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Research Article

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Inhibition of corrosion of aluminium in an aqueous solution at pH 11 by succinic acid-Zn^{2+} system

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ABSTRACT

The inhibition efficiency of succinic acid in controlling corrosion of Aluminium in an aqueous solution at pH 11, in the absence and presence of Zn^{2+} has been evaluated by weight loss method. The formulation consisting of 250 ppm of succinic acid and 50 ppm of Zn^{2+} has 95% corrosion inhibition efficiency. A synergistic effect exits between succinic acid and Zn^{2+}. The mechanistic aspects of corrosion inhibition have been evaluated by polarization study and AC impedance spectra. In the presence of inhibitor , linear polarization resistance increases ;corrosion current decreases; charge transfer resistance value increases; impedance value increases and double large capacitance decreases . The protective film has been analyzed by SEM and EDAX.

Key words: Corrosion inhibition, Aluminium at pH11, succinic acid, synergistic effect

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INTRODUCTION

Aluminium and its alloys are very good corrosion resistant materials in neutral aqueous solution, due to the formation of passive film. It is well known that pitting corrosion occurs on metals covered with passive films. During pitting corrosion, large parts of the metal surface are covered with a protective film and are in the passive state, while other small parts of the surface are in the active state. Corrosion behaviour of aluminium in various medium has been studied. Several inhibitors have been used to control corrosion of aluminium. To prevent the corrosion of Aluminium in alkaline medium inhibitor such an onion extract (1) and hibiscus rosasinensis (2) have been used. The inhibition effect of some phenyl sulfonylacetophenoneazo derivatives (PSAAD) on the corrosion of Al in 0.5 M HCl solutions has been studied by potentiodynamic polarization, electrochemical impedance spectroscopy, and electrochemical frequency modulation. The results obtained showed that the addition of the PSAAD inhibits the hydrochloric acid corrosion of Al. Potentiodynamic polarization measurements showed that the PSAAD act as mixed type inhibitors but predominately act as cathodic inhibitors. The inhibition efficiency increases with increasing the PSAAD concentration, but decreases with increasing temperature. A kinetic model and the Langmuiradsorption isotherm fit the experimental data well. A good correlation was found between the theoretical data and the experimental results.(3) The effect of imidazole derivatives on the inhibition of aluminum corrosion in 0.5 M HCl has been studied using potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and electrochemical frequency modulation (EFM) measurements. The results showed that all imidazole derivatives are good inhibitors. Polarization curves demonstrated that the imidazole derivatives were of mixed-type inhibitors. The adsorption of each inhibitor on aluminum surface obeys Frumkin adsorption isotherm. Surface morphology studies were done using scanning electron microscopy (SEM) to characterize the film formed on aluminum surface. Quantum chemical calculations show that imidazole derivatives can adsorb on the aluminum surface through the nitrogen atoms as well as π-electrons in the imidazole ring.(4) Inhibition properties of sodium metabisulfite ($Na_2S_2O_5$) on pitting corrosion of 6061aluminum alloy, in 5×10^{-2} M Nacl solution of pH near 7.2 at 298 K, were characterized using open circuit potential, polarization resistance, cyclic and chrono-amperometric polarization measurements. In addition, scanning electron microscopy coupled with energy dispersive spectroscopy and X-ray photoelectrons were employed. Sodium metabisulfite acted as a cathodic-type corrosion inhibitor. The passivation range and the polarization resistance increased with($Na_2S_2O_5$) concentration. The inhibition effects were also reflected through the substantial reduction of both the rate of pit nucleation and the current rise characterizing the pit propagation progress. The SEM-EDS and XPS analyses revealed the formation of a passive film, which contains sulfur atoms.(5) The effects of 0.3 wt.% Al added to flowing liquid zinc on the corrosion inhibition and erosion-corrosion interfacial characteristics of Fe-3.5 wt.% B alloy were investigated in order to separate the pure erosion rate from the total erosion-corrosion rate and further study the erosion-corrosion interaction created by flowing zinc. The result indicated that the erosion-corrosion rate increased slowly and then sharply thereafter, while the corrosion-inhibition rate increased linearly and slowly at a bath temperature of 460-550 °C.(6) The inhibition effect of 3-(12-sodiumsulfonate dodecyloxy) aniline monomeric surfactant (MC12) and its analog polymer Poly 3-(dodecyloxy sulfonic acid) aniline (PC12) on the corrosion of aluminum in 0.5M Hcl solution was investigated using weight loss and potentiodynamic polarization techniques. The presence of these two compounds in 0.5M Hcl inhibits the corrosion of aluminum without modifying the mechanism of corrosion process. It was found that these inhibitors acted as mixed-type inhibitors with anodic predominance as well as the inhibition efficiency increases with increasing inhibitor concentration, but decreases with raising temperature. Langmuir and Frumkin adsorption isotherms fit well with the experimental data. Thermodynamic functions for both dissolution and adsorption processes were determined. The obtained results from weight loss and potentiodynamic polarization techniques are in good agreement with contact angle measurements.(7) A simple and low-cost method to render 6061 aluminum alloy surface superhydrophobicity and excellent corrosion inhibition hasbeen developed. The superhydrophobic aluminum alloy surface has been fabricated by hydrochloric acid etching, potassium permanganate passivation and fluoroalkyl-silane modification.(8) Nithya et al., have used an aqueous extract of beetroot to prevent the corrosion of aluminium in an aqueous solution at pH 11 .(9) The present work is undertaken to evaluate the inhibition efficiency of succinic acid in controlling corrosion of aluminium immersed in an aqueous solution at pH 11, in the absence and presence of Zn^{2+} using the mass loss method to study the mechanistic aspects of corrosion inhibition by potentiodynamic polarization and AC impedance spectra.

