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Adsorption and surface morphological studies of Corrosion Inhibition of Mild Steel using bioactive compounds in chloride medium

S.Chitra [1], B.Anand [2]
[1] Center for Research, Mahendra Engineering College, Namakkal, Tamilnadu, India.
[2] Department of Chemistry, Sir Theagaraya College of Arts and Science, Chennai.
[1] chitrachem@gmail.com

Abstract

Corrosion has been chronic problem to industries and has increased cost of production. Seaweeds are a rich source of unique bioactive compounds which are used as corrosion inhibitor for mild steel corrosion now a day. The inhibition of mild steel corrosion in chloride environment was investigated using adsorption and surface morphological methods. The obtained result revealed that sea weed performed well as corrosion inhibitor in chloride environment.The inhibition efficiency increases with increase in additive concentration. The results obtained shows that various concentrations of bioactive compounds inhibited the corrosion in chloride solution through the adsorption of the inhibitor molecule on the mild steel surface by blocking its active sites. The use of sea weeds (bioactive compounds) as an inhibitor for corrosion of mild steel in chloride environment is advocated in this study.

Key words: Bioactive compounds, Chloride, Corrosion, SEM, Mild steel.

1. Introduction

Many researchers have studied the effects of various types of organic inhibitors on the corrosion resistance of mild steel in different environment [1]. Most of the previous studies were focused on the inhibition of metals in HCl or H_2SO_4 solutions using organic compounds containing N, S and O atoms as corrosion inhibitors [2]. A lot of research has been done with naturally occurring substances since they are known to be eco-friendly and with little or no side effect on the humans. Among the naturally occurring substances reported in the corrosion study of metals like brass, aluminium, tin and mild steel, there leave extracts, gums and exudates, dyes, oils from plant materials, plant seeds and fruits, and anti-bacterial drugs [3]. The mild steel when immersed in aqueous environment gets corroded due to its thermodynamic instability [4]. Therefore, the corrosion behaviour and inhibition of mild steel in sodium chloride environment have been given attention by several workers during last few years. The present work includes the study of corrosion behaviour of mild steel in sodium chloride solution and its control by using inhibitor marine algae Cladophoropsis sundanensis extract. The inhibitor sea weed extract (SWE) was extracted with ethanol using soxhelt extractor from marine algae Cladophoropsis sundanensis. The inhibitive efficiencies of inhibitor were determined by weight loss, adsorption parameter and scanning electron microscopy techniques.

2. Materials and methods

2.1 .Preparation of Specimen

According to ASTM method as reported already [5], cold rolled mild steel strips were cut into pieces of 5cm × 1 cm having the following composition (in percentage) % C=0.017; Si=0.007; Mn=0.196; S=0.014;P=0.009; Ni=0.013; Mo=0.015; Cr=0.043 and Fe=99.686 was used. The samples were polished, drilled a hole at one end and numbered by punching. During the study, samples were polished with various grades of SiC abrasive papers (from grits 120 to 1200) and degreased using Acetone.

2.2. Preparation of the inhibitor

The seaweed Cladophoropsis sundanensis collected from Ramaeshwaram coastal region was picked with hand and immediately washed with sea water to remove the foreign and sand particles. Then the sea weed as air dried at room temperature and it is refluxed in ethanol for six hours using soxhelt extractor. Residue was concentrated and evaporated. Finally the dried extracts used as inhibitor.

2.3. Determination of Corrosion rate

The marine algae Cladophoropsis sundanensis ethanol extracts was used as inhibitor for this experiment. The corrosive medium used was 2M solution of NaCl. It was prepared by appropriate dilution of analytical grade of the NaCl with distilled water without further purification [6].

The coupons were cleaned and immersed in the containers that contain chloride medium of known concentration. We used glass hooks to hold the coupons in the medium. All experiments were done at room temperature. All the specimens were weighted before immersion in medium. After every experiment, the specimens were taken out from the container, dried with warm air, polished with emery papers and reweighed after several washing with distilled water and acetone. From the initial and final weights of the specimens, the loss of weights was calculated [7].

$$\text{Corrosion Rate} = 534 * W / D* A* T$$

Where W is the weight loss (g), D is the density of the specimen (7.85 g/cm3), A is the surface area of specimen (cm3) and t is the immersion time.

Table 1: Weight loss values and calculated inhibition efficiency for mild steel corrosion in 2M NaCl in the presence and absence of Cladophoropsis sundanensis extract.

