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A novel inhibition of corrosion of Al-SiC composites in acidic medium

V.Umasankar[1], S.Karthikeyan [2*] , M.Anthony Xavier[1]

[1] School of Mechanical & Building Sciences, VIT University, Vellore- 632 014, India.

[2] Surface Engineering Research Lab, Centre for Nanobiotechnology, VIT University, Vellore- 632 014, India.

[2*] corresponding author (skarthikeyanphd@yahoo.co.in)

Abstract

The novel inhibitive effect of N-(4-aminosulphaacetamide) on the corrosion of Al-SiC composites in 1N HCl has been investigated using weight loss, gasometric measurements , potentiodynamic polarization and impedance studies. This study clearly indicated that the compound acted as cathodic inhibitor. Diffused reflectance spectra confirmed the formation of adsorbed film of inhibitor on metal. The adsorption of the compound on composite surface obeyed Temkin's adsorption isotherm. The quantum chemical analysis substantiates the inhibition efficiency of the compound determined by electrochemical methods.

Keywords : Corrosion inhibitor, Thio compounds, Impedance measurements, Adsorption

Introduction

Metal matrix composites (MMC) symbolize as a substitute to conventional materials for the production of high performance materials. The materials can be manufactured in such a way as to exhibit a combination of the characteristics of the metallic matrix and the

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reinforcement phase. The characteristic shape thus developed can be used in machineries. Matrix (Aluminium) and reinforcement(SiC) components have shared interphase, which are absolutely necessary for the fulfillment of the tasks undertaken by the MMCs. Aluminium alloy composite with SiC though results in better strength ,thermal expansion and wear resistance. When these materials are exposed to acidic environment, damaging of machine parts results due to the corrosion of composites. Various methods are used to decrease the corrosion of metal in acidic and salt water environments. Among them, the use of inhibitors is most commonly suggested . Several thiourea derivatives have been identified as effective corrosion inhibitors for mild steel and aluminium[1-5] . In recent years, the inhibition of metal dissolution has been investigated by employing ecofriendly inhibitor. Eno etal [6] and Shukla [7] have reported the inhibitive actions of sparflaxin and cefalexin on the corrosion of steel in acidic media. Karthikeyan and his co investigators [8-9] have studied the influences of cloxacillin and ampicillin drugs as corrosion inhibitors of mild steel in acidic media.

The corrosion inhibiting performances of these compounds are based on their molecular structure. The lone pair of electrons and electron releasing groups determine the adsorption of these molecules on the metal surface. The present paper illustrates the influence of a green inhibitor viz., N-(4-aminosulphaacetamide), SAM on the corrosion of Al-SiC composites in 1N HCl medium using weight loss, gasometric measurements and various electrochemical techniques. Quantum mechanical studies have been used to demonstrate the inhibition performance of the compound is mainly through direct adsorption on the surface of the composites.

Experimental methods

Al-SiC prepared from AA 6061 had the compositions , Fe = 0.19%, Cu = 0.27%, Si = 0.56%, Zn = 0.03%, Mg = 0.94% and Al remainder, and of size 2 cm x 1 were used for weight loss and gasometric studies. The weight loss study was carried out at room temperature for three hours in 1N HCl.

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The inhibition efficiency (IE %) was determined by the following equation,

I.E (%) = (W –Wi /W) X 100

Where W & Wi are the weight loss values in the absence and presence of the inhibitor. Al-SiC cylindrical rod of the same composition as above and implanted in araldite resin with an exposed area of 1cmx 0.5 cm was used for potentiodynamic polarisation and AC impedance measurements. A platinum foil with surface area of 30 mm^2 and $Hg/Hg_2Cl_2/HCl(1N)$ were used as counter and reference electrodes for electrochemical studies using EG&G Princeton Applied research model-7310. Gaussian software was used to calculate the quantum chemical parameters like HOMO, LUMO, energy gap and dipole moment of the compound. The surfaces of corroded and corrosion inhibited Al-SiC panels were examined by diffuse reflectance studies in the region 200- 700 nm using U-3400 spectrometer (UV-VIS-NIR Spectrometer, Hitachi, Japan).

Results and Discussion

Weight loss and gasometric studies:

The results of weight loss and gasometric studies are given in table 1. It was visualized that the dissolution of composite in acid medium is reduced when the concentration of SAM is increased. The maximum corrosion inhibition was obtained at the concentration of 90 ppm of inhibitor. The effective inhibition is due to the adsorption of the compound on the surface of the composite.

