

ELECTROCHEMICAL BEHAVIOR OF THE INHIBITORY ACTION OF FENETILTRICLORO-SILANE FOR AISI 304 STAINLESS STEEL IN H₂SO₄

COMPORTAMENTO ELETROQUÍMICO DA AÇÃO INIBIDORA DO FENETILTRICLORO-SILANO PARA O AÇO INOXIDÁVEL AISI 304 EM H₂SO₄

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Abstract

The metal-mechanical industry worldwide is used to years of conventional treatments of metal surfaces such as phosphate, nickel plating and chroming, but in the current globalization of the market there is an increasing of environmental demands the use of less toxic metals treatment. Studies have shown that using of silanes in place of traditional treatments allowed minimizing the corrosion of metals, and reduce environmental impact. The objective of this work is to study the electrochemical behavior of fenetiltricloro - silane (C₈H₉Cl₃S) for AISI 304 stainless steel (SS) in the media of 5 mol L⁻¹H₂SO₄. The techniques employed were: the open circuit potential, anodic and cathodic potentiodynamic polarization curves, electrochemical impedance spectroscopy and optical microscopy. The results of the anodic and cathodic potentiodynamic polarization show a mixed inhibitor efficiency, in the active region of the anodic curve the inhibitor efficiency is 41 ± 8%, minimizing the potential increase, reaching a small catalyst in the transpassive region next to 1 V / SME, leading after the film break the current densities similar in the absence and presence of the silane film.

Keywords: corrosion, silane, AISI 304 SS.

Resumo

A indústria metal-mecânica mundial utiliza há anos os tratamentos de superfícies metálicas convencionais, como o fosfatização, a niquelação e a cromagem, mas na atual globalização do mercado, há um aumento das exigências ambientais o que leva à utilização de tratamento que usem metais menos tóxicos. Estudos têm demonstrado que a utilização de silanos, em substituição dos tratamentos tradicionais permitiu minimizar a corrosão de metais, e reduzir o impacto ambiental. O objetivo deste trabalho é estudar o comportamento eletroquímico de fenetiltricloro - silano (C₈H₉Cl₃S) no aço inoxidável AISI 304 em meio de 5 mol L⁻¹H₂SO₄. As técnicas utilizadas foram: o potencial de circuito aberto de curvas de polarização, anódicas e catódicas, espectroscopia de impedância eletroquímica e microscopia óptica. Os resultados das polarizações anódicas e catódicas mostram uma eficiência de inibidor misto, na região ativa da curva anódica a eficiência do inibidor é de 41 ± 8%, minimizando o potencial de aumentar, atingindo um catalisador de pequeno porte na região próxima da transpassiva a 1 V / SME, levando após a quebra do filme a densidades de corrente semelhantes na ausência e presença do filme de silano.

Palavras-chave: corrosão, silano, aço inoxidável AISI 304

Introduction

Silanes are compounds used by industry for metal-mechanics, due to good corrosion protection, besides acting as coupling agents, which can promote the adhesion of organic coatings on inorganic substrates (AQUINO, 2006; OOIJ, 2005; GENTIL, 1987).

Studies directed towards the protection of metals using silanes show that they are an environmentally friendly alternative, at least as harmful to the environment compared with traditional processes of surface treatment such as phosphating and chrome plating (RAMOS, 2009; H. J., 2004).

The silane-based coatings were excellent for corrosion protection on various metals such as aluminum and its alloys (van OOIJ; ZHU, 2004), copper (ZUCCHI, 2004), iron and steel (SUBRAMANIAN, 1998; OOIJ, 1998).

Materials and Methods

In this work the AISI 304 SS was studied and it is used in: equipment for chemical, petrochemical, pharmaceutical and food (SILVA, 2006). The chemical composition of steel used is shown in Table 1.

Table 1: Chemical composition of austenitic stainless steel 304.