EXPERIMENTAL SECTION

2.2. Preparation of specimens
Commercial aluminium specimens of dimensions 1.0 x 4.0 x 0.2cm, containing 95% pure aluminium were polished to mirror finish, degreased with trichloroethylene, and used for the Mass-loss method .

2.3. Weight loss method
Three aluminium specimens were immersed in 100mL of the solution at pH 11 and various concentrations of the inhibitor in the absence and presence of Zn^{2+} for a period of 1 day. The weight of the specimen before and after immersion was determined using shimadzu balance AY62.Inhibition efficiency (IE) was calculated from the relationship.

$$IE = 100\ [1-W2/W1)]\ \%$$

Where W1 and W2 are the corrosion rates in the absence and presence of the inhibitor, respectively.

2.7. Potentiodynamic polarization study
Polarization study was carried out in a CHI electrochemical work station impedance analyzer model CHI660A. A three electrode cell assembly was used. Aluminium was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode. The corrosion parameters such as linear polarization Resistance. (LPR), corrosion potential, Ecorr, corrosion current, Icorr, and Tafel slopes (ba and bc) were measured.
2.8. Alternating current impedance spectra

AC impedance spectra were recorded in the same instrument used for polarization study, using the same type of three electrode cell assembly. The real part (Z') and imaginary part (Z") of the cell impedance were measured in ohms for various frequencies. The charge transfer resistance (Rt) and double layer capacitance (Cdl) values were calculated.

RESULTS AND DISCUSSION

3.1. Analysis of result of weight loss method
The corrosion rate of aluminium in an aqueous solution at pH 11 (dil NaOH) in the absence and presence of inhibitors obtained by weight loss method are given in Table 1. The inhibition efficience are also given in this table.

