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Effect of Algae Biofilms on the Corrosion of Stainless Steel

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Abstract

Stainless steel (SS) materials have been widely used in different environments due to their good corrosion resistance. However, pitting corrosion induced by microorganisms is commonly observed. In this work, corrosion of 316L SS in the absence and presence of *Scenedesmus vacuolatus (S. vacuolatus)* was monitored using open circuit potential (OCP), and electrochemical impedance spectroscopy (EIS). Biofilm formation on the SS was analyzed using scanning electron microscopy (SEM) and metallographic microscopy. Surface and corrosion products were analyzed using energy dispersive spectroscopy (EDS). *S. vacuolatus* cells adhered to the SS coupon by extracellular polymeric substances (EPS) at the early times of exposure and the number of attached algae increased after 21 days of exposition. The results of EIS reflected that the attachment of *S. vacuolatus* enhanced SS corrosion.

Keywords: Stainless steel; *Scenedesmus vacuolatus*; Biofilms

Introduction

Stainless steel exhibits resistance to corrosion in freshwater, neutral pH, and ambient atmosphere and temperature. This is because of the formation of a passive film on the surface. However, corrosion of stainless steels has been in moderate conditions, and it is attributed to microbiologically influenced corrosion (MIC) [1-3]. MIC is caused by a variety of microorganisms, such as bacteria, archaea, fungi, algae, and others, acting together to create conditions resulting in metal loss [4]. MIC of stainless steel is relatively less known than those of carbon steel. Therefore, it is very important to study corrosion of SS induced by algae, which is considered as the first step for the control of algae corrosion and biofouling. The aim of this work was to study the corrosion of 316L SS in the absence and presence of the green alga *Scenedesmus vacuolatus.*

Material and Methods

Coupons of SS (2 cm x 1cm) for algae adherence and coupon of with 1cm2 exposed area for electrochemical analyses were 7 cm x 1.5 cm (for electrochemical analyses) were immersed vertically in a flask with *S. vacuolatus* culture in BG11 broth (initial $OD_{(664nm)} = 1.5$, $\approx 1.7x10^5$ cells. ml-1) under constant agitation (Figure 1). Coupons were withdrawn from the cultures after 7, 14 and 21 days. Biofilm formation on the SS was observed using scanning electron microscopy (SEM) and metallographic microscopy and surface and corrosion products were analysed using energy dispersive spectroscopy (EDS) after the different times of exposure. Corrosion of SS coupons was monitored using open circuit potential (OCP) and Sterile culture medium was used as control. electrochemical impedance spectroscopy (EIS). The experiments were done in duplicate.

Results and Discussion

SEM images showed grouped *S. vacuolatus* cells adhered to the SS coupon by extracellular polymeric substances (EPS) at the early times of exposure. After 21 days of exposition, the number of attached algae increased, and cells were homogeneously distributed over the surface (Figure 2). The algae biofilm was composed of S. vacuolatus cells, EPS, and corrosion products. Similar results were obtained by Landoulsi et al. [5].

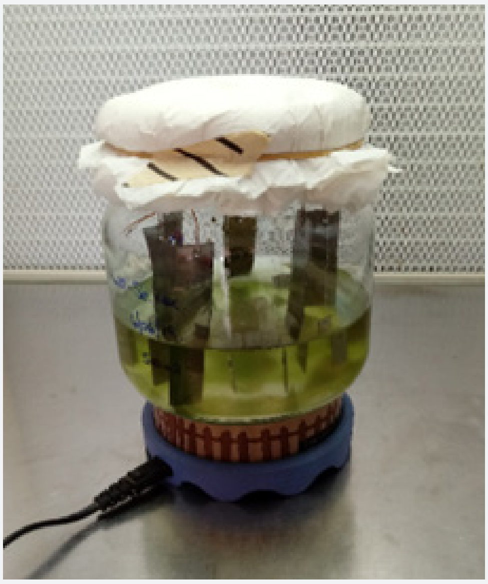

Figure 1: *Scenedesmus vacuolatus* culture with SS coupons.