Chemical composition of stainless steel AISI 304				
% C	% Cr	% Ni	% Mo	Other
0.08 max.	19.0	10.0	-	-

Were used the feniltricloro-silane ($C_8H_9Cl_3S$) (Figure 1) at a concentration equal to 1×10^{-3} mol L^{-1} and pH 4.5 (OLIVEIRA, 2006), adjusted with 1 mol L^{-1} potassium hydroxide. In The electrolytic solution 5 mol L^{-1} H_2SO_4 .

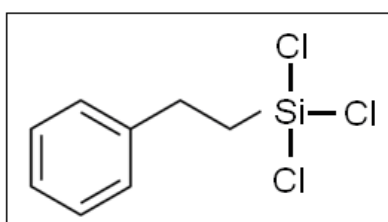


Figure 1: Structure of feniltricloro-silane.

To clean the electrode surface, polished on a polishing with sandpaper of # 200, 300, 400, 600 and 1200, successively washed with distilled water and dried with jets of cold air.

According to Figure 2 for the deposition of silane layers on AISI 304 stainless steel, it started with a treatment using commercial alkaline degreasing 5% for 5 minutes, followed by immersion in 5% sodium hydroxide for 10 minutes (CHILD, 1999; CAPIOTTO, 2006), and finally dried with hot air jets. The second step consists in immersion of the work electrode in a silane solution by 5 minutes, quick drying with hot air jets and heating to 100 ° C for 10 minutes.

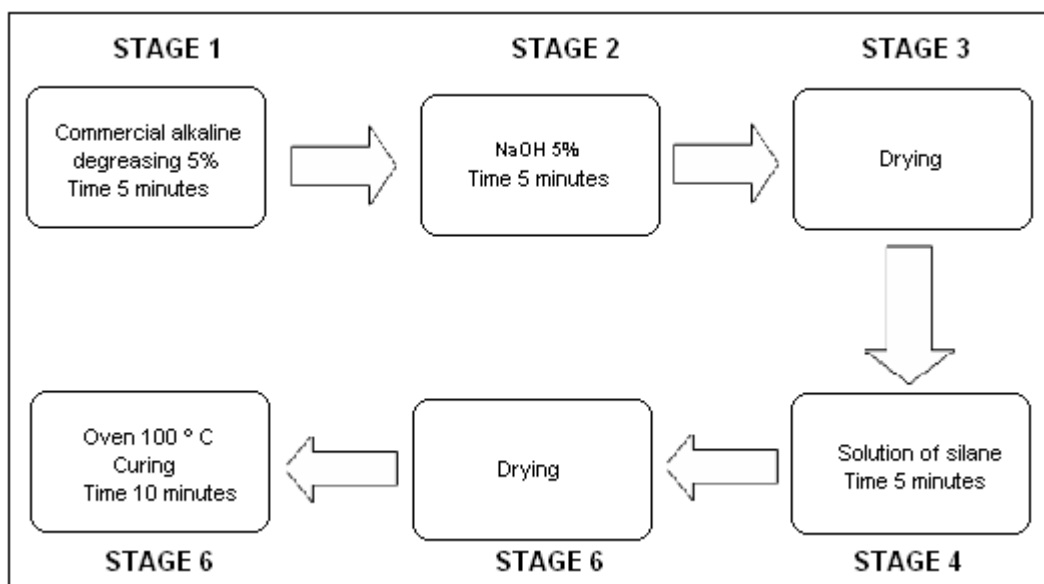


Figure 2: Steps for obtaining silane layer on 304 SS.

The procedure of figure 2 was repeated two times at the formation of a bilayer in the electrode work.

The electrochemical cell consists of three electrodes, in which the counter electrode is a platinum wire with an area about 10 times greater than the area of working electrode, the reference used was a mercurous sulfate electrode (MSE) and the work electrode used was AISI 304 stainless steel with an area of 0.66 cm^2 surrounded by an inert resin.

All experimental measurements were performed in a room at a temperature of $23 \pm 2 \text{ }^\circ\text{C}$.

The corrosion potential measurements were performed to obtain the corrosion potential (E_{corr}) with a deviation of $\pm 5 \text{ mV}$ within 30 minutes.