Potentiodynamic polarization measurements:

The polarization studies revealed that in the presence of SAM both corrosion potential (E_{corr})and corrosion current(I_{corr}) values have decreased as compared with 1N HCl (table 2). The anodic and cathodic Tafel slopes have been shifted to less negative directions equally, however but the values of b_c are enhanced to greater a extent. So the inhibition of corrosion of Al-SiC composites in acidic medium follows

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cathodic mode of action of SAM as it reduces evolution of hydrogen gas (Figure 1). These results are in good conformity with weight loss and gasometric studies.

Impedance studies:

The Nyquist plots for the dissolution of Al-SiC composites in the presence and absence of different concentration of SAM are given in table 3. It is cleared from figure 2 that perfect semicircles are got for the corrosion inhibition process representing that the reaction follows charge transfer mode. The charge transfer resistance is found as high and it attains maximum value at 90 ppm of SAM ,where as double layer capacitance values is reduced with increased concentrations of inhibitor [10]. This can be ascribed to the effective adsorption of the compound on the surface of Al-SiC composites.

Hydrogen permeation measurements

Hydrogen permeation measurements result for the corrosion of composites in the presence and absence of the inhibitor are given in Table 4.Hydrogen permeation current values for Al-SiC composites in 1N HCl is high , due to the presence of belligerent nature of chloride ions. It can be seen from the table that sulphaacetamide increases the permeation current as its concentration increases.. The enhancement in permeation current can be attributed to the decomposition of the compound on the metal surface [11] and thus evolving H_2S gas[12] . The whole process occurs in two stages. In the first stage, Sulphaacetamide molecules are adsorbed on the metal surface through the interaction of lone pairs of electrons of nitrogen and sulfur atoms. In the second stage, the adsorbed molecules of the compound may slowly undergo chemical modification. As a rule , the sulphur compounds decompose with the formation of H_2S by the action of hydrogen gas evolved on the surface of Al-SiC.

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Diffused Reflectance Studies

UV reflectance studies were carried out using spectrophotometer in different concentrations of inhibitor with composite specimens. The reflectance curves for polished specimen, specimen immersed in 1N HCl and various concentrations of inhibitor are shown in the figure 4. The percentage of reflectance is maximum for polished composite surface and it gradually decreases for the specimen dipped in 1N HCl solution. This study confirms that the change in surface characteristic is due to the corrosion of composites in acidic medium. When compared with blank solution, the reflectance percentage increased as the concentration of the compound increased .This can be attributed to the increase in layer thickness formed on composites [13]. The plot of log.c vs Ø (Figure 5) gave a straight line establishing that the adsorption of inhibitor on metal surface observes Temkin's adsorption isotherm.

Quantum mechanical studies:

The computed quantum chemical parameters like energy of highest occupied molecular orbital (E_{HOMO}), energy of lowest unoccupied molecular orbital (E_{LUMO}), LUMO- HOMO, energy gap (ΔE), dipole moment (μ), are summarized in Table 5. The HOMO and LUMO distribution on amino phenyl moiety (Figure 6-7) is greater than sulphoxide groups of the compound. It has been greatly claimed that, higher the value of E_{HOMO}, greater is the ease for an inhibitor to donate electrons to unoccupied d orbital of metal atom and higher is the inhibition efficiency. Further lower the E_{LUMO}, easier is the acceptance of electrons from metal atom to form feedback bonds. The gap between HOMO-LUMO energy levels of molecules determines the adsorption of inhibitor. Greater the values of energy gap of an inhibitor and dipole moment , greater is the inhibition efficiency of that molecule [14-15].

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Conclusions

1. N-(4-aminophenyl sulphonyl acetamide) retards the dissolution of Aluminium composites effectively in 1N HCl.

2. The inhibition of corrosion of composite in acidic medium , by the compound is under cathodic control.

3. R_{ct} and C_{dl} values obtained from impedance measurements justify the impressive performance of the compound.

4. UV -reflectance studies confirm the mere adsorption of the inhibitor molecule on composite surface .

5. The presence of inhibitor in 1N HCl is found to enhance the entry of hydrogen through Al-SiC surface.

6. The quantum mechanical studies substantiate the effective performance of compound as excellent corrosion inhibitor for Al-SiC composites in acidic medium.

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Table 1. Values of inhibition efficiency for the corrosion of Al/SiC composites in 1N HCl in the presence of different concentrations of SAM obtained from weight loss and gasometric measurements.

Concentration of Inhibitor (ppm)	Inhibition efficiency (%)	
	Weight loss Studies	Gasometric measurements
Blank	---	---
30	74	73.7
60	84	83.9
90	92	92.0

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Table 2: Corrosion kinetic parameters of Al/SiC composites in 1N HCl in the presence of different concentrations of SAM obtained from potentiodynamic polarization studies.

