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Improvement of silane coatings using corrosion inhibitors

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Extended Abstract

Silane-based pretreatments are an interesting alternative for replacing the chromatization and phosphatization processes, decreasing the environmental impacts, and improving the corrosion resistance of metals [1, 2]. However, silanes generally present little active protection due to low densities of cross-linked covalent bonds (Si-O-Si areas) and small defects caused by solvent evaporation during the film formation [3, 4]. In this work, different concentrations of two corrosion inhibitors were directly added to tetraethoxysilane (TEOS) sol to produce the coatings: a green one (the extract of grape juice production residue, RSU) and a commercial one (benzotriazole, BTAH). Coatings were produced using sol-gel dip coating and characterized by Electrochemical Impedance Spectroscopy (EIS) in a 3.5% w/v NaCl solution. Figure 1 presents the Nyquist diagrams showing capacitive loops for the samples coated with TEOS in the absence or the presence of synthetic (TEOS+BTAH) or green (TEOS+RSU) corrosion inhibitors. The larger the semicircle of the capacitive loop, the greater the corrosion resistance [5,6]. Thus, Figure 1 shows that all inhibitors improved the anticorrosive performance of the pure silane coating. The best anticorrosive behavior performance was verified for the sample produced with TEOS+10⁻² mol/L BTAH. Nonetheless, the sample prepared using TEOS+200ppm RSU showed promising results, as its performance was like that using TEOS+10⁻³ mol/L BTAH. The EIS data were simulated using the equivalent electrical circuits of Figure 2, and the results are shown in Table 1. The charge-transfer resistance (R_{ct}) of the TEOS+10⁻² mol/L BTAH sample was similar to that found by Silva Jr. et al. [7] for 3-aminopropyl trimethoxysilane (APS) silane coatings deposited on carbon steel pretreated with 5-amino-1,3,4-thiadiazole-2-thiol (AMT) as an inhibitor. However, the direct addition of BTAH to the TEOS sol produced a coating with a higher R_{ct} (2008 Ωcm^2) than that in which the TEOS coating was deposited on an AMT pretreated carbon steel ($R_{ct} = 882 \Omega\text{cm}^2$) [8]. This result suggests that the inhibitor addition may affect the anticorrosive properties of the coating more positively. Besides exhibiting the highest R_{ct} values, the TEOS+10⁻² mol/L BTAH sample also showed the lowest electrical double-layer capacitance value (C_{dl}), indicating that this system may be able to increase the dielectric phenomena that occur when there is contact between the electrolyte and the substrate [9]. Concerning the TEOS+RSU systems, the sample using 200 ppm showed the best anticorrosive performance, exhibiting $R_{ct} = 1677 \Omega\text{cm}^2$ and $C_{dl} = 2.46 \times 10^{-3} \text{ F/cm}^2$, which are values similar to those found for the sample containing 10⁻³ mol/L BTAH (Table 1). Despite being promising, the sample TEOS+200ppm RSU showed a

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very capacitive character, with diffusion at low frequencies. Marujo et al. [10] observed that the best RSU concentration for inhibiting the carbon steel in a saline medium was 300 ppm, which may indicate that it is the most suitable concentration for adding to the TEOS sol to be used in the TEOS+RSU system.

Keywords: corrosion, silane coating, corrosion inhibitors

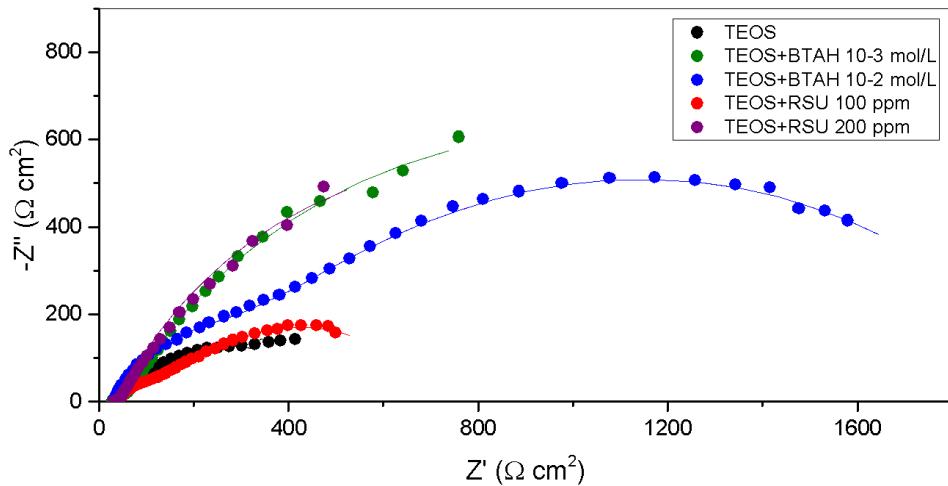


Figure 1 – Nyquist diagrams of TEOS and TEOS+ inhibitors samples in a 3.5% m/v NaCl solution

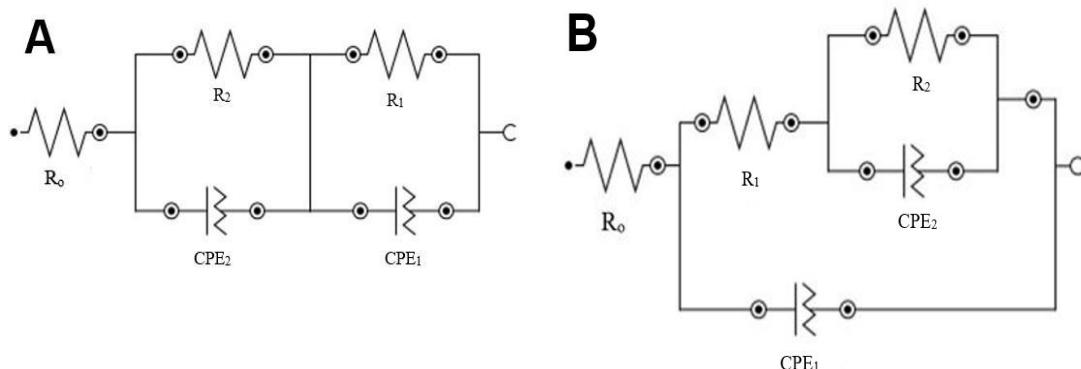


Figure 2 – Equivalent electrical circuits for simulation and adjustment of EIS data using NOVA 1.10 software

Table 1 – Results obtained from the simulation of EIS data

Sample	Circuit	R_0 Ωcm^2	R_{ct} Ωcm^2	N	Q mMho	C_{dl} F/cm^2	χ^2
TEOS	$[R(RQ)(RQ)]$	5.77	460	0.725	4.06	9.55×10^{-4}	0.018
TEOS+BTAH 10 ⁻³ mol/L	$[R(RQ)(RQ)]$	5.90	1997	0.755	5.99	2.02×10^{-3}	0.047
TEOS+BTAH 10 ⁻² mol/L	$[R([R(RQ)]Q)]$	6.32	2008	0.648	5.70	9.28×10^{-4}	0.037
TEOS+RSU 100 ppm	$[R(RQ)(RQ)]$	8.75	655	0.684	14.92	5.64×10^{-3}	0.032
TEOS+RSU 200 ppm	$[R(RQ)(RQ)]$	6.44	1677	0.785	6.03	2.46×10^{-3}	0.088

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