The polarization tests were carried out with potentiostat Gamry PC4-300, operating in potentiostatic mode configuration of three electrodes. The potentiodynamic anodic polarization curves were taken from the corrosion potential to 1.5 volts, with a scan rate equal to 1 mVs^{-1} . The potentiodynamic cathodic polarization curves were performed from the corrosion potential with a scan rate equal to 1 mVs^{-1} .

Tests of electrochemical impedance spectroscopy were performed in the same cell of the polarization tests, using a frequency analyzer Gamry, EIS model 300, coupled to the PC4-300 potentiostat. The working electrode was maintained at its corrosion potential.

The surfaces of the electrode before and after experiments were micrographs using an Olympus microscope BX-41 M.

Results

According to Figure 3, the value of corrosion potential for the system without silane and double layer of silane did not vary significantly.

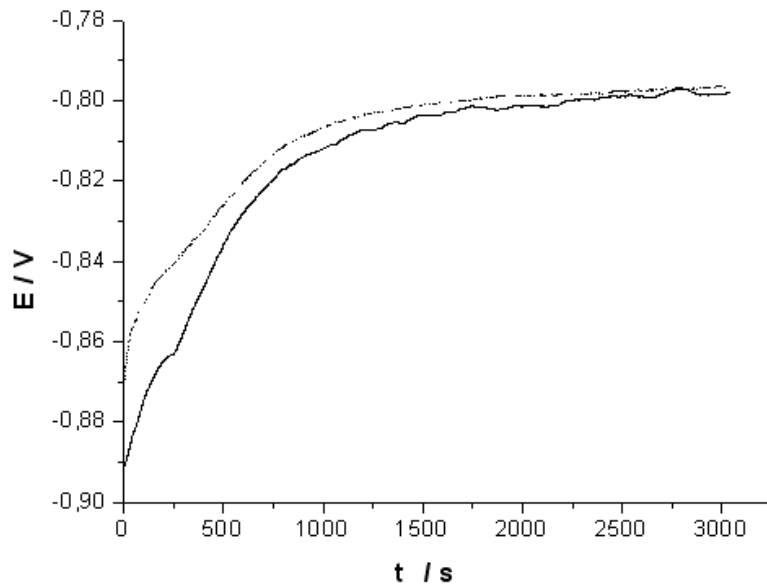


Figure 3: Curves circuit potential for AISI 304 SS in 5 mol L⁻¹ H₂SO₄: (- -) in the presence (—) and absence of silane.

Figure 4 shows the anodic potentiodynamic polarization curves for the systems studied, with emphasis on the active region.

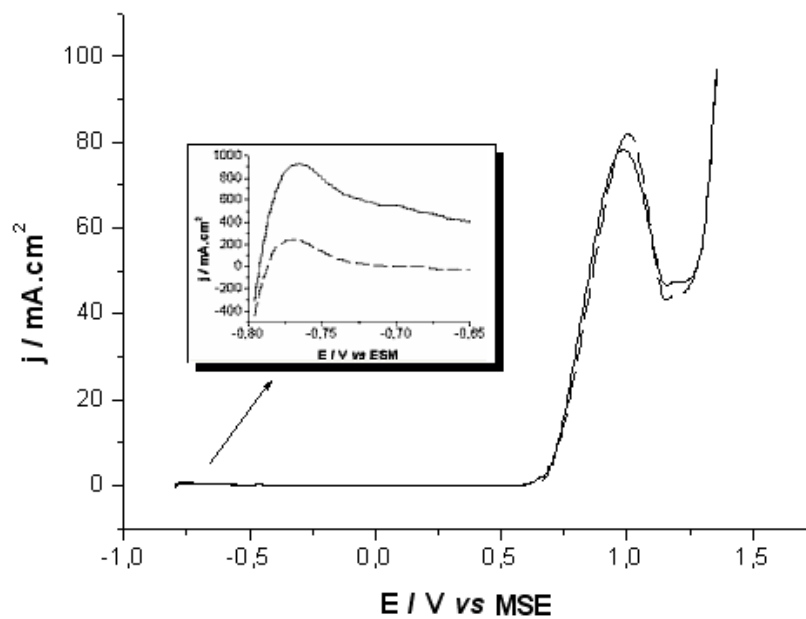


Figure 4: Potentiodynamic anodic polarization curves for AISI 304 SS in 5 mol L⁻¹ H₂SO₄: in the presence (- -) and absence (—) layers of silane.