Con. SAM	E_{corr} (mV vs SCE)	I_{corr} (µA cm-2)	b_a (mV dec-1)	b_c (mV dec-1)	IE (%)	θ
1N HCl	-485.17	555.28	89.0	148.3	-	-
30 PPM	-460.23	144.14	73.2	133.2	74.04	0.74
60 PPM	-430.52	93.17	60.1	104.6	83.22	0.83
90 PPM	-419.67	46.19	52.2	90.8	91.6	0.92

Table 3.Impedance values for the corrosion of Al/SiC composites in 1N HClin the presence of different concentrations of N-(4-aminophenyl sulphonyl) acetamide.

Concentration of Inhibitor (ppm)	1N HCl solution	
	Charge Transfer resistance (R_{ct}) Ohm.cm^2	Double layer capacitance (C_{dl}) µF.cm^{-2}
Without inhibitor	46	167
30	132	64.5
60	168.8	42.2

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90	185	19

Table 4. Values of permeation current for the corrosion of Al/SiC composites in 1N HCl in the presence of different concentrations of SAM.

Concentration of Inhibitor (mM)	Steady state permeation current (μA)
	1N HCl
Blank	25.3
30	28.6
60	36.7
90	44.0

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Table 5: Quantum mechanical parameters for the inhibitor

Compound	LUMO (eV)	HOMO (eV)	ΔE (Cal.Mol^{-1})	Dipole moment (Debye)
N-(4-aminophenyl sulphonyl) acetamide	-1.697	-11.258	9.561	5.343

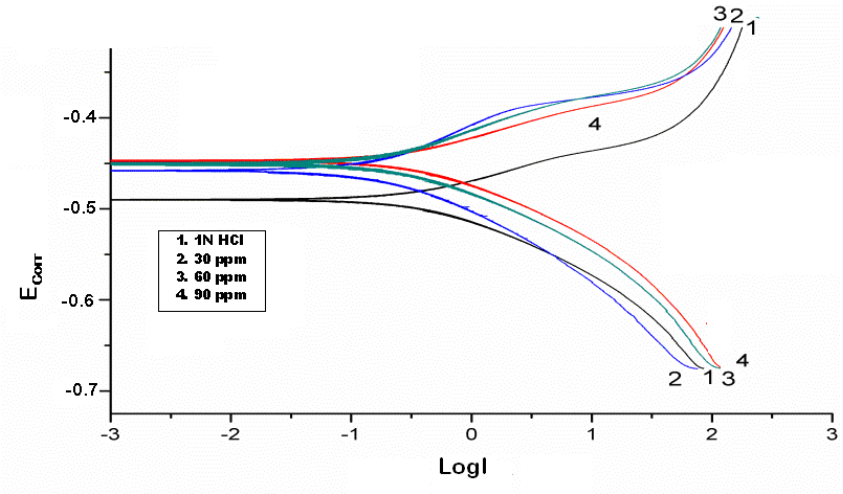

Figure 1

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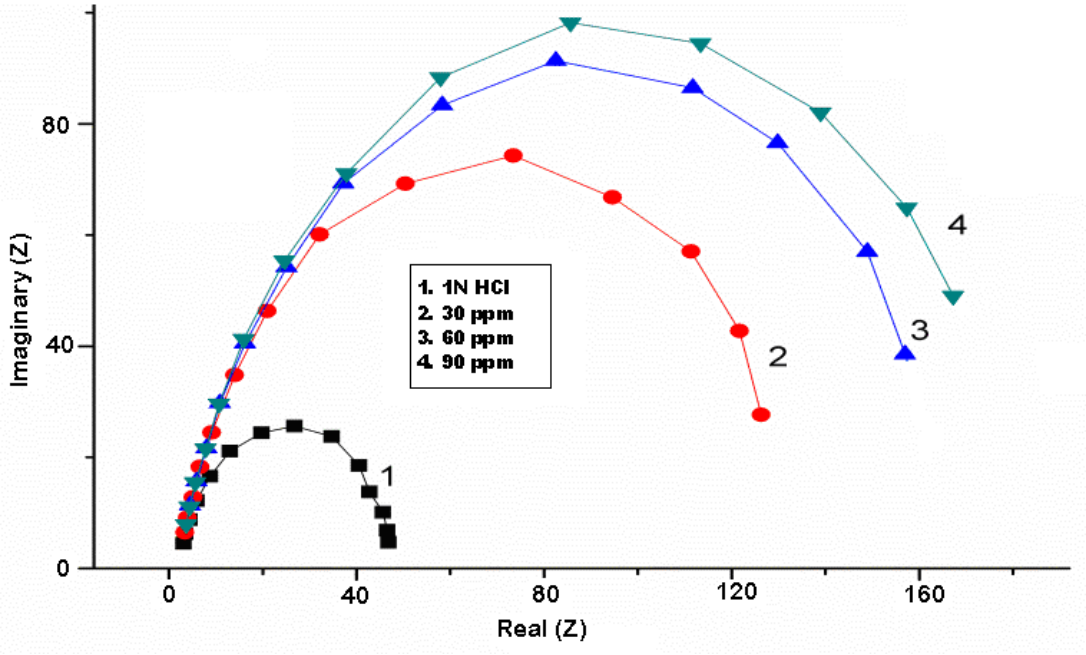

Figure 2.

