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RESEARCH PAPER

CORROSION BEHAVIOR OF Al/SiC/PKSA HYBRID COMPOSITES IN 1.0 M H_2SO_4 ENVIRONMENT USING POTENTIODYNAMIC POLARIZATION TECHNIQUE

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ABSTRACT

The potentiodynamic polarization of aluminium 6063 alloy reinforced with silicon carbide (SiC) and palm kernel shell ash (PKSA) particulates at various mixing ratios was investigated. Double stir casting method was adopted for the production of the hybrid reinforced composites. The existence of the reinforcements within the matrix alloy acted as active sites for corrosion initiation. Hence, pitting corrosion was observed. The range of values for E_{corr} and I_{corr} obtained at 24 h in 1.0 M H_2SO_4 were between -627.74 and -644.46 mV, and between 423.81 and 860.23 μA/cm^2, respectively. The E_{corr} values ranged from -654 to -697.22 mV, and the I_{corr} ranged from 1075.65 to 3057.16 μA/cm^2 at 72 h in 1.0 M H_2SO_4. The relative resistance to corrosion of the samples is dependent on the thin oxide film formed on the surface of the samples.

Keywords: Corrosion; Corrosion studies; metal matrix composites; potentiodynamic polarization; PKSA; metallic composites

INTRODUCTION

The focus of several studies in recent years has been the development of advanced engineering materials for several applications in different industries such as automobile, aviation, building, marine, and so on [1-5]. Metal matrix composites are categorized as advanced engineering materials [6–10]. Some of the metals involved in the development of metal matrix composites (MMCs) are aluminium, magnesium, titanium, copper, and so on. However, aluminium is the most researched metal matrix because of its admirable physical and mechanical properties [11-15]. Hybrid or monolithically reinforced aluminium matrix composites have exhibited various improved physico-mechanical properties [15–17]. Corrosion is a process that is continuous and could be tasking to control and terminate. Hence, this destructive phenomenon tends to occur in practically all environments. The environment and the nature of the metal are among the factors that influence corrosion behaviour of the material [18]. Conversely, the inclusion of foreign particulates as reinforcements in aluminium matrix influences its behaviour in a corrosive environment [4]. The corrosion behaviour of the composites is altered due to the physical and electrochemical interactions of the secondary reinforcing particulates through pits initiation within the metal matrix resulting in accelerated corrosion [4,19]. The utilization of MMCs in aggressive environments requires the assessment of the corrosion behaviour of the MMCs in a simulated accelerated environment. This is a relevant parameter to be determined before the conclusion on the use of the produced MMCs [20]. The inclusion of multi-wall carbon nanotube (MWCNT) as reinforcement in AA5083 matrix alloy alters the corrosion resistance of the matrix in HCl solution with an increase in the corrosion resistance [21]. Haridas et al. [6] examined the corrosion behaviour of Al6063 composites reinforced with SiC and rice husk ash (RHA) particulates at different ratios in $AlCl_3$ solution. More so, aluminium alloy composites reinforced with seashell were subjected to corrosion in an acidic and alkaline media. The seashell inclusion in the matrix improved the corrosion resistance of the composite [22].

The corrosion behaviour of hybrid reinforced Al6063 composites with SiC and palm kernel shell ash (PKSA) particulates in corrosive media has not been studied. Previous studies have investigated the physico-mechanical properties and wear properties of the produced composites [8,15,23, 24] and concluded that they are best utilized in light-weight applications in building construction (roofing sheets) and automobile body parts. The corrosion study of MMCs is important to determine the susceptibility of the metal matrix to degradation in a corrosive environment. Therefore, this current study examined the potentiodynamic polarization of synthesized AMCs in 1.0 M H_2SO_4 solution. The corrosion environment is utilized in determining the suitability of the MMCs produced in aggressive areas. Hence, a simulated acidic rain environment was utilized to test the behaviour of the MMCs produced in the solution.

MATERIAL AND METHODS

In this study, Aluminium alloy (Al6063) is the metal matrix used and it was obtained from an aluminium producing industry in Lagos, Nigeria. The alloy is 98% pure Aluminium with some other elements such as Si (0.43%), Fe (0.17%), Mg (0.48%), Mn (0.04%), Ti (0.02%), Cu (0.01%), Zn (0.01%), Cr (0.01%, and Sn (0.01%). The hybrid reinforcing materials were silicon carbide (SiC) with 99% purity, and palm kernel shell ash (PKSA) particulates. The PKSA was obtained from palm kernel shell (PKS) as reported in our previous studies [3,8].

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The chemical compositions of the PKSA are reported by [3]. The designation of the composites produced is shown in **Table 1**. The production technique used was through the double two-stir casting method as illustrated by several authors [24-26].

