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The effect of Zr-based conversion nanoceramic treatments on the electrochemical behavior of 2024 e 7475 aluminum alloys

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Abstract

Nanoceramic coatings based on hexafluozirconic acid (H_2ZrF_6) obtained at different pHs were considered as ecofriendly conversion coatings for corrosion protection of AA2024 and AA7475. Polarization curves and electrochemical impedance spectroscopy showed corrosion improvement resistance provided by the coatings in dilute sodium chloride solution.

Keywords: aluminum alloys, Zr-based nanoceramic coatings, electrochemical behavior

Introduction

Aluminum alloy foils are widely used in aircraft, automotive, civil and home commodities industries. In most cases chromate based conversion coatings have been traditionally and extensively used for corrosion protection of this metal due to their ability to provide excellent corrosion resistance. However, the use and disposal of chromium compounds are receiving regulatory attention because of the toxicity and carcinogenicity of Cr^{6+} species.
In the last years, a promising new pretreatment was the development of zirconium/titanium oxide films of nanometric thickness (nanoceramic coatings) on the metal surface. Effective parameters such as immersion time, pH, acid concentration and metal composition have direct influence on the coating´s microstructure and corrosion performance [1].
The presence of intermetallics particles in aluminum alloys often function as hot spots for any electrochemical surface processes, acting as anodic or cathodic sites, depending on the exact alloy composition [2]. Concerning nanoceramic coatings, the presence of these particles may act as local cathodes, increasing the local pH promoting deposition around them [3].
The present work focuses on the effect of the solution pH and alloy composition on the electrochemical behavior of Zr-based nanoceramic coatings on commercial aircraft aluminum alloys, namely AA2024 and AA7475, in sodium chloride electrolyte.

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Methodology

Samples of AA2024-T3 and AA7475-T651 (supplied by Embraer) with dimension of 2 cm x 4 cm x 0.2 cm were used as substrates. The test area of 0.95 cm^2 was delimited with beeswax and the surface treatment sequence is illustrated in Fig. 1.

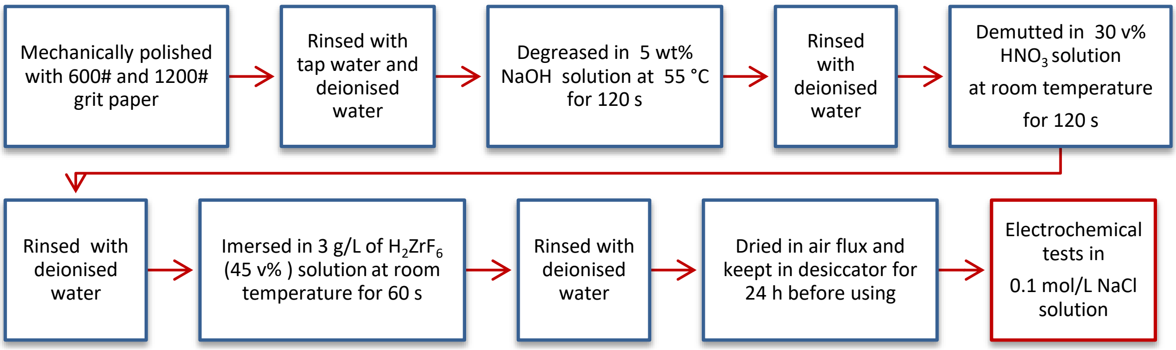

Figure 1 – Sequence treatment of the samples.

Electrochemical behavior of samples was measured by using potentiodynamic polarization and EIS tecniques with a potentiostat/galvanostat Autolab PGSTAT 302 instrument and an electrochemical cell with a three-electrode arrangement. Samples were immersed in test solution for 300 s before each test and the open circuit potential (E_{OCP}) values were recorded. Scan rate of 10 mV/s was used for potentiodynamic tests and EIS tests were carried out over a frequeny ranging from 10 MHz to 10 mHz with a 10 mV amplitude signal at E_{OCP}.

Results and discussion

The E_{OCP} behavior is shown in Fig. 2. The E_{OCP} of untreated and treated alloys oscillates near a defined value of -0,52 V (Ag/AgCl) and -0.68 V (Ag/AgCl) for AA2024 and AA7475, respectively. The small fluctuations of these values was due to transient process resulted of the penetration of Cl^- ions through the porous of the passive layer giving place to local pitting initiation and its subsequent repassivation [4].

