Composite triazole-containing PEO-coatings as the effective way of corrosion protection of AMg3 aluminum alloy

Ya.I. Kononenko*,[1], A.S. Gnedenkov[1], S.L. Sinebryukhov[1], V.S. Filonina[1], I.E. Vyaliy[1], S.V. Gnedenkov[1]
[1]Institute of Chemistry of FEB RAS, 159 Pr. 100-letiya Vladivostoka, Vladivostok, 690022, Russia
*✉e-mail: kononenko.yai@gmail.com

Introduction and topicality >

Aluminum is a structural material with such important properties as lightweight, strength, ductility, etc. It found application in many industries. However, during exploitation, aluminum can contact with the aggressive environment, which results in corrosion degradation (**fig. 1**).

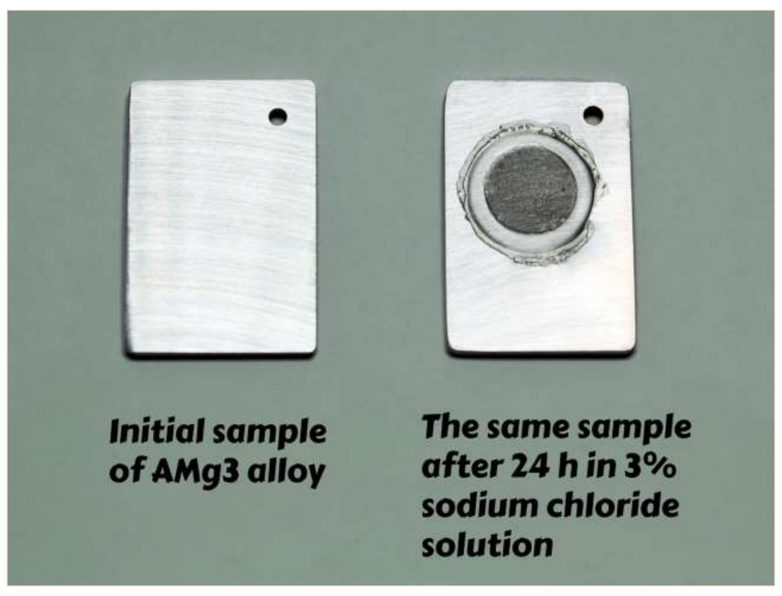


Figure 1 — Corrosion of the AMg3 alloy in the aggressive environment

One of the ways to prevent aluminum corrosion is the formation of protective coatings on it`s surface. Plasma electrolytic oxidation (PEO) is one of the easiest and optimal methods to protect the surface of valve metals (including aluminum and its alloys). In some cases the duration of the corrosion protection of PEO-coatings may be insufficient due to high heterogeneity (including porosity) of obtained surface layers. Corrosion inhibitors are widely used for modification of coatings in order to provide autonomous self-healing properties and prolong the provision of protective ability. The most studied metallic corrosion inhibitors are phosphates, nitrites, molybdates, tungstates, vanadates, borates, rare earth salts and the organic corrosion inhibitors including different types of triazoles [1]. Thus, authors of the article [2] describe an efficiency of a composite coating applied by a sol-gel method, with benzotriazole. It was established that this corrosion inhibitor, in the protective layer, capable of starting the process of healing damage of the coating on AA7075 alloy.

This study is focused on formation of composite coatings on AMg3 alloy with the introduction of inhibitors of the triazole group of various concentrations in the previously formed base PEO-layer with purpose to improve the protective properties of the material.

Experimental part >

The experiments were carried out on samples made of AMg3 aluminum alloy with size of 20×30×2 mm. The surface preparation of the samples was realized through wet grinding with SiC paper with a gradual decrease in abrasive grain size from 28-40 to 14-20 μm, followed by washing in isopropyl alcohol and drying in a desiccator. PEO was carried out in a tartrate-fluoride electrolyte in a galvanostatic mode for 40 s. The current density was equal to 1.79 $A \cdot cm^{-2}$ and the duty cycle was equal to 1. To ensure the best filling of coating microtubes with inhibitor, the formed samples were subjected to vacuum impregnation in aqueous solutions of 1,2,4-triazole and benzotriazole at various concentrations (0.05 M and 0.1 M), with the following exposure to inhibitor solutions for 1 h under constant stirring, and then dried in a desiccator at a temperature of 40 °C for 24 h.