Figure 5 presents a plot of the cathodic potentiodynamic polarization for 304 stainless steel and 304 stainless steel + silane.

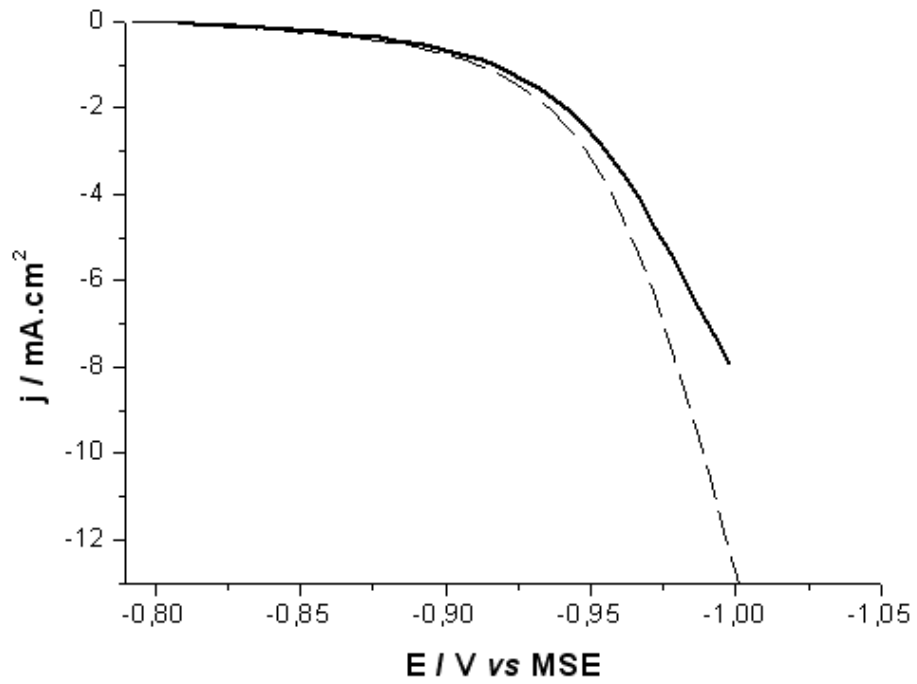


Figure 5: Potentiodynamic cathodic polarization curves in 5 mol L⁻¹ H₂SO₄ in the: presence (- -) and absence (—) layers of silane.

Figure 6 is shown a diagram of electrochemical impedance spectroscopy Nyquist type for the systems studied in this work.

