

# Inhibitive Action of Potassium Iodide on the Corrosion of Stir-Cast Al–Si/SiC in NaCl-KI Interface

F. Asuke · M. Abdulwahab · O. S. I. Fayomi · V. S. Aigbodion ·  
A. P. I. Popoola

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**Abstract** The inhibitive action of potassium iodide (KI) on the corrosion of Al–Si/SiC particulate composite in 3.65% NaCl solution was investigated using gravimetric and potentiodynamic polarization techniques at 298 K. The results showed that KI in NaCl-aluminum alloy/SiC composite environment decreased the corrosion rate at all the concentrations considered. Inhibitor efficiencies (IEs) of 97.17, 97.34, and 97.57% with 0.5 g/v addition using gravimetric method were achieved after 92, 196, and 288 h of exposure times, respectively. The IEs from the potentiodynamic polarization method under both conditions (uninhibited/inhibited) were significantly enhanced. The high-resolution scanning electron microscopy for surface morphology of the as-corroded, uninhibited specimens showed the formation of pits and cracks compared with the as-corroded inhibited specimens. The addition of KI as corrosion inhibitor indicates increased potential value, % IE, and polarization resistance value with the decreasing current density. The two methods employed for the

corrosion assessment of the composite were in agreement, and mixed-type corrosion has been demonstrated to occur which followed Langmuir adsorption isotherms.

**Keywords** Al–Si/SiC composite · Inhibitor efficiency · Thin film · Interface

## Introduction

Metal matrix composites (MMCs) as a new generation of materials have found a wide range of industrial applications in aerospace and automobile industries [1]. Reinforcement materials—usually ceramics—are incorporated into the MMCs to obtain excellent properties, such as specific stiffness, high elastic modulus, and wear resistance [2, 3]. Among the MMCs, aluminum matrix composites (AMCs) are gaining considerable amount of industrial importance because of their excellent combination of physical, mechanical, and electrochemical properties. Due to their interesting combination of properties, these materials are being used in many engineering applications such as, automobile: pistons, track shoes, brake drums, and cylinder liners [4]; marine [5, 6]; mining; and mineral-processing applications [7, 8].

One of the major limitations of the AMCs has been low corrosion resistance in aqueous environment. Several researches have been carried out extensively on the corrosion of AMCs and common reinforcements such as SiC and Al<sub>2</sub>O<sub>3</sub>. Fang et al. [9] studied the synergistic effect of wear and corrosion on Al<sub>2</sub>O<sub>3</sub> particulate-reinforced 6061 AMC, and reported that reinforcement was detrimental to the corrosion resistance of the AMC. Saraswathi et al. [5] studied the corrosion behavior of Al–Si/SiC composite in three different media, namely, synthetic mine water,

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F. Asuke · M. Abdulwahab  
Department of Metallurgical and Materials Engineering,  
Ahmadu Bello University, Zaria, Nigeria

F. Asuke · M. Abdulwahab · O. S. I. Fayomi ·  
V. S. Aigbodion · A. P. I. Popoola  
Department of Chemical and Metallurgical Engineering,  
Tshwane University of Technology, Pretoria, South Africa

O. S. I. Fayomi  
Department of Mechanical Engineering, Covenant University,  
Ota, Ogun State, Nigeria

V. S. Aigbodion (✉)  
Department of Metallurgical and Materials Engineering,  
University of Nigeria, Nsukka, Nigeria  
e-mail: aigbodionv@gmail.com; victor.aigbodion@unn.edu.ng

3.5%NaCl solution, and 3.5% NaOH solution through immersion technique, and reported that the corrosion rate in 3.5%NaCl solution was minimum followed by synthetic mine water while that of 3.5% NaOH solution was the highest.

In their work, the use of inhibitor was not considered. One of the methods of combating corrosion in aqueous environment is the application of corrosion inhibitors. Asuke et al. [10] studied the corrosion inhibition of Al–Si/SiC composite with palm wine as inhibitor using gravimetric technique. They reported a maximum inhibition efficiency of 47.63% at 30 °C with the optimal concentration of 1.0% v/v. In the present study, the corrosion inhibition of Al–Si/SiC composite in 3.65% NaCl-KI interface has been investigated using gravimetric and potentiodynamic polarization techniques.