Table 1: Corrosion rates of Aluminium in an aqueous solution at pH 11 (dil NaOH),in the absence and presence of inhibitor system and the inhibition efficiencies (IE) obtained from weight loss method

Inhibitor system : succinic acid (SA)and Zn^{2+}

succinic acid ppm	Zn^{2+} system ppm	Corrosion rate mdd	Inhibition efficiency %
0	0	25.64	--
50	0	-11.50	55
100	0	-9.74	62
150	0	-8.20	68
200	0	-7.69	70
250	0	-7.17	72

Table 2: Corrosion rates of Aluminium in an aqueous solution at pH 11 (dil NaOH),in the absence and presence of inhibitor system and the inhibition efficiencies (IE) obtained from weight loss method

Inhibitor system : succinic acid (SA) and Zn^{2+}

succinic acid ppm	Zn^{2+}system ppm	Corrosion rate mdd	Inhibition efficiency %
0	50	25.64	--
50	50	7.94	69
100	50	6.41	75
150	50	5.64	78
200	50	4.61	82
250	50	3.84	85
0	50	21.79	15

3.2. Influence of Zn^{2+} on the inhibition efficiency of succinic acid(SA)

The influence of Zn^{2+} on the IE of SA is given in Table 1. In the presence of Zn^{2+} (50ppm) excellent inhibitive property is shown by SA. A synergistic effect exists between SA and Zn^{2+} for example , 2mL of SA has 92% IE, 50ppm of Zn^{2+} has 13% IE.But their combination has 98%.

3.3. Influence of N-Cetyl N,N,N-trimethylammonium Zn^{2+} (50ppm) system.

The influence of CTAB on the inhibition efficiency of SA(250ppm)-Zn^{2+} (50ppm) system is given in Table 2. It is interesting to find that the IE of the SA - Zn^{2+} system is not changed by the addition of CTAB. CTAB is a biocide .It can control the corrosion caused by inhibition efficiency. It is expected that this formulation will have excellent biocidal efficiency also.

3.4. Analysis of polarization curves

The potentiodynamic polarization curves of aluminium immersed in various solutions at pH 11 are shown in Fig1. The corrosion parameters such as corrosion parameters such as corrosion potential ($E_{corr)}$, corrosion current (I_{corr}), tafel slopes ($b_{a,}$ b_c) and linear polarization (LPR) are given in Table 3.When aluminium is immersed in an aqueous solution at pH 11, the corrosion potential is -649 mV vs SCE. When the inhibitors are added, (250ppm of SA and 50ppm of Zn^{2+}) the corrosion potential shifted to anodic side (-557mV vs SCE). Further LPR value increases from 2256 to 302028 and corrosion current decreases from 2.6855 10^{-7} A/cm^2 to 1.33x 10^{-7} A/cm^2. These results suggest that a protective film is formed on the metal surface .This protects the metal from corrosion.

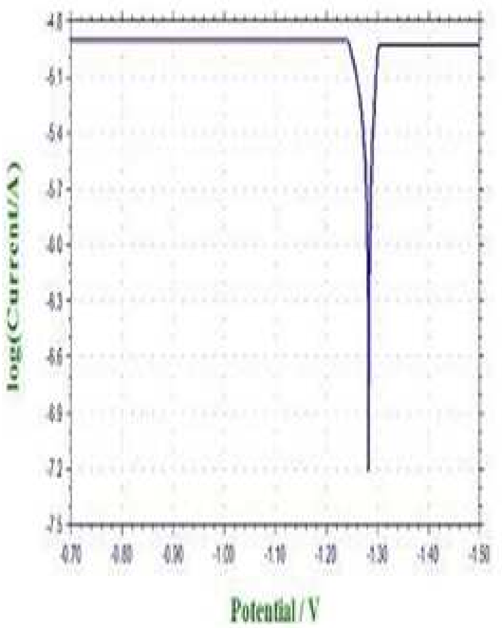
Table 3: Corrosion parameters of Aluminium immersed in an aqueous solution at pH 11 (dil NaOH),in the absence and presence of inhibitor system obtained from polarization study

Inhibitor system : succinic acid (SA)and Zn^{2+}

SA ppm	Zn^{2+} ppm	Ecorr mV vs SCE	bc mV	ba mV	LPR Ohm cm^2	I corr A/cm^2
0	0	-1.283	203	107	2256	$2.6855x10^{-7}$
250	50	-0.963	261	143	302028	$1.33x10^{-7}$

3.5. Analysis of AC impedance spectra

AC impedance spectra (electrochemical impedance spectra) have been used to confirm the formation of protective film on the metal surface . If a protective film is formed on the metal surface , charge transfer resistance (Rt) increases and double layer capacitance value (C_{dl}) decreases (10 -17).



