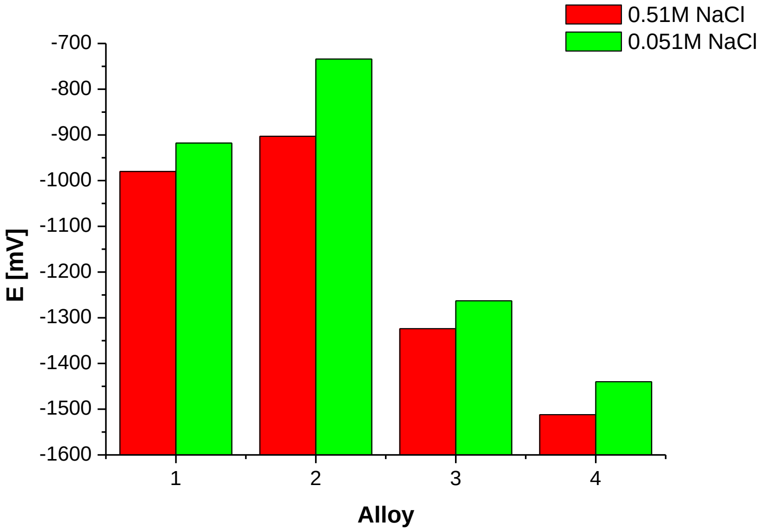

Figure 2 -Histogram of the final corrosion potential

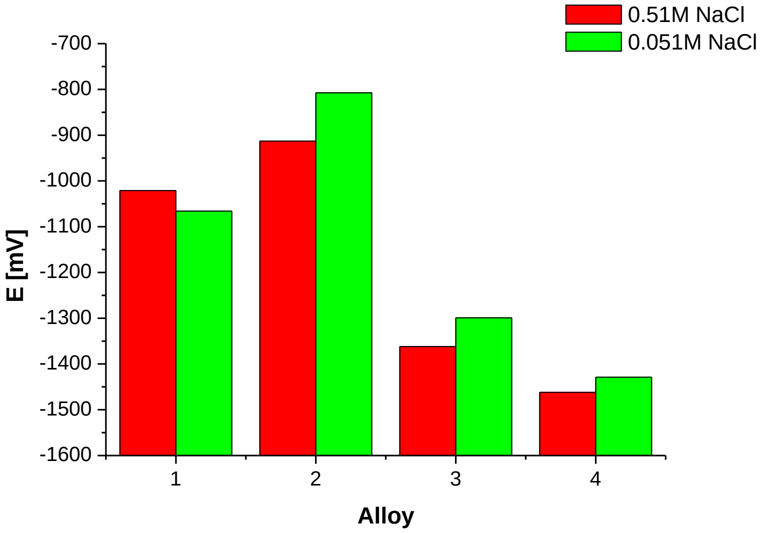

Figure 3 -Histogram of the e(j=0) for polarization resistance method

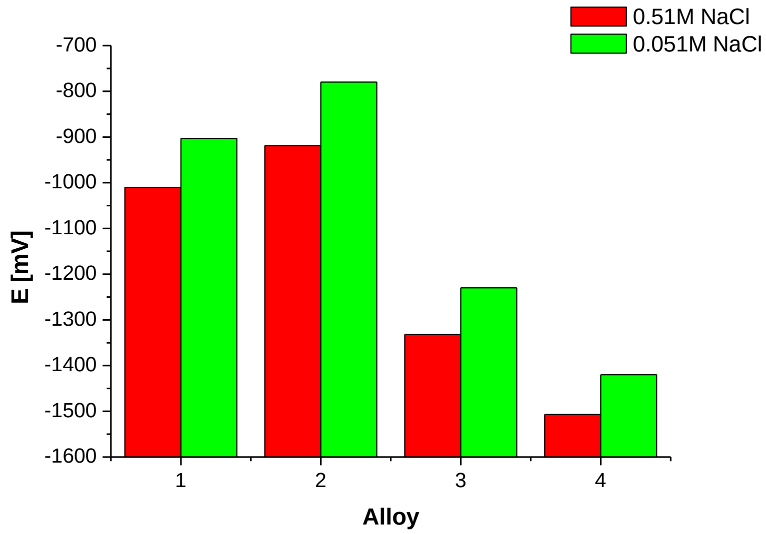

Figure 4 -Histogram of the e(j=0) for potentiodynamic method

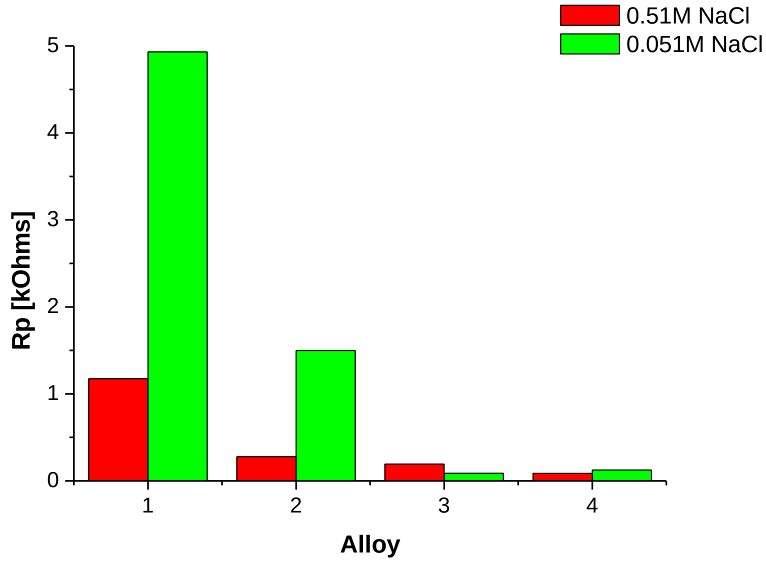

Figure 5 -Histogram of the polarization resistance

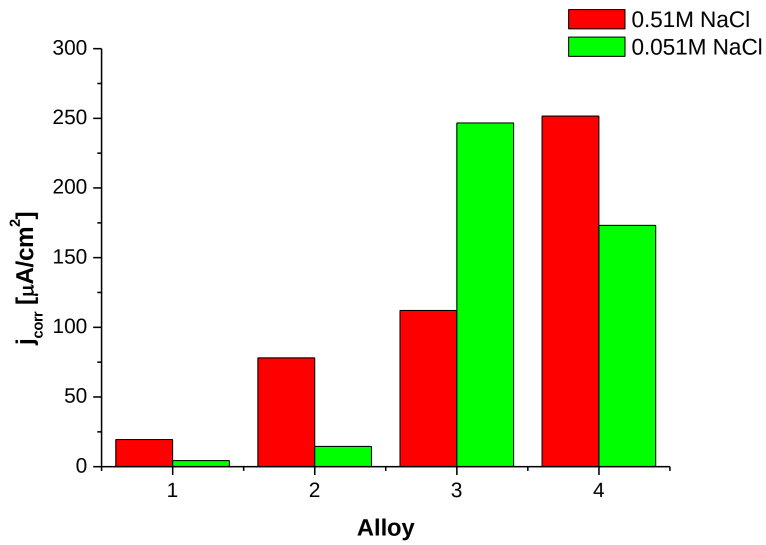

Figure 6 -Histogram of the corrosion current density

The obtained results of the corrosion behavior of sacrificed electrodes show their different behavior depending on the concentration of alloying elements.

The most negative final corrosion potential in 0.51 M and 0.051M NaCl had alloy 4 as a result of higher content of Zn, Sn, In and Ga in comparison to other investigated alloys.

As for the value of polarization resistance and current density in 0.51M NaCl solution alloy 4 had the lowest value of Rp, and most of j_{corr}, while in 0.051M NaCl solution alloy 3 had the lowest value of Rp, and most of j_{corr}.

CONCLUSION

The choice of alloying elements due to the specificity of their effect on the corrosion activity is a very important condition for obtaining high-quality alloys for the production of protectors.

Based on the experimental results of monitoring corrosion behavior of Al alloys and corrosion potential versus time, it was found that the alloys 3 and 4 showed excellent corrosion activity in chloride solutions, with observed more negative values of corrosion potential for alloy 4, which is result of higher content of zinc, tin, indium and gallium in comparison to other alloys.

