International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.3, pp 1109-1113, 2015

A green approach on the corrosion studiesof Al-SiCcomposites in Sea water

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Abstract: The controlled dissolution on the corrosion of Al-Si Ccomposites in sea water (3.5% NaCl) has been investigated using Mass loss, Gasometric measurements, Current-Potential measurements and Impedance studies in the presence and absence of Cefalotin (CFLN) as green inhibitor. This study has confirmed that the compound retarded the dissolution of Al-SiC in sea water environment by acting as mixed inhibitor. Diffused reflectance spectra confirmed the formation of adsorbed film of inhibitor on metal. The adsorption of the compound on composite surface followed Temkin's adsorption isotherm. The quantum chemical analysis validates the inhibition action of the green inhibitor determined by electrochemical methods.
Keywords : Corrosion inhibitor, Thio compounds, Impedance measurements, Adsorption.

Introduction

Metal matrix composites (MMC) signify as a substitute to conventional materials for the production of high performance materials. The materials can be manufactured in such a way as to show a combination of the features of the metallic matrix and the reinforcement phase. The characteristic shape thus established can be used in machineries. Matrix (Aluminium) and reinforcement (SiC) components have shared interphase, which are completely necessary for the contentment of the tasks undertaken by the MMCs.Aluminium alloy composite with SiC as reinforcement , however results in better strength, thermal expansion and wear resistance, when these materials are exposed to marine environment, destruction of machine parts occurs due to the dissolution of composites. Various methods are used to decrease the dissolution of metal in acidic and salt water environments. Among them, use of inhibitors is the most commonly recommended way of controlled dissolution of composites. Thiourea derivatives have been reported as effective corrosion inhibitors for mild steel and aluminium by many researchers [1-5]. In recent years, the inhibition of metal dissolution has been investigated byusing ecofriendly inhibitor. Enoetal [6] and Shukla [7] have reported the inhibitive actions of sparflaxin and cefalexin on the corrosion of steel in acidic media. Karthikeyan et al [8-9] have investigated the effects of cloxacillin and ampicillin drugs as corrosion inhibitors of mild steel in acidic media.

The corrosion inhibiting performances of these compounds are founded on theirelectronic structures. The unshared electrons and electron releasing groups define the adsorption of these molecules on the metal surface. The present paper demonstrates the effect of Cefalotin(CFLN) as a green inhibitor on the dissolution of Al-SiC composites in sea water medium using Mass loss, gasometric measurements and various electrochemical techniques. This antibiotic is a class of β-lactam antibiotics originally derived from the fungus Acremonium which is used in the treatment of infections caused by bacteria . The structure of the Cefalotin inhibitor is given in Fig 1.

Quantum mechanical studies have been used to validate the inhibition effects of the green drug through its unswerving adsorption on the surface of the Al-SiCcomposites.

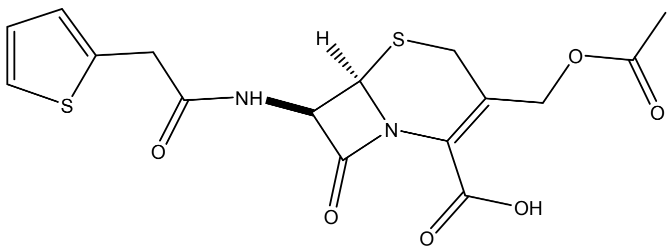

Fig 1.Structure of Cefalotin

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 seawater medium. The inhibition efficiency (IE %) was calculated by the following equation, I.E (%)= (M –Mi /M) X 100

Where M&Mi are the mass loss values in the absence and presence of the inhibitor. Al-SiC cylindrical rod of the same composition as above and embedded in araldite resin with an exposed area of 1cmx 0.5 cm was used for Current-Potential and AC impedance measurements. A platinum foil with surface area of 40 mm^2 and $Hg/Hg_2Cl_2/KCl_{(satd)}$ were used as auxiliary and reference electrodes for electrochemical studies using EG&G Princeton Applied research model-7310. Gaussian software was employed to compute the quantum chemical parameters like HOMO, LUMO, energy gap and dipole moment of the green inhibitor. The surfaces of affected and unaffected Al-SiC specimens were inspected by diffuse reflectance studies in the region 200- 700 nm using U-3400 spectrometer (UV-VIS-NIR Spectrometer, Hitachi, Japan).