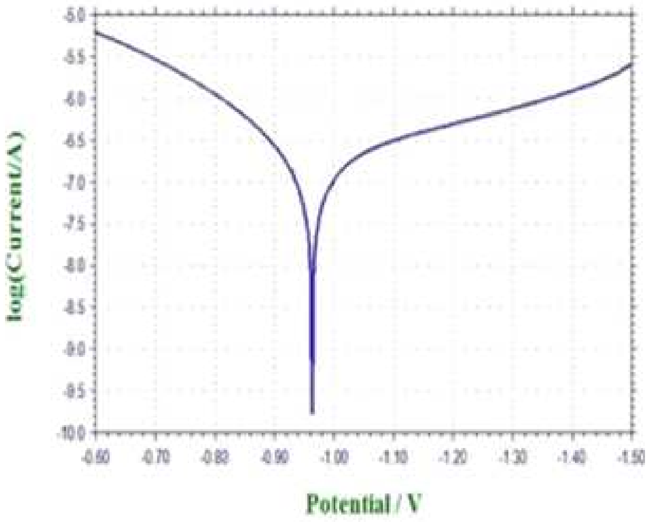


Fig 1: Polarization curves of aluminium immersed in an aqueous solution at pH 11

Fig 2: Polarization curves of Al immersed in an aqueous solution in presence of SA 250ppm and Zn^{2+} 50ppm

The AC impedence spectra of aluminium immersed in various solution are shown in figure 3 and 4. The AC impedence spectra such as charge transfer resistance (Rt), double layer capacitance value (C_{dl}) derived from Nyquist and Bode plots are given in Table 4.When aluminium is immersed in an aqueous solution at pH 11, the charge transfer resistance R_t is 309 ohm cm^{2}, the double layer capacitance $\mathbf{C_{dl}}$ is 1.618×10^{-8} F/cm^2 . When the formulation consisting of SA and Zn^{2+} is added , the R_t, value increases and C_{dl} value decreases. This confirms that a protective film is formed on the metal surface. This decreases the corrosion rate of aluminium and increases the inhibition efficiency.

Table 4:Corrosion parameters of Aluminium immersed in an aqueous solution at pH 11 (dil NaoH),in the absence and presence of inhibitor system obtained from AC impedance spectra

Inhibiton system :Succinicacid (SA) and Zn^{2+}

SA Ppm	Zn2+ ppm	Rt ohm cm2	Cdl F/cm2	Bode plot Impedance log(z/ohm)
0	0	309	1.618×10^{-8}	2.686
250	50	1185	0.4219×10^{-8}	3.182

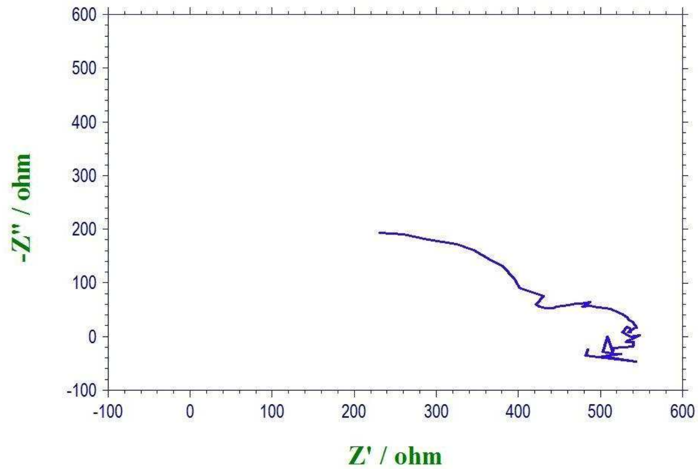


Fig 3:AC impedance spectra of aluminium immersed in an aqueous solution at pH 11 (Nyquist plot)