### Experimental Procedures

#### Materials and Sample Preparation

Stir-cast aluminum composites of the as-received specimens with the dimension of 20 × 20 × 3 mm and with chemical composition of 5%Si, 15%SiC, and 80%Al were used as coupons for the corrosion study in 3.65%NaCl solution. Initially, the coupons were mechanically polished with emery papers down to 600 grit. The coupons were degreased in ethanol, dried, weighed, and stored in a desiccator. The initial weight of each coupon was measured and recorded. Corrosion studies were conducted at the room temperature (298 K).

#### Gravimetric Measurement (GM)

The gravimetric corrosion test was carried out on the previously weighed coupons with and without inhibitor at 298 K. The volume of the NaCl solution was 100 mL with and without the addition of potassium iodide (KI) inhibitor. The various KI inhibitor concentrations used were 0.5, 1.0, 1.5, and 2.0 g/v in 100 ml of 3.65 g of NaCl solution. For each coupon, using the gravimetric method, the coupons were washed, dried and weights taken after 96, 192, and 288 h of exposure times. The corrosion rate and inhibitor efficiency were determined along with the degree of surface coverage for each inhibitor concentration at 298 K.

#### Electrochemical Measurement

The potentiodynamic polarization (PP) and linear polarization resistance were used to study the corrosion inhibition of the Al–Si/SiC composite in NaCl solution. In the electrochemical test, a glass corrosion cell kit with a platinum counter electrode, a saturated Ag/Ag reference electrode, and Al–Si/SiC composite coupon as working electrode were used. The working electrodes' coupons were placed in the glass corrosion cell kit, leaving a 1 cm<sup>2</sup> area of surface to make contact with the solution. Polarization tests were carried out in a solution consisting of 3.65%NaCl solution at room temperature using a potentiostat. The polarization curves were determined by stepping up the potential at a scan rate of 0.003 V/s. The corrosion rate and potential were estimated by the Tafel extrapolation method using both the anodic and cathodic branches of the polarization curves.

**Table 1** Corrosion rates (CRs), Percent Inhibition efficiency (% IE), and surface coverage ( $\theta$ ) for Al–Si/SiC in 3.65%NaCl solution without and with varying concentrations of KI, as obtained from gravimetric technique at 298 K

Exposure time (h)	Concentration of inhibitor (g/v)	CR 0.5 M NaCl (mm/day)	Surface coverage ( $\theta$ ) for NaCl	Inhibition efficiency (%) for NaCl
96	0	1.0219	...	...
	0.5	0.0185	0.9717	97.17
	1.0	0.0346	0.9551	95.51
	1.5	0.0453	0.9262	92.62
	2.0	0.3192	0.5931	59.31
192	0	0.5565	...	...
	0.5	0.0952	0.9734	97.34
	1.0	0.0176	0.9575	95.75
	1.5	0.0303	0.9291	92.91
	2.0	0.1719	0.5981	59.81
288	0	0.3220	...	...
	0.5	0.0067	0.9757	97.57
	1.0	0.0120	0.9624	96.24
	1.5	0.0165	0.9352	93.52
	2.0	0.1149	0.6438	64.38

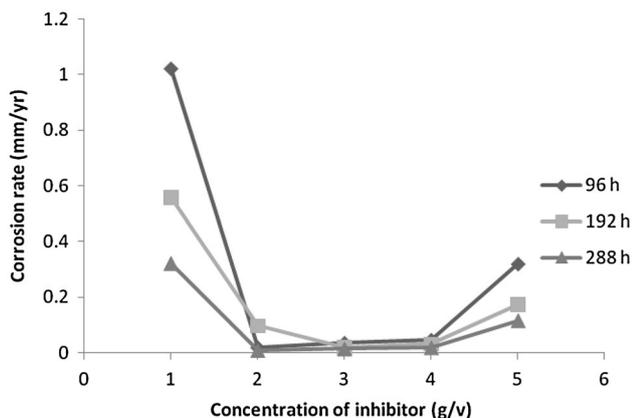
## Surface Morphology

The surface morphology of the as-corroded uninhibited and inhibited aluminum coupons were observed with high-resolution scanning electron microscopy (model: Joel JSM 7600F).

## Results and Discussion

### Results

The results obtained from the gravimetric corrosion evaluation for the aluminum alloy composite in 3.65% NaCl solution along with the variations in inhibitor concentration are presented in Table 1 and Fig. 1. Table 2 shows the electrochemical corrosion data obtained for aluminum alloy composite-3.65% NaCl/KI interface. Figure 2 indicates the polarization curves for the composite. The micrographs of the surface morphology of the as-corroded uninhibited/inhibited composites in 3.65% NaCl/KI condition are presented in Figs. 3 and 4. The percentages of inhibitor efficiency (% IE) using different methods for corrosion assessment are shown in Fig. 5, while in Fig. 6, the Langmuir adsorption isotherms for the environmental condition have been demonstrated.