Results and Discussion

Mass loss and gasometric studies:

Table 1. Values of inhibition efficiency for the corrosion of Al/SiC composites in sea waterin the presence of different concentrations of CFLN obtained from mass loss and gasometric measurements.

Addition of Green Inhibitor (ppm)	Inhibition efficiency (%)	
	Mass loss Studies	Gasometric measurements
Un inhibited system	---	78.2
40	78	86.6
80	87	97.0
120	97	

The results of Mass loss and gasometric studies are given in table 1. It was visualized that the dissolution of composite in sea water medium is diminished when the concentration of green inhibitor is enhanced. The maximum corrosion inhibition was obtained at the concentration of 120 ppm of inhibitor. The impressive inhibition is due to the adsorption of the CFLN on the surface of the Al-SiC composite.

Currnt-Pontential measurements:

Table 2: Current-Potential results of Al/SiC composites in sea water in the presence of various concentrations of CFLN .

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	-515.32	578.20	92.2	149.o	-	-
40 PPM	-470.24	127.20	70.6	127.6	78.00	0.78
80 PPM	-439.59	75.16	81.3	134.8	87.00	0.87
120 PPM	-413.22	17.34	61.0	102.4	97.00	0.97

The current-potential studies indicated that in the presence of CFLN both corrosion potential (E_{corr}) and corrosion current($I_{corr)}$ values have reduced as compared in their absence when the metal matrix composites are exposed in sea water as given in table 2. The anodic and cathodic Tafel slopes have been shifted to positive direction sin random fashion, however but the values of Cathodic tafel slopes are enhanced to greater a extent. It is evident that the dissolution of corrosion of Al-SiC composites in sea water adapts mixed type fasion and thus it effectively reduces the dissolution of composites and also the evolution of hydrogen gas in sea water medium. These results are in good agreement with results of mass loss and gasometric studies for the performance of CFLN

Impedance results:

Table 3. Impedance values for the dissolution of Al/SiC composites in sea water in the presence of different concentrations of green inhibitor.

Dosage of Green Inhibitor (ppm)	Sea water solution	
	Charge Transfer resistance (R_{ct}) Ohm.cm^2	Double layer capacitance (C_{dl}) µF.cm^{-2}
Un inhibited system	50	155
40	142.2	34.1
80	188.4	20.15
120	235	4.65

The Nyquistre presentations for the dissolution of Al-SiC composites in the presence and absence of different concentration of CFLN are given in table 3. It is understood that perfect semicircles are obtained for the controlled dissolution of composites in the presence of CFLN in sea water demonstrating that the electro kinetic dissolution of composites observe charge transfer reaction. The charge transfer resistance is noted as high and it reaches maximum value at 120 ppm of CFLN, where as double layer capacitance values has diminished with increased concentrations of green compound [10]. This can be attributed to the effective adsorption of the molecule on the surface of Al-SiC composites, when immersed in sea water medium.

Diffused Reflectance Studies

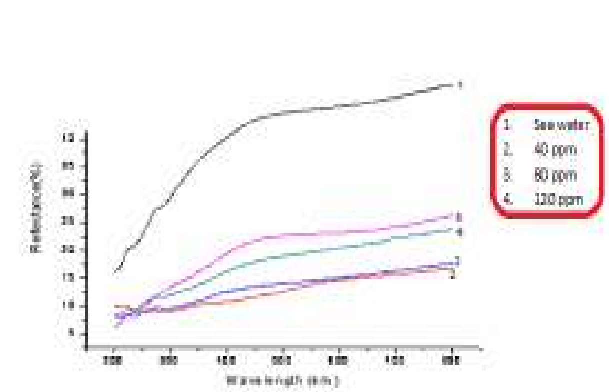

Fig 2.Uv Reflectance Curves for AL-SIC Composites in Sea Water with and without Cefalotin Inhibitor.