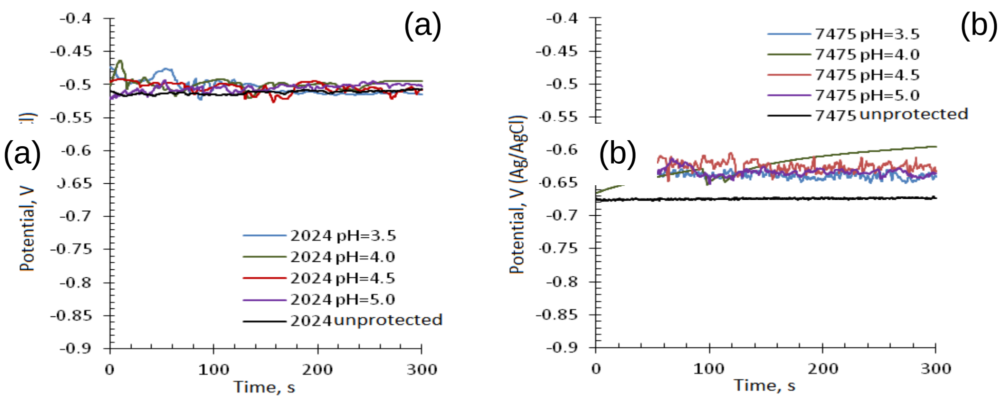

Figure 2 – Variation of the E_{OCP} with time for untreated and treated samples. (a) AA2024 and (b) AA7475

Polarization curves for treated and untreated samples are shown in Fig. 3. Significant reduction of current densities was observed for both aluminum alloys in pH 3.5 and pH 4.

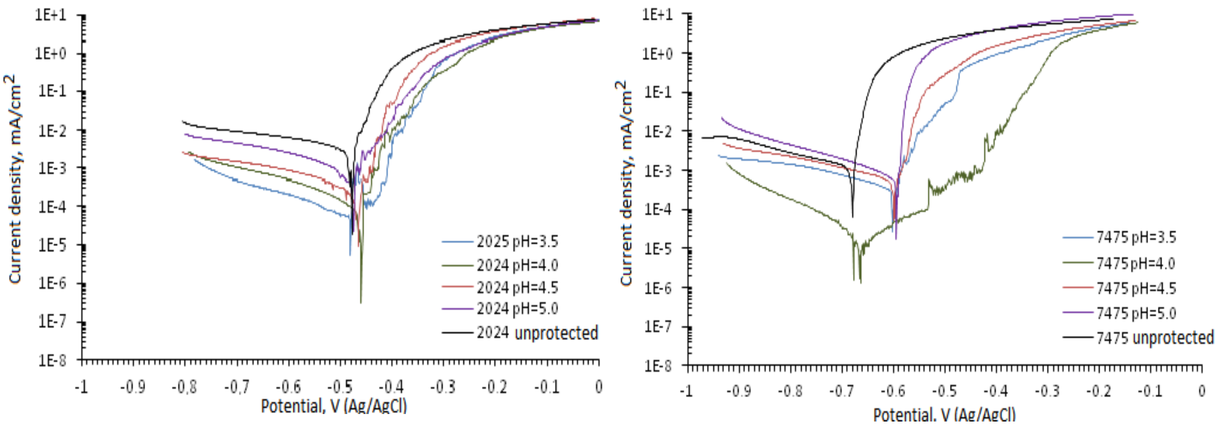

Figure 3 – Polarization curves for untreated and treated samples. (a) AA2024 and (b) AA7475

Nyquist plots (Fig. 4) indicate a tendency to a semicircle in the high frequency region, which is indicative of charge-controlled reactions. The diameter of the arc can be regarded as polarization resistance (R_p) of the coating. The largest (estimated) semicircle for pH up to 4 reveals that these coatings are able to protect both aluminum alloys in dilute chloride solution.

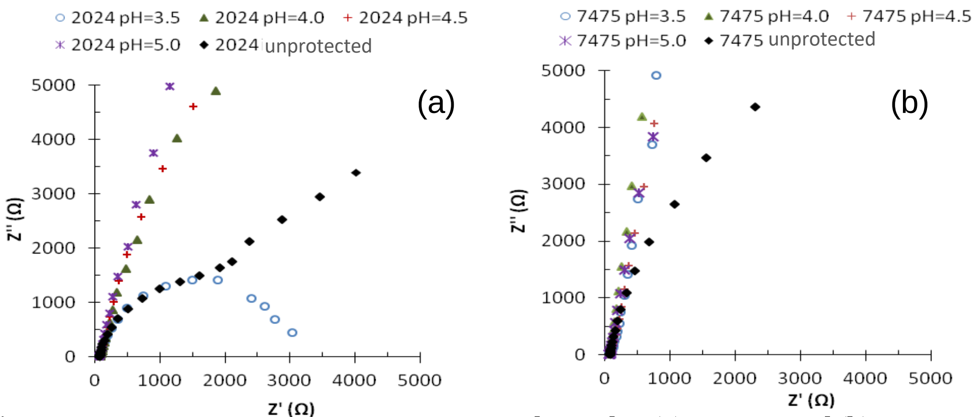

Figure 4 – Nyquist plot for untreated and treated samples. (a) AA2024 and (b) AA7475

Conclusions

Zr-based nanoceramic coatings improved corrosion resistance of both aluminum alloys. The AA2024 showed lower corrosion performance than AA7475. The best results on protection were achieved for pH 4. Zr-based conversion coatings can be considered as good starting point for the aircraft applications, but further studies shall be done for their optimization.

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