**Fig. 1** Variations of the corrosion rate with the concentrations of inhibitor for aluminum coupons in 3.65% NaCl without and with varying concentrations of KI at 298 K

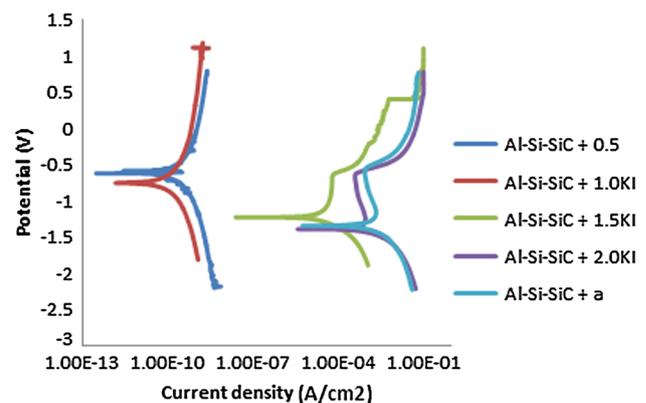
**Table 2** Electrochemical corrosion data obtained for Al–Si/SiC in 3.65% NaCl solution without and with varying concentrations of KI as obtained from polarization technique at 298 K

S/N	C (g/v)	$I_{\text{corr}}$ (A/cm <sup>2</sup> )	$b_a$ (v/dec)	LPR $R_p$ ( $\Omega\text{cm}^2$ )	$-E_{\text{corr}}$ (V)	CR (mm/y)
1	0	8.83E–07	0.15529	2.60E+04	1.2293	2.14E–03
2	0.5	3.17E–11	0.33916	1.11E+09	0.75272	7.70E–08
3	1.0	2.75E–10	2.3665	1.06E+09	0.75272	6.66E–07
4	1.5	3.57E–10	1.5361	5.41E+08	0.62152	8.64E–07
5	2.0	7.12E–07	–0.3249	5.58E+05	1.2293	1.727E–03

## Discussion

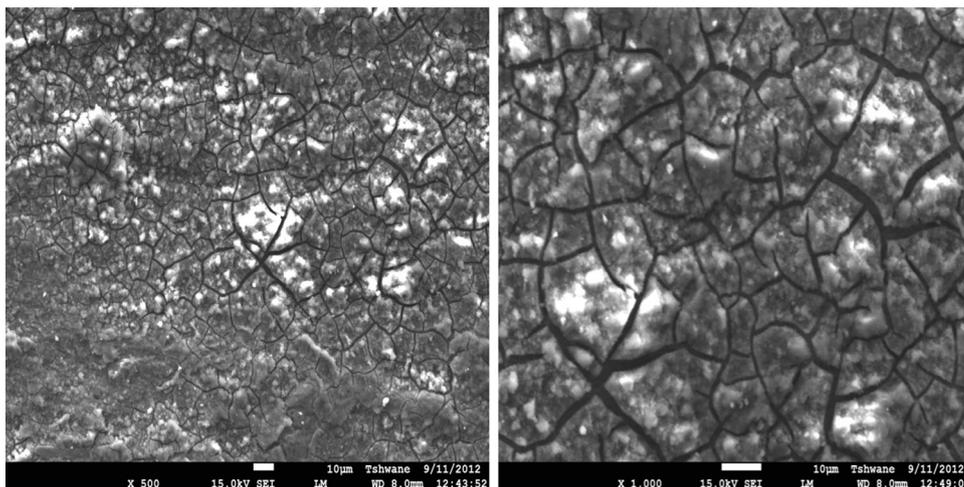
### Gravimetric Measurement

A 3.65% NaCl solution was used as an environment to study the corrosion inhibition of Al–Si/SiC at 298 K. Results showed that corrosion rate (CR) of the composite decreased with the addition of KI corrosion inhibitor and with exposure times of 96, 192, and 288 h (Tables 1; Fig. 2). At the interface and various exposure times, corrosion rate decreased throughout with the percentage inhibitor efficiency (% IE). Specifically, Fig. 2 shows a decrease in corrosion rate with the increasing concentration of inhibitor for all the immersion times at 298 K. Considering an exposure time of 96 h, higher % IE was calculated to be 97.17% at 0.5 g/v KI addition. While at 0.5 g/v inhibitor concentration for 192- and 288-h exposure times, corrosion rate/IE values were found to be 0.0952/97.34% and 0.0067/97.57%, respectively. However, corrosion resistance of aluminum composite in 0.5 g/v KI is higher than those obtainable at other concentrations. This behavior has been attributed to the formation of thin oxides as evidenced in the EDS (Fig. 4), which interfere with the anodic and cathodic reactions. Therefore, formation of pits and their growths become difficult. The thin layer of the