UV reflectance studies were carried out using spectrophotometer in various concentrations of CFLN in sea water with composite specimens. The reflectance curves for polished specimen, specimen engrossed in sea water and various concentrations of green compound are shown in the figure 2. The percentage of reflectance is high for polished composite surface and it progressively declines for the specimen dipped in sea water solution. This study ratifies that the change in surface characteristic is due to the corrosion of composites in acidic medium. When compared with uninhibited system, the reflectance percentage increased as the concentration of the compound increased .This can be accredited to the increase in layer thickness formed on composites [11-13]. The plot of log.c vs Ǿ provided a straight line relationship indicating that the adsorption of green compound on Al-SiC surface obeys Temkin's adsorption isotherm.

Quantum mechanical studies:

Table 4: Quantum mechanical parameters for the inhibitor

Green inhibitor	LUMO (eV)	HOMO (eV)	ΔE (Cal.Mol^{-1})	Dipole moment (Debye)
Cefalotin(CFLN)	-3.0837	-7.6598	4.5761	3.912

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 4. The HOMO and LUMO distribution on azabicyclo-Oct-2-ene moieties (Figure 3-4) are greater than thienyllactyl amino moieties of CFLN. It has been prominently claimed that, higher the value of E_{HOMO}, greater is the tendency for an inhibitor to release electrons to unoccupied d orbital of metal atom and lower is the composite dissolution. Further lower the E_{LUMO}, easier is the withdrawl of electrons from composite surface (Al surface) to form feedback bonds. The gap between HOMO–LUMO energy levels of molecules defines 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].

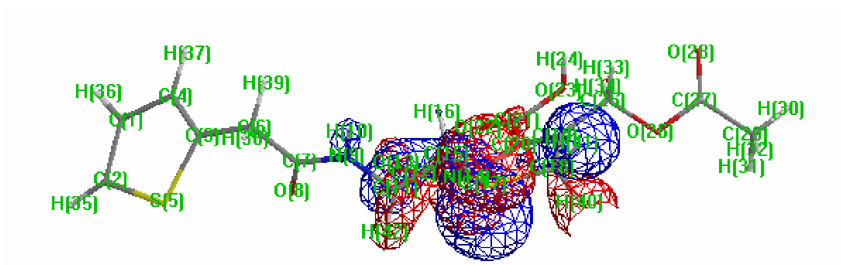

Fig 3. Highest Occupied Molecular Orbital of CFNL

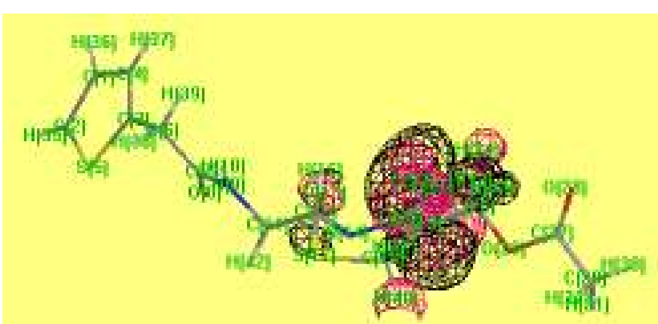

Fig 4. Lowest Unoccupied Molecular Orbital of CFLN

Conclusions

1. Cefalotin inhibitor retards the dissolution of Aluminium composites effectively in sea water medium.
2. The inhibition of corrosion of composite in sea water follows mixed type of electro kinetic reaction.

3. R_{ct} and C_{dl} values obtained from impedance measurements defend the impressive performance of the compound.
4. UV –reflectance studies prove the mere adsorption of the green inhibitor on composite surface.
5. The quantum mechanical studies demonstrate the real performance of green compound as an excellent corrosion inhibitor for Al-SiC composites in sea water.

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