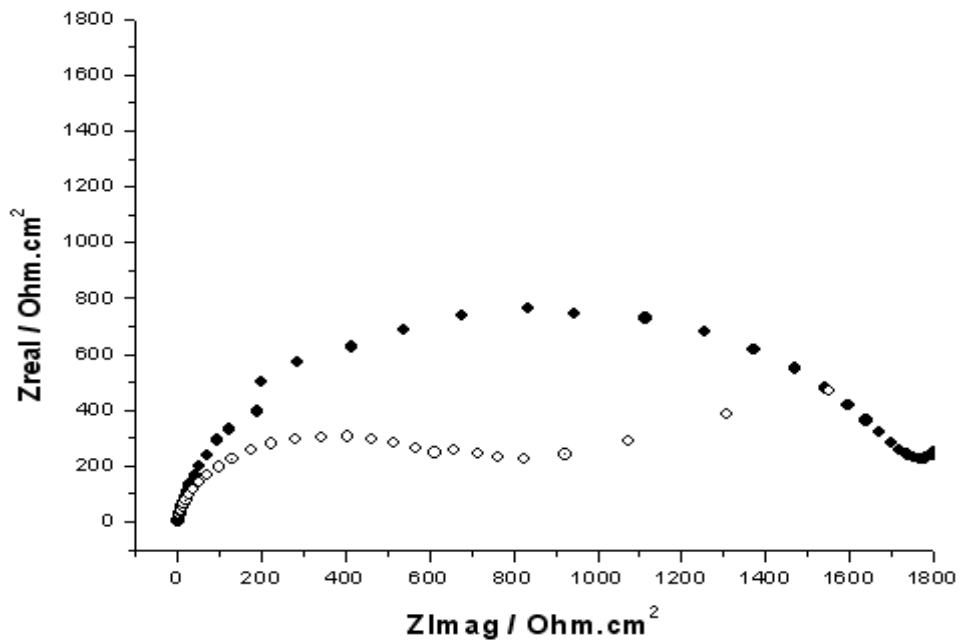


Figure 6: Diagram of Electrochemical Impedance Spectroscopy Nyquist type for different substrates of AISI 304 SS in 5 mol L⁻¹ H₂SO₄ media: (○) absence and (●) presence of silane.

The microscopic analysis is shown in Figure 7.

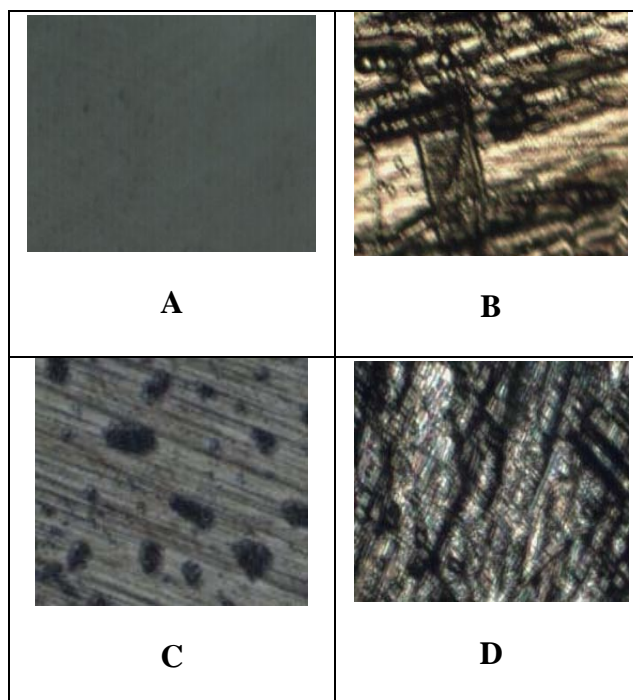


Figure 7: Microscopic Analysis with an increase of 100 x (A) AISI 304 stainless steel polished, (B) AISI 304 stainless steel after anodic polarization in 5 mol L⁻¹ H₂SO₄ media, (C) AISI after immersion in the solution of silane and (D) AISI + silane after anodic polarization.

Discussion

The value of corrosion potential for the system without silane and with a double layer of silane was -795 ± 3 mV / SME (figure 3), suggesting that the mechanism of the reaction did not change with the presence or absence of the bilayer of silane on the surface of the electrode.

The results of potentiodynamic anodic polarization (figure 4) and cathode (figure 5) show a decrease in current density for steel + silane, suggesting a greater resistance to polarization of this medium with an inhibitor efficiency of $41 \pm 8\%$. However, with increasing potential, there is a small catalyzes the first transfixed the region, close to 1 V / SME, leading after the rupture of the film similar densities currents in the absence and presence of silane bilayer. Thus, the bilayer feniltricloro silane in AISI 304 stainless steel has mixed inhibitor efficiency.

The diagram of electrochemical impedance spectroscopy (figure 6) is in agreement the results of polarization curves, showing higher impedance to the system contend silane.

Conclusions

- (1) The feniltricloro - silane (C₈H₉Cl₃S) acts as a corrosion inhibitor in the active-passive region of 430 SS in 5 mol L⁻¹ H₂SO₄, with an efficiency of $41 \pm 8\%$;
- (2) The feniltricloro - silane acts as a catalyst for the reaction of hydrogen evolution for the 430 SS in sulfuric acid media;

Acknowledgments

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