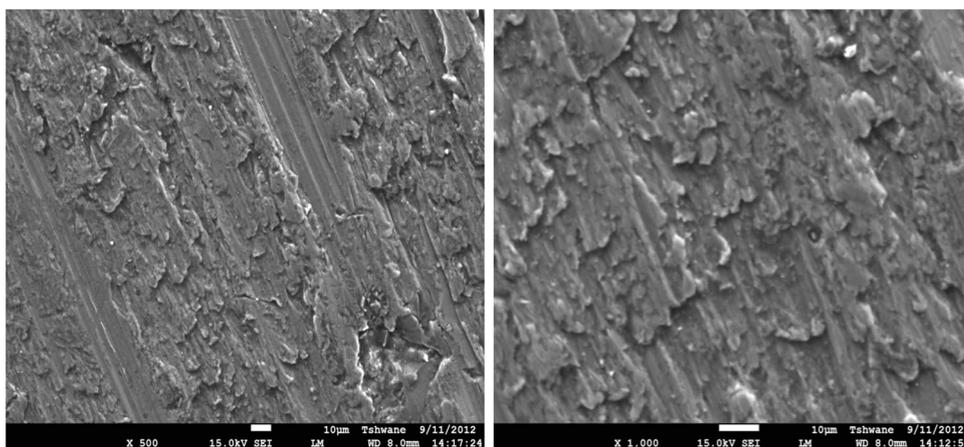


**Fig. 2** Linear polarization curves of Al–Si/SiC in 3.65% NaCl solution without and with varying concentrations of KI from gravimetric technique at 298 K

**Fig. 3** SEM micrographs of uninhibited Al–Si/SiC in 3.65% NaCl solution after 288 h of exposure time in different magnifications



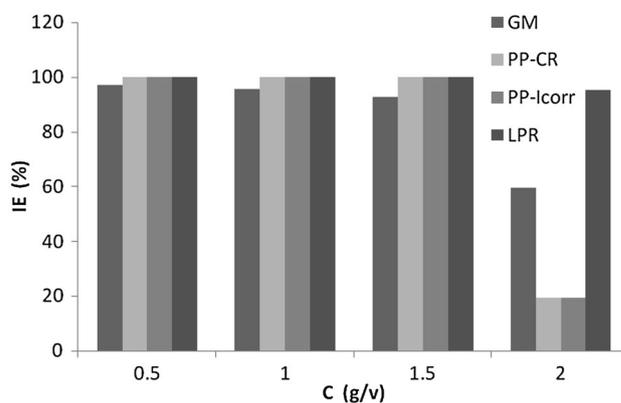
**Fig. 4** SEM micrographs of inhibited Al–Si/SiC in 3.65% NaCl-0.5 g/v KI after 288 h of exposure time in different magnifications



oxides adheres to the metal surface resulting in a decrease in the corrosion rate.