The sample from each composition in **Table 1** was cut to dimension (Ø30 mm × 3 mm). Each sample was ground using different grit sizes between 240 and 1000 SiC paper before being cleaned with acetone, then washed with water and dried. Accelerated electrochemical studies were done on the synthesized composite using the potentiodynamic method. The potentiodynamic measurements were made in the 1.0 M H_2SO_4 solution at 25ºC using Autolab PGSTAT 302N equipment. The samples with an active surface of 1 cm^2 were polished and cleaned before placing them in the measurement vessel. The working electrode is the composite sample, the counter electrode is platinum, and the reference electrode is silver/silver chloride. The equipment was allowed to run for about 30 min to achieve the corrosion potential (E_{corr}) required for the experiment, then the anodic polarization curves were recorded with an automatic potential shift at a rate of 10^{-3} V. The polarization measurements were carried out from -1.5 V to +1.5 V at a scan rate 0.0016 V/s according to ASTM G102-89 [27]. The measurements were performed at 24 and 72 h of immersion of the various specimens in 1.0 M H_2SO_4 solutions. The corrosion current densities (I_{corr}) and the corrosion potential (E_{corr}) for the various samples were determined from the Tafel plots of log current versus potential.

Table 1 Designation of composite samples

Sample designation	Aluminium (wt.%)	PKSA (wt.%)	SiC (wt.%)
A0	100	0	0
A1	98	0	2
A5	90	8	2
A6	98	2	0
A9	90	2	8

RESULTS AND DISCUSSION

The potentiodynamic polarization curves of the samples made from unreinforced Al6063 alloy (A0), monolithic reinforced aluminium composites (A1 (with 2% SiC) and A6 (with 2% PKSA)), and the hybrid reinforced aluminium composites (Samples A5 (8% SiC/2% PKSA) and A9 (2% SiC/8% PKSA)) exposed to 1.0 M H_2SO_4 solution for 24 and 72 h are shown in **Figs. 1 and 2**, respectively. **Fig. 1** revealed similar polarization trends as well as passivation characteristics for all the samples exposed to the electrolytes. The E_{corr} value (-0.628 V) and I_{corr} value (423.81 μA/cm^2) of A0 at 24 h of exposure were more positive than for the other specimens. Hence, Sample A0 is less susceptible to corrosion (**Table 2**) because the relative purity of A0 easily forms oxide(s) of Al and is reinforced with alloying element Cr which aided the development of corrosion resistance passivation oxide skin on Al6063. The presence of reinforcements within the matrix of Al6063 is likely an active site for corrosion initiation. In addition, there is a tendency for the formation of flawed oxide layers on the composites wherever the reinforcements intersect the surface of the composites. These regions are possible stress raisers where subsequent corrosion activities initiate [8,28]. At 72 h immersion time, the I_{corr} value for A9 was 1075.65 μA/cm^2 and was the lowest amongst similarly exposed specimens indicating the highest corrosion resistance in the H_2SO_4 solution. The pH of the solution may have increased in addition to the reduced oxygen concentration in the corroding system as a result of the initial rapid corrosion rate the specimen experienced. It is generally known that extraneous ions, such as sulphates and chlorides, normally form soluble complexes with passivating oxide skins on Al which expands the active region and contract the passive regions on the E/pH diagram (Pourbaix diagram). This will increase the corrosion rate after prolonged exposure. For the immersion in H_2SO_4 solution for 24 and 72 h, the sample with the least I_{corr} values gave the highest E_{corr} values (**Table 2**).

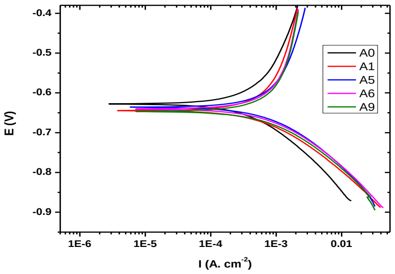

Fig. 1 Polarization curves for the composites in 1.0 M H_2SO_4 solution at 24 h

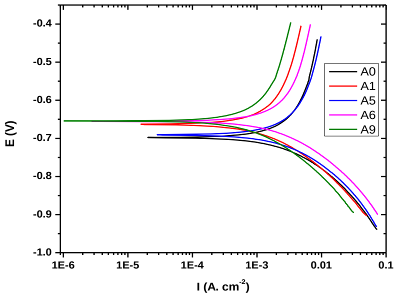

Fig. 2 Polarization curves for the composites in 1.0 M H_2SO_4 solution at 72 h

Table 2 Corrosion parameters from PDP curves for samples in H_2SO_4 solution

Sample immersed in 1.0M H_2SO_4 solution for 24 h		
Sample	**E_{corr} (mV)**	**I_{corr} (μA/cm^2)**
A0	-627.735	423.810
A1	-644.462	651.760
A5	-635.773	827.630
A6	-640.570	860.230
A9	-641.197	857.990
Sample immersed in 1.0M H_2SO_4 solution for 72 h		
Sample	**E_{corr} (mV)**	**I_{corr} (μA/cm^2)**
A0	-697.220	3057.160
A1	-662.989	1533.200
A5	-690.241	3243.630
A6	-654.775	2308.050
A9	-654.000	1075.650

CONCLUSIONS

The study investigated the corrosion behaviour of hybrid reinforced Al6063 matrix in H_2SO_4 solution using the potentiodynamic polarization technique. The existence of reinforcements inherent in the Al6063 matrix serves as likely active sites for corrosion initiation. There is the propensity for flawed oxide layer formation anywhere the surfaces of the composites are intersected by the reinforcements. These regions are possible stress raisers for corrosion activity initiation. The reinforced metal matrix composites showed better corrosion resistance compared to the unreinforced alloy. The usage of the MMCs produced in areas with a high concentration of acid will result in fast chemical disintegration of the material and eventual catastrophic failure.

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