

A comparative Corrosion Studies of Aluminum Metal Matrix Composites Reinforced with nano (Al_2O_3 and SiC) Particles In Fao Water

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Abstract:

In the present investigation, the static electrochemical corrosion behavior