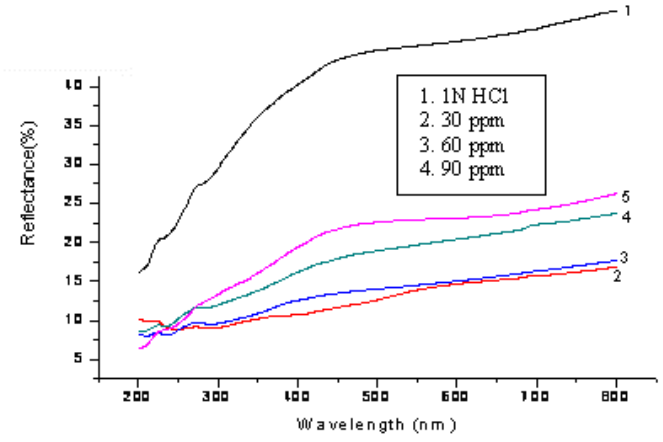

Figure 3

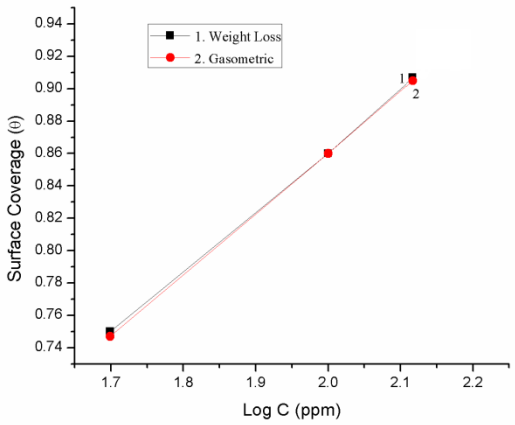

Figure 4

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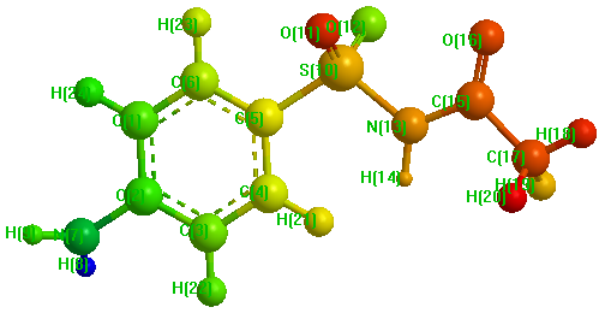

Figure 5

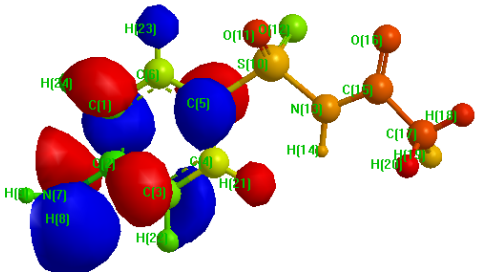

Figure 6

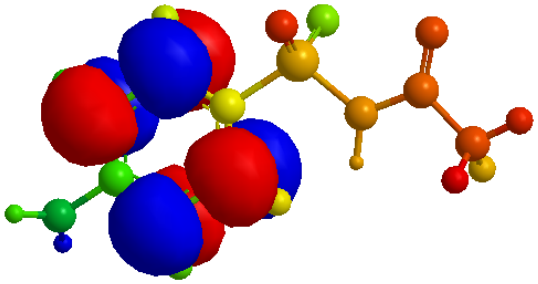

Figure 7

Legends for figure

1. Potentiodynamic polarization plot for Al-SiC composites in 1N HCl with different concentrations of inhibitor.
2. Impedance curves for the corrosion of aluminium composites in 1N HCl in the presence and absence of SAM.
3. UV Reflectance curves for Al-SiC composites in 1N HCl with different concentrations of inhibitor.
4. Temkin's adsorption isotherm for the compound in 1N HCl.
5. Optimized structure of SAM.
6. Highly occupied molecular orbital (HOMO) for SAM.
7. Lowest unoccupied molecular orbital (LUMO) for SAM