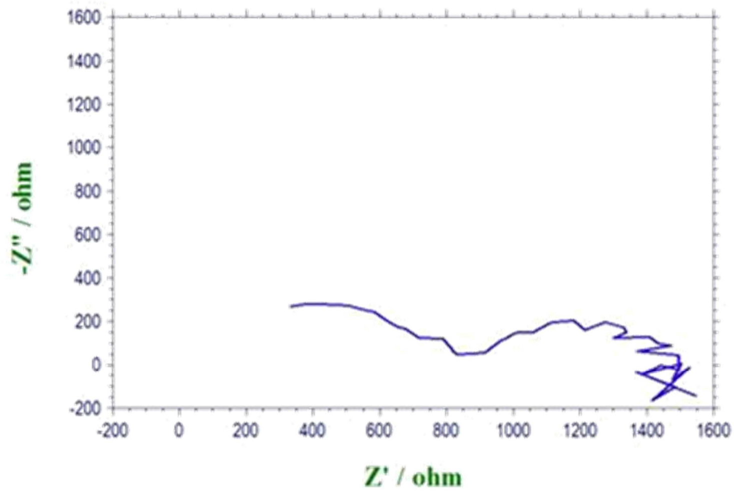


Fig 4:AC impedance spectra of aluminium immersed in an aqueous solution +SA 250ppm + Zn^{2+} 50ppm at pH 11(Nyquist plot)

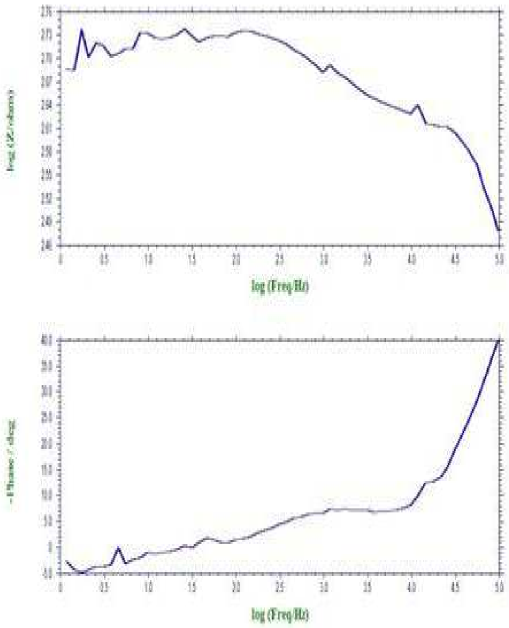


Fig 5:AC impedance spectra of aluminium immersed in an aqueous solution at pH 11 (Bode plot)

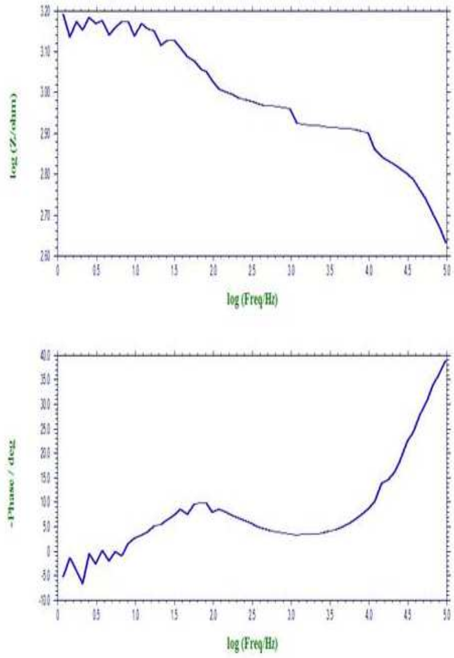


Fig 6:AC impedance spectra of Al immersed in an aqueous solution in presence of SA 250+Zn^{2+} 50ppm

CONCLUSION

The present study lead to the following conclusions Inhibition efficiency of succinic acid in controlling corrosion of aluminium in distilluted water in the absence and presence of Zn^{2+} has been evaluated by AC impedance spectra reveal that the protective film consists of Al^{3+} and succinic acid complex.

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