The protective properties of the formed coatings was assessed using the electrochemical methods, including electrochemical impedance spectroscopy (EIS) and open circuit potential (OCP) measurements. Experiments were carried out in a three-electrode cell (**fig. 2**) with a silver chloride (Ag/AgCl) electrode as a reference electrode and platinum mesh as a counter electrode using the VersaSTAT MC potentiostat/galvanostat electrochemical system (Princeton Applied Research, USA). 3 wt. % NaCl solution was used as an electrolyte.

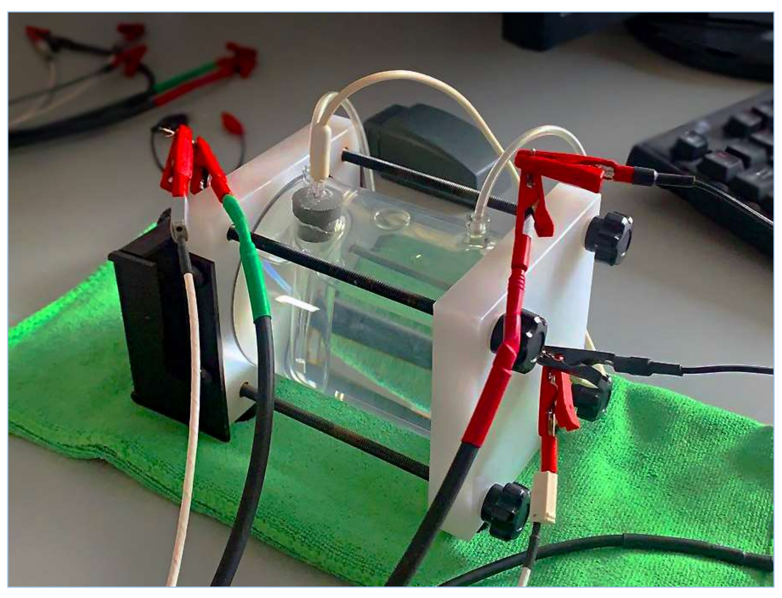


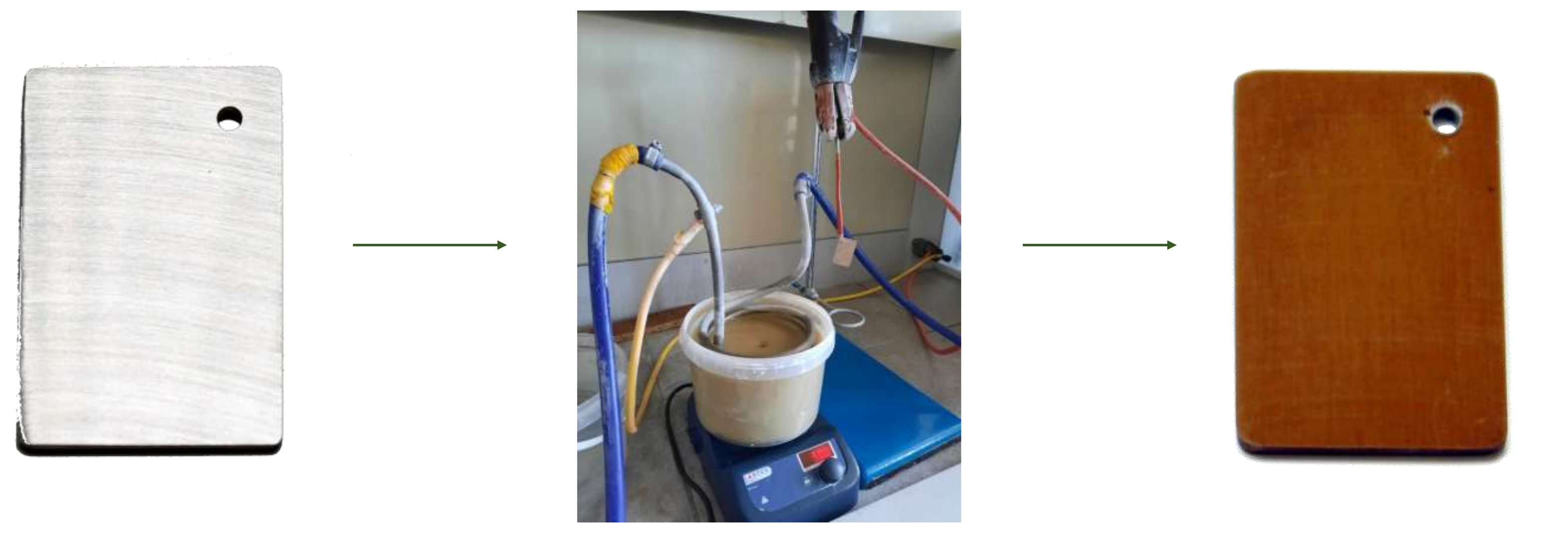
Figure 2 — Cell for studying the electrochemical characteristics of samples

For surface morphology analysis, Sigma (Carl Zeiss, Germany) scanning electronic microscope (SEM) was used.