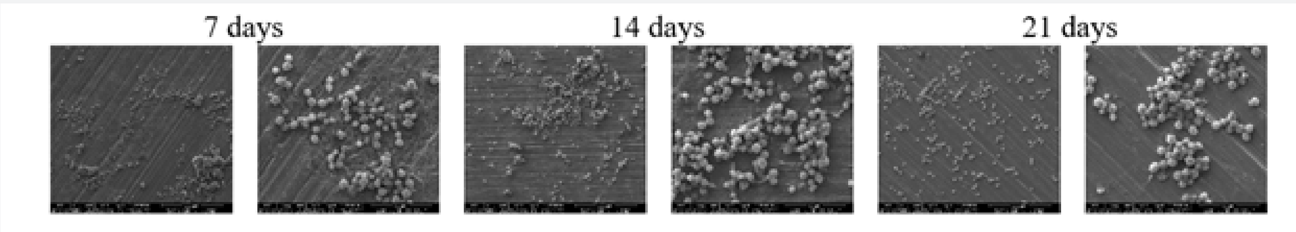

Figure 2: Microphotograph of SEM of SS coupons after 7,14 and 21 days of exposure in the algae culture.

The OCP measurements made in the presence of algae presented strong oscillatiosn, reflecting the effect of biofilm formation on the passive film and the variation to enrichment/depletion cycles of oxygen at the SS/biofilm interface [5]. Variation of oxygen concentrations in the bulk solution during the daytime and nighttime contributed to the fluctuation of OCP values [6] The OCP values measured in the sterile control showed a slight and steady increase during the 21 days.

The diameters of Nyquist plots (ZIm vs Zreal) were lower in the presence of the biofilm and decreased gradually with time, reflecting that the attachment of *S. vacuolatus* enhanced SS corrosion. In the equivalent electrical circuit used to fit the EIS results, the double layer capacitance was replaced by a constant phase element, with $n < 1$ attributed to the heterogeneity of the biofilms (Figure 3).

Conclusion

a) Biofilms of *S. vacuolatus* produced changes in the OCP and in the impedance spectra of 316 SS reflecting their interaction with the passive oxide film formed on the SS surface.

b) However, the corrosion rate (obtained from EIS data) in the presence of the algal biofilms was very low.

Further studies are necessary to elucidate the role that the algal biofilm could play in the onset of localised corrosion.

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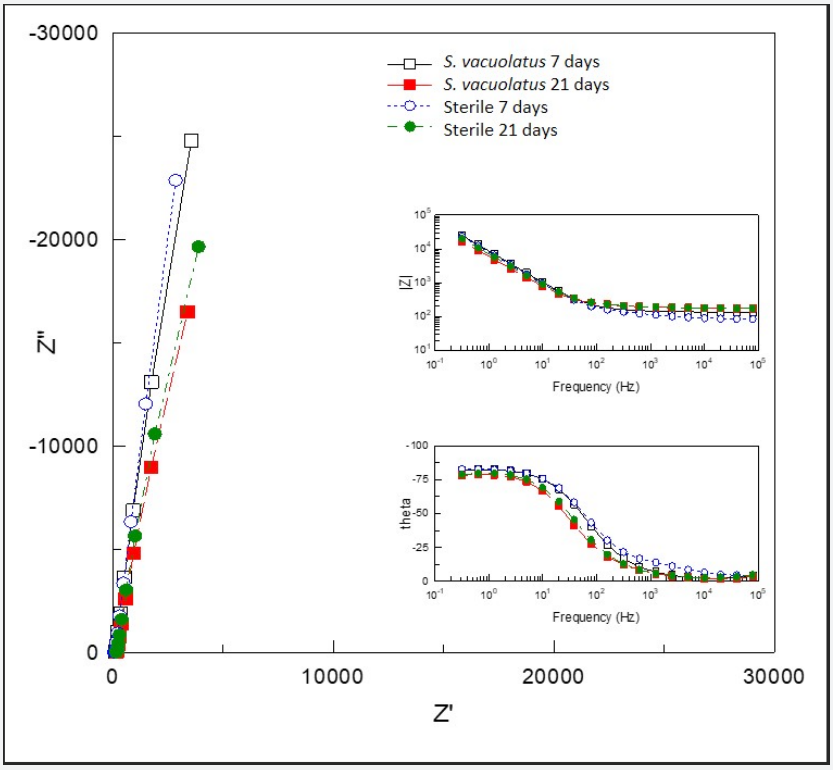

Figure 3: Electrochemical impedance spectroscopy measurement. SS coupons exposed to BG11 sterile medium and SS coupons exposed to algae culture 7 and 21 days.

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