The values of corrosion current densities are extremely high (and low polarization resistance), for alloys 3 and 4, but alloy 4 still gave extremely high values of corrosion current density in 0.051M and 0.51M NaCl. This behavior can be attributed to the effect of chemical composition.

Analyzing all the results obtained, it can be concluded that the alloys 3 and 4 completely fulfill a given goal of research and as such can be used effectively as protectors to protect valuable structures and equipment that requires this type of protection.

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IZVOD

UTICAJ INDIJUMA, GALIJUMA I BIZMUTA NA KOROZIONO PONAŠANJE LEGURA NAMENJENIH ZA PROTEKTORE

U ovom radu je izvršeno ispitivanje ponašanja Al-Yn legura u rastvorima hlorida različitih koncentracija, uz dodatak legirajućih mikro elemenata indijuma, galijuma i bizmuta. Pored ovih elemenata vršilo se legiranje i sa kalajem.

Tako dobijene legure aluminijuma su ispitivane na dodatne korozione i elektrohemijske testove kako bi se videla mogućnost proizvodnje žrtvenih elektroda.

U pripremi postupka na kome bi se baziralo ovo, polazi se od činjenice da postoji veliki broj uticajnih faktora, počev od hemijskog sastava, postupka topljenja, legurajuće i livene metode, koje bi omogućile dobijanje visoko kvalitetnih legura koje mogu da se efikasno koriste kao protektori.

Ključne reči: *korozija, protektori, legure*

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