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Corrosion inhibition performance of different bark extracts on aluminium in alkaline solution

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Abstract The present work shows the effect of stem bark extracts of three trees namely *Moringa oleifera* (MO), *Terminalia arjuna* (TA) and *Mangifera indica* (MI) on the corrosion behaviour of Aluminium Alloy (AA) in 1 M NaOH. The inhibition performance was studied by using gravimetric, potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) measurements. Among these extracts, MO exhibited the maximum inhibition efficiency η (%) of 85.3% at 0.6 g/L at 303 K. Polarization measurement showed that all the examined extracts are of mixed-type inhibitors. Langmuir's adsorption isotherm was found to be best fit. Morphology of the surface was examined by scanning electron microscopy (SEM) and atomic force microscopy (AFM) which confirmed the existence of a protective film of inhibitor molecule on AA surface.

1. Introduction

Aluminium and its alloys are finding wide applications in various industries such as automotive, aerospace, construction and electrical power generation due to high energy density (8.1 kWh kg^{-1}) and an electrode potential of 2.35 V vs. simple hydrogen electrode (SHE) in alkaline medium. Alkaline solution is most corrosive in nature for aluminium than the other corrosive media. Therefore, it is desirable to study the corrosion and protection of aluminium in alkaline medium. The corrosion resistance of aluminium depends on the presence of natural surface oxide film and stability. It is reported that due to the presence of OH^- ion protective oxide film dissolves in alkaline solution and negative potential develops on the aluminium surface (Abiola and Otaigbe, 2008). In the development of the aluminium anode for the aluminium/air battery, the corrosion behaviour of pure aluminium and its alloys has been extensively studied in aqueous alkaline solutions, that's why self-corrosion can cause not only a lower utilization efficiency of aluminium, but also possible battery explosion as a result of hydrogen build up (Oguzie, 2007). Plenty of organic and inorganic compounds have been used by various researchers as corrosion inhibitors to protect the dissolution of this oxide film (Abdel-Gaber et al., 2008) and thus reducing the rate of metal loss in alkaline medium. Most of the compounds are synthetic chemicals which are expensive and hazardous to the environment. Thus it is desirable to choose a very cheap and environmentally safe inhibitor to diminish the self-corrosion rate of aluminium in alkaline solution.

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For this purpose, the natural products of plant origin are a better choice because they are environmentally benign and contain incredibly rich source of naturally synthesized organic compounds in which most are known to have inhibitive action that can be extracted using simpler techniques with low cost. There are few studies available on the use of plant extract as corrosion inhibitor for aluminium in alkaline medium (Abiola and Otaigbe, 2009; Abdel-Gaber et al., 2008; Chaubey et al., 2015). In the present work, we have selected the aqueous extract of the bark of MO, TA and MI for the corrosion inhibition study on AA in 1 M NaOH solution by using gravimetric, potentiodynamic polarization and electrochemical impedance spectroscopy measurement respectively. The experimental results were supported by SEM and AFM investigations.

2. Materials and methods

2.1. Specimen and test solution

Corrosion tests were performed on AA specimens of following composition (wt.%): Si = 0.77, Fe = 0.93, Cu = 0.02, Mn = 0.11, Mg = 0.01, Zn = 0.01, Cr = 0.05, Ti = 0.02, V = 0.01, Ga = 0.01 and remainder Al. The aggressive solution of 1 M NaOH is prepared by dissolving 40 g of sodium hydroxide pellets in 1000 ml of double distilled water.

2.2. Preparation of bark extracts solution

MO, TA and MI tree barks were collected and dried in shade. 5 g of dried bark powder was taken in 500 ml of NaOH in a round bottom flask and refluxed for 3 h. The solution was allowed to stand for some time and then filtered. The volume of the filtrate solution was maintained up to 100 ml, which was used as stock solution of inhibitors. After that, the residue of all barks was dried and weighed and taken in different concentrations for the experiment.

2.3. Gravimetric measurement

The dimension of AA coupon used in the gravimetric study is 2.5 × 2.0 × 0.043 cm. Silicon carbide papers with grade 600, 800 and 1000 were used for abrasion of AA coupons and finally degreased with acetone and dried at room temperature. The gravimetric measurement was carried out in the temperature range of 303–333 K, with an immersion period of 3 h. The corrosion rate (C_R) and inhibition efficiency (η%) was calculated using the following equations :

$$C_R = \frac{K \times W}{A \times T \times D} \quad (1)$$

$$\eta\% = \frac{w_0 - w_i}{w_0} \times 100 \quad (2)$$

where K is constant (87.6×10^4), T is the exposure time in hours (h), A is the area of a coupon in cm^2, W is the weight loss in gram (g), D is the density of AA in g/cm^3, w_0 and w_i are the weight loss in the absence and presence of inhibitors, respectively.

2.4. Electrochemical experiment

The dimension of AA coupons used for the electrochemical study is 7.0 × 1.0 × 0.043 cm. Electrochemical measurement was carried out by using Gamry Potentiostat/Galvanostat (Model 300) at 303 K. Three electrode cell assemblies were used for this measurement, in which AA, calomel and platinum foil were used as working, reference and counter electrodes respectively. For data fitting Echem Analyst (version 5.0 software) packages were used. EIS measurements were performed in the frequency range 10^6–10^{-2} Hz using AC signals of amplitude 10 mV peak to peak at open circuit potential.

Potentiodynamic polarization curves were obtained by changing the electrode potential automatically from −0.25 V to +0.25 V vs. OCP at a scan rate of 1 mV/s. The anodic and cathodic curves of the linear Tafel plots were extrapolated to obtain corrosion current densities (i_{corr}). All the experiments were measured after immersion of AA for 15 min in 1 M NaOH in the absence and presence of inhibitors.

2.5. Surface analysis

AA coupons of size 2 × 2.5 × 0.046 cm were immersed in 1 M NaOH in the absence and presence of inhibitor for 3 h at 303 K. The inhibited system contains optimum concentration (0.6 g/L) of MO, TA and MI barks. FEI Quanta 200F microscope model was used for SEM at an accelerating voltage of 5000 V and 5KX magnification. The AFM was performed using NT-MDT multimode, Russia, controlled by solver scanning probe microscope controller.

3. Results and discussion

3.1. Gravimetric measurements

3.1.1. Effect of inhibitor concentration

The inhibition efficiencies with different concentrations of barks are compiled in Fig. 1. It can be seen from Fig. 1 that gradually increased inhibitor concentration increases the percentage inhibition efficiency (η%). The inhibitive action of the inhibitor is due mainly to the presence of Hetero atoms such as oxygen, nitrogen and aromatic rings with π-bonds in

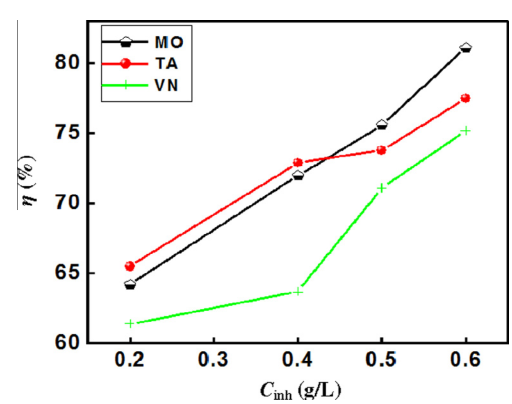

Figure 1 Variation of inhibition efficiencies (η%) with concentration of bark extracts for AA in 1 M NaOH.

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