Inhibitor Concentration (M)	(4 hrs)		(6 hrs)	
	Mass Loss	IE%	Mass Loss	IE%
Blank	0.0777	-----	0.0306	------
$1*10^{-4}$	0.0651	16.21	0.0210	31.37
$2*10^{-4}$	0.0596	23.29	0.0180	41.17
$3*10^{-4}$	0.0517	33.46	0.0128	58.16
$4*10^{-4}$	0.0465	40.15	0.0102	66.66
$5*10^{-4}$	0.0402	63.85	0.0066	78.43

Figure 1: Comparison of inhibition efficiency of Cladophoropsis sundanensis extract in various concentrations for 4hrs and 6hrs.

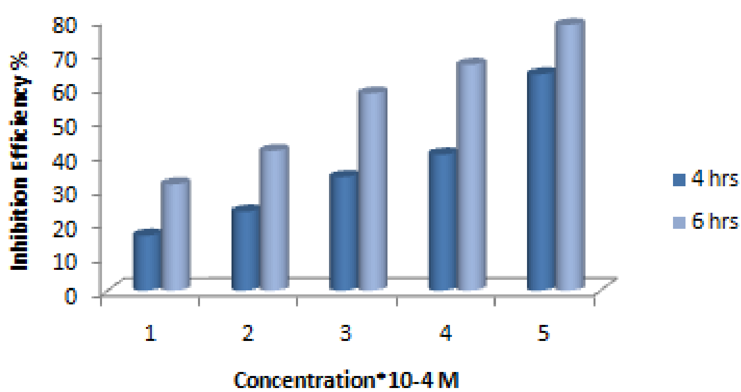


Table 2: Thermodynamic parameters for the adsorption of Cladophoropsis sundanensis in 2M NaCl on the mild steel.

Medium	Concentration in (M)	Surface coverage (θ)	ΔGads KJ / mol^{-1}	K x (10^{-2} M^{-1})
NaCl	$5*10^{-4}$	0.63	-8.310	1.80

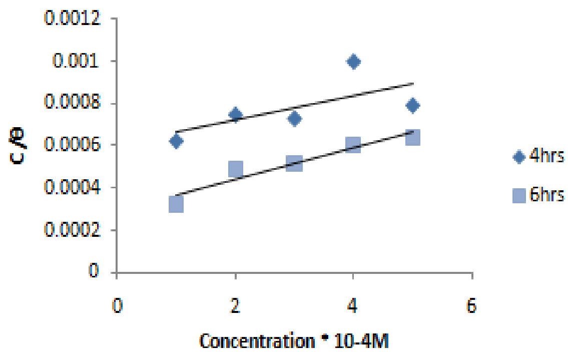
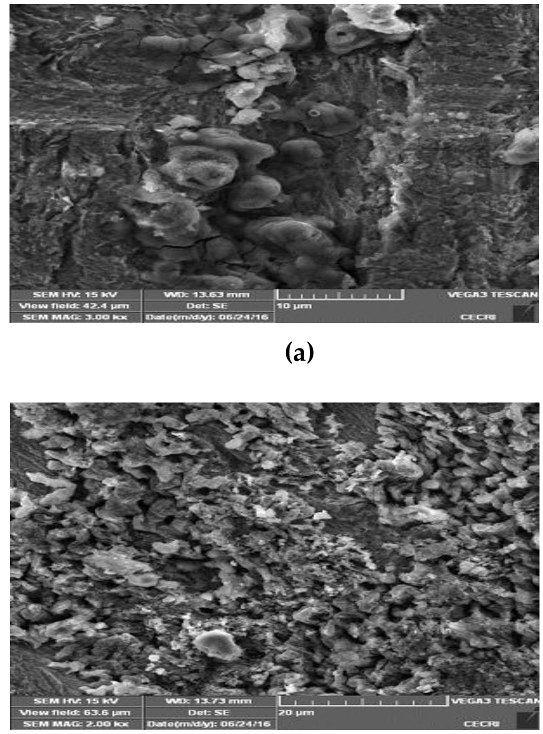


Figure 2: Langmuir's adsorption isotherm for mild steel in 2M NaCl containing various concentrations of Cladophoropsis sundanensis extract.