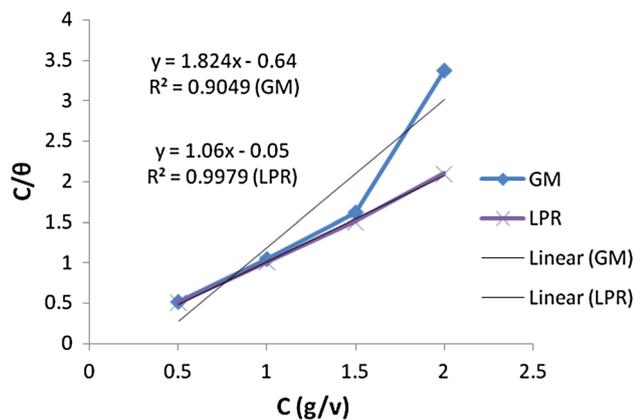
*Potentiodynamic Polarization*

From the potentiodynamic measurement for Al–Si/SiC composite (Table 2), potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion density (PP- $I_{corr}$ ), and linear polarization resistance (LPR) were used as criteria for evaluation of corrosion resistance of aluminum composite in the environment. Figure 2 indicates the polarization curves for Al–Si/SiC at 298 K. In general, the composite demonstrated a decreased corrosion rate and current density with the addition of KI inhibitor at all concentrations. However, the corrosion potential ( $E_{corr}$ ) and polarization resistance ( $R_p$ ) increase with the increasing inhibitor concentrations. This is in agreement with previous studies of [11]. The inhibited composite showed that corrosion rate decreased from  $2.14E-03$  mm/y to  $7.70E-08$ ,  $6.66E-07$ ,  $8.64E-07$ , and  $1.727E-03$  mm/y at 0.5, 1.0, 1.5, and 2.0 KI additions, respectively. It is



**Fig. 5** Comparative chart of inhibitor efficiencies (% IE) for 3.65% NaCl solution/KI concentrations obtained by gravimetric (GM), potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion current (PP- $I_{corr}$ ), and linear polarization resistance (LPR)

important to note that corrosion resistance of Al–Si/SiC–NaCl-0.5 g/v KI interface is much higher than other interfaces with IE of 99.99% being obtained at 0.5 g/v KI



**Fig. 6** Langmuir isotherms for the adsorption of KI compounds on the aluminum composite surface in 3.65% NaCl solution obtained by gravimetric and potentiodynamic polarization methods at 298 K

addition for PP and 95.57% at 188 h for GM. However, based on the changes in anodic and cathodic branches for both environments, the inhibitor is believed to be mixed-type.

#### Scanning Electron Microscope–Energy Dispersive Spectroscopy (SEM–EDS)

The surface morphology of uninhibited aluminum composite (see Fig. 3) shows severe pits, cracks, and selective dissolution of intermetallic occurring at the surface in comparison with Fig. 4, which corresponds to the lower corrosion rate obtained from the linear polarization analysis. The microstructures of the inhibited composites do not exhibit severe pits and cracks.

#### Inhibitor Efficiency and Adsorption Behavior

The percentage inhibitor efficiency (% IE) of the Al–Si/SiC in NaCl solution was calculated using the equation reported by [12]. The variations in the % IE using gravimetric (GM), potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion density (PP- $I_{\text{corr}}$ ), and linear polarization resistance (LPR) are presented in Fig. 5. This shows how different corrosion methods used in the research have effects in the inhibition. The results show that addition of KI increased the IE with an increase in the inhibitor concentrations. This is due to the fact that, as the KI addition increases, the surface area covered by this inhibitor increases, and hence higher IE was achieved.

The inhibition efficiency of the inhibitor increased with the increasing concentration of the inhibitor. The general increase in inhibition efficiency with inhibitor concentration is attributed to the adsorption of molecules of the inhibitor on the surface of the coupons. It can be explained

that the increase in the inhibition efficiency with the increasing KI concentration is an indication of an increase in the number of components of the KI adsorbed over the coupons surface blocking the active sites, in which direct NaCl attacks proceed and protect the coupons from corrosion. Also the increase in inhibition efficiency is suggestive of electrostatic interaction of the phytochemical constituents of the KI on coupon surface forming a protective layer and shielding the metal from corrosion.

KI as an inhibitor can be said to exhibit a mixed-type corrosion inhibition because of the simultaneous change in the anodic and cathodic regions during the electrochemical study. Equally, there exist correlations between GM and potentiodynamic polarization resistance. The adsorption mechanism has been demonstrated through a relationship between  $C/\theta$  against  $C$  that indicated linearity at 298 K in the environment (see Fig. 6). Since the correction factors ( $R^2$ ) were calculated and found to be close to unity—GM (0.9049) and LPR (0.9979)—a Langmuir adsorption isotherm is believed to have been obeyed.

#### Conclusions

From the above results and discussion, the following conclusions are made:

- i. KI has proven to be a good corrosion inhibitor in Al–Si/SiC in NaCl environment at 25 °C.
- ii. The corrosion resistance and inhibitor efficiency of Al–Si/SiC composite increased with the addition of KI as inhibitor with the inhibitor efficiency reaching as high as 97.57% using the gravimetric method of corrosion evaluation.
- iii. Surface morphology of the uninhibited aluminum composite coupon shows formation of severe pits and cracks.
- iv. A mixed-type corrosion inhibition occurs and Langmuir adsorption isotherms were proposed for the aluminum composite in the environment considered.

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