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A comparative analysis on the effects of sodium nitrate and hexamine on the corrosion of aluminium alloy in an acidic environment

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Abstract

Despite aluminium and its alloys being relatively resistant to corrosion reaction as a result of their passivating tendencies, aluminium alloys usually succumb to acidic attacks resulting in mostly pitting corrosion. This study is focused on comparing the efficiency of sodium nitrate with that of hexamine on the acid corrosion of aluminium when used individually as inhibitors in 1 M Hydrochloric acid. The gravimetric method was used for the corrosion study. Sodium nitrate was found to have higher inhibitor efficiency of 94% compared to that of hexamine (44%), positioning the former as a better inhibitor for aluminium alloy in 1 M HCl. ΔG_{ads} was evaluated and the obtained Standard free energy of adsorption were in the range of -13 to

-17 kJ/mol for NaNO_3 and -6 to -12 kJ/mol for hexamine, signifying the physisorption mode of adsorption.

Introduction

Aluminium is used extensively in various areas of the industrial sector. Due to its non-toxic properties, it is used as a package for non-perishable food to be sold to consumers. It is also applied in the building of aircraft, and car parts, and due to its lightweight property, it is applied to a large extent by the National Aeronautics and Space Administration (NASA) in building spacecraft [1], [2]. Aluminium has various advantageous properties including strength, lightness, corrosion resistance, formability, and recyclability which are combined for an increasing number of applications ranging from structural materials to thin packaging foils [3]. The three main properties of aluminium that form the basis on which it is applied in various capacities in the engineering sphere are its low density of about 2.7 g/cm^3 , its ability to attain high mechanical strength by suitable alloying and heat treatments, and finally, its relatively high corrosion resistance [4].

Pitting corrosion of aluminium and its alloys occur as a result of their passivating tendencies, when exposed to acid solutions [1]. The chloride anion which is present in hydrochloric acid is responsible for an aggressive localized attack on various metals including aluminium. The pitting corrosion of aluminium, just like any other localized corrosion form, is dependent on the size, characteristic properties as well as distribution of inter-metallic compounds [5].

Generally, almost all features of a metal-environment system are involved in the occurrence of pitting corrosion. In this specific case, aluminium pitting in chloride solution is a function of the chloride concentration and temperature in the system besides from the identity, composition, and micro-structural characteristics of the aluminium metal. The related repassivation or protection potential, as well as the pitting potential, are factors that can affect the degree of pitting in chloride solutions [6]. Using inhibitors would help to limit the effect of the hydrogen-corrosive environment on aluminium and its alloy during exposure. Corrosion inhibition performance of 5-(3-Pyridyl)-4H-1,2,4-triazole-3-thiol on aluminium alloy AA6061 in 0.1 M HCl solution was tested by the weight loss method, potentiodynamic polarization and electrochemical impedance spectroscopy. The results indicated that with an increase in the concentration of the inhibitor and temperature the inhibition efficiency also increased. The adsorption of a Cl on oxidized copper is a complex process due to the fact that surface oxide atoms can be partially hydrated and hydroxylated. When triazoles are adsorbed, their donor atoms can replace water or hydroxyls on the surface of copper oxide or, if the molecule has a planar symmetry, it can be parallel to the oxide plane due to π -interactions [7], [8], [9], [10], [11].

Inhibitors do not completely stop the corrosion process but rather have the effect of delaying the initial onset of corrosion thereby reducing its rate in a corrosive environment. Also, the "multifactor" nature of the corrosion process has a great complicating effect on the theoretical choice of a corrosion inhibitor that would be effective in all conditions. It often involves very careful experimental studies and this results in unwarranted uncertainty regarding the fundamental character of the physical chemistry related to the development and study of corrosion inhibitors [12]. There are

two classifications of inorganic corrosion inhibitors which are the anodic and cathodic inhibitors. The anodic inhibitors which are also known as passivation inhibitors carry out the process of passivation by facilitating a reduction reaction in which it blocks the anodic reaction and supports the natural reaction of passivation on the metal's surface. Examples of anodic inhibitors include but are not limited to nitrates, sodium chromates, phosphates, and silicates [13]. In basic and neutral solutions and with quantities of up to 0.1 M, sodium nitrate has an inhibitive effect on the corrosion of steel.

Hexamine (Hexamethylene tetramine) is a white heterocyclic organic chemical compound that has been known for over a hundred years. It is produced by the reaction of ammonia with formaldehyde [14]. It is universally used in small quantities mainly for the production of explosives but in recent times, it has gained increased popularity in engineering industries as an organic corrosion inhibitor for metals like aluminium, mild steel, cast iron, and many others in both acidic and aqueous solutions [15], [16], [17], [18], [19], [20].

Consequently, this study aims to compare the inhibiting effects of sodium nitrate, an inorganic inhibitor, and hexamine, an organic inhibitor on the corrosion degradation of aluminium alloy immersed in 1 M Hydrochloric acid.

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Section snippets

Methodology

The material used for the experiment in this study was aluminium alloy purchased from the open market in Ota, Nigeria. The composition of the aluminium alloy is shown in Table 1.

Reagents used for the immersion test include distilled water (H_2O); 1 M hydrochloric acid (HCl); sodium nitrate ($NaNO_3$) at various concentrations (from 2% to 8%) and hexamine ($C_6H_{12}N_4$) at various concentrations (from 2% to 8%). The structure of hexamine is shown in Fig. 1 and the structure of sodium nitrate is shown in

Corrosion rate of aluminium alloy in HCl environment

The graphical representation in Fig. 3 shows the changes in corrosion rate over time by the aluminium alloy samples immersed in 1 M HCl acid environments containing various concentrations of $NaNO_3$ as an inhibitor. From the data analysis, the corrosion rates of the samples in the various $NaNO_3$ concentrations all showed reduced corrosion rates over time. Nevertheless, at the end of the 60-days (1440 h) immersion period, the solution with the 8% inhibitor had the least rate of corrosion of

Conclusion

From the study, the following conclusions can be drawn. Corrosion rates in the environment containing 8% corrosion inhibitor reduced consistently over time while that of the control increased consistently over the period. NaNO₃ inhibitor performed better than hexamine by yielding the highest inhibitor efficiency of 94%. Inhibition efficiency increased significantly for the sodium nitrate concentrations unlike the hexamine inhibitor. ΔG_{ads} values obtained indicate the physisorption mode of

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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