Results >

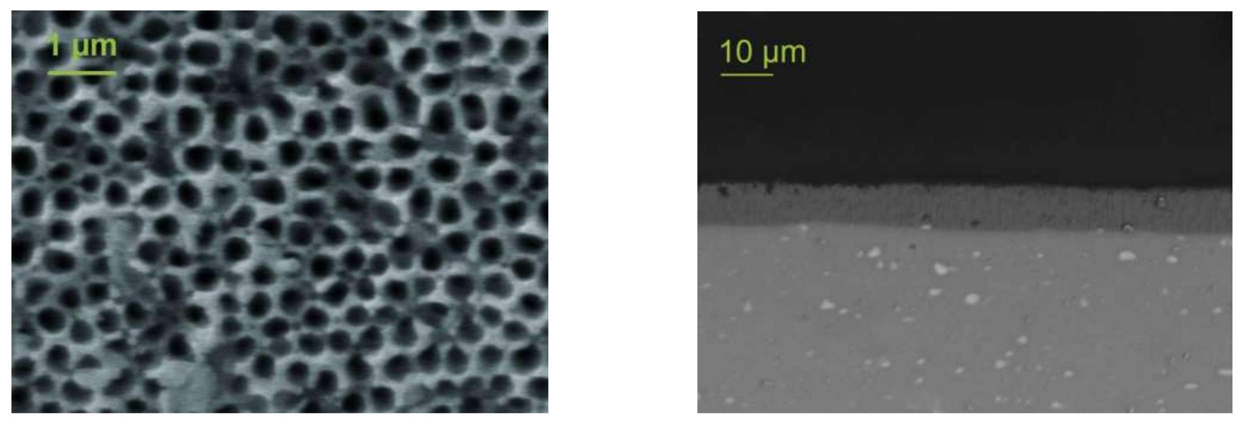
As a result of this study, the composite inhibitor-containing coatings with a self-healing ability were obtained on the AMg3 aluminum alloy. Coatings consisted of a PEO-layer with a self-organized microtubular structure (**fig. 3 (A)**) and inhibitors of the triazole group (**fig. 3 (B)**).

A



Prepared sample of AMg3 alloy | Plasma electrolytic oxidation Setup | PEO-coated sample

B



Frontal SEM-image of the PEO-coating | SEM-image of a cross section of the PEO-coating

Figure 3 — Formation of the PEO coating (A) and study of the structure (B)

Figure 4 shows the results of EIS study of the uncoated aluminum alloy AMg3, the PEO-coated sample, and samples with inhibitor-containing layers after the exposure for 1 h in a 3 wt. % NaCl solution.