2.4 Surface characterization

The mild steel immersed in blank solution and in the inhibitor solution for a period of 4 hour and 6 hour was removed, rinsed with double-distilled water, dried and observed in a scanning electron microscope to examine the surface morphology [8-10]. The surface morphology measurements of mild steel were examined using scanning electron microscope. In the comparison of the SEM micrograms, there were a rough surface on mild steel in absence of extract and a smooth surface with deposited extract in presence of the Cladophoropsis sundanensis extract. This confirms that the extract inhibited corrosion of mild steel through adsorption of the inhibitor molecules on metal surface [11]. After immersing in the inhibitor containing solution, the entire metal surface was covered with a layer formed with inhibitor as a barrier to corrosion, as denoted by rougher over abrasions.



(a)

(b)

Figure 3: SEM images of: (a) mild steel immersed in 2M NaCl and (b) mild steel immersed in Cladophoropsis sundanensis extract.

3. Results and discussion

3.1 Weight loss study

Inhibition efficiency of environmentally safe Cladophoropsis sundanensis extracts was tested in 2M solution of NaCl solution against mild steel at room temperature by weight loss technique. Results obtained from weight loss measurements are as shown in Table 1. From the obtained result, it is clear that the corrosion of mild steel significantly decreased by the introduction of extract into the corrosive medium [12-13]. The increase of IE seems to be proportional to its corresponding concentration with time [14]. It was revealed that the adsorption and coverage of extract on the surface effectively inhibit corrosion by its bioactive compounds [15]. It has been observed that the corrosion rates of the mild steel in the corroding medium were reduced on addition of different concentrations of the inhibitor.

As it is believed that the action of corrosion inhibitors follows by adsorption on the metal surface by the inhibitor molecules using their adsorption centers, it is important to find out the possible adsorption mechanism by examining the experimental data with possible adsorption isotherms [16]. The surface coverage (θ) was measured for all inhibitor concentrations in NaCl solution that was assessed by weight loss data, and the detailed adsorption behavior was explained. The linear-relationship can be obtained on plotting c/θ as a function of c, with a slope of unity [17]. It was found that the linear correlation coefficients clearly prove that the adsorption of sea weed extract from 2M NaCl solutions on the Mild steel obeys the Langmuir adsorption isotherm, as shown in figure 2.

3.2. Adsorption Parameter

Basic information on the interaction between the inhibitor and the mild steel surface can be proved by the adsorption isotherm and in general, inhibitors can function either by physical (electrostatic) adsorption or chemisorption with the metal. To acquire more information about the interaction between the inhibitor molecules and the metal surface, different adsorption isotherms were tested. A linear-relationship can be obtained on plotting c/θ as a function of c, with a slope of unity [18]. The thermodynamic parameters K and ΔG_{ads} for the adsorption of the studied inhibitors on mild steel is obtained by Langmuir's adsorption isotherm are plotted in Figure 2 and the obtained values are given in Table 2. It was found that the linear correlation coefficients clearly prove that the adsorption of sea weed extract from 2M NaCl solutions on the mild steel corrosion obeys the Langmuir adsorption isotherm. The negative values of ΔG^0_{ads} for the addition of inhibitors indicate that the process of adsorption of studied inhibitors is spontaneous in nature

3.3. Scanning electron microscopy analysis of metal surface

The SEM images of Mild steel specimens immersed in 2M NaCl for four hour and six hour in the absence and presence of extract are shown in Figure 3 image (a) and (b) , respectively. The SEM micrographs of mild steel surface in Figure 3 (a) show the roughness of the metal surface, which indicates the corrosion of surface in chloride medium. The surface observed was very rough and heavily damaged due to metal dissolution [19]. Clear defects and cracks were observed on the corroded surface. However, the presence of inhibitor suppresses the rate of corrosion, and surface damage has been diminished considerably [Figure 3 (b)] as compared to the blank solution [Figure 3(a)], suggesting formation of a protective inhibitor film at the mild steel surface. It can be elucidated that the surface coverage increases, which in turn results in the formation of insoluble complex on the surface of the metal - inhibitor complex, and the surface is covered by a thin layer of inhibitors which control the dissolution of mild steel.

4. Conclusion

1. The inhibition efficiency of Cladophoropsis sundanensis on corrosion of mild steel in 2M NaCl increases on increasing of concentration of the extract. Adsorption of inhibitor molecules of the extract on mild steel surface is found to obey Langmuir adsorption isotherm.
2. The negative values of ΔG^0_{ads} for the addition of inhibitors indicate that the process of adsorption of studied inhibitors is spontaneous in nature and exothermic.
3. Inhibition efficiency values were found to show good trend with weight-loss method studies.
4. Surface morphological studies confirm that corrosion inhibition of mild steel is due to adsorption of the extract on surface.

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