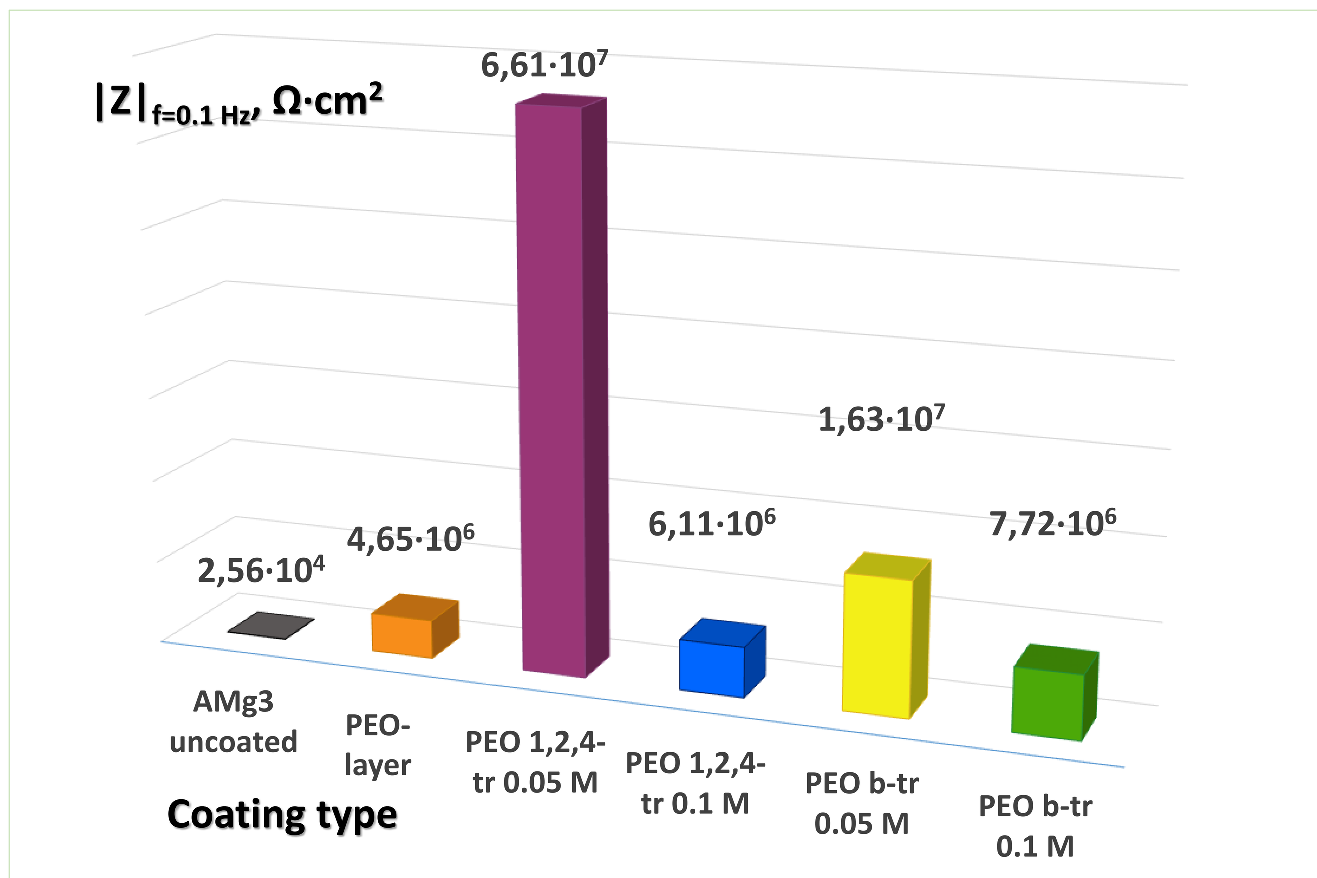


Figure 4 — The coating specification and electrochemical parameters of samples according to the results of EIS test

As can be seen from the analysis of the impedance modulus measured at low frequency ($|Z|_{f=0.1}$ Hz, **fig. 4**) after 1 h of exposure, all samples with composite inhibitor-containing coatings perform higher corrosion resistance compared to the uncoated sample and base PEO-layer.

The sample with the PEO-layer impregnated with 1,2,4-triazole at a concentration of 0.05 M is characterized by the best protective properties. The value of $|Z|_{f=0.1}$ Hz for this composite coating is more than one order of magnitude higher than the values for the sample with base PEO-layer (**fig. 4**). An increase in the concentration of inhibitors to 0.1 M leads to a decrease in the $|Z|_{f=0.1}$ Hz, and, as a consequence, a decrease in corrosion resistance, due to the PEO-layer degradation, which is consistent with the data presented in [2].

Conclusions >

During the study, heterooxide layers with a microtubular structure were obtained on the AMg3 aluminum alloy. The impregnation of corrosion inhibitors into the PEO-coating contributed to a significant increase in the corrosion resistance of the studied material. The sample impregnated with 1,2,4-triazole at a concentration of 0.05 M is characterized by the best protective properties.

Acknowledgements >

The samples preparation, protective coating formation, and electrochemical measurements were supported by the Grant of Russian Science Foundation, Russia (project no. 21-73-10148, https://rscf.ru/en/project/21-73-10148/). The study of coating composition was supported by the Grant of Russian Science Foundation, Russia (project no. 20-13-00130, https://rscf.ru/en/project/20-13-00130/).

References >

[1] Fan Zhang, Pengfei Ju, Mengqiu Pan, Dawei Zhang, Yao Huang, Guoliang Li, Xiaogang Li Corrosion Science 144 (2018) 74-88.
[2] M. Farahani, H. Yousefnia, Z.S. Seyedraoufi, Y. Shajari Ceramics International 45 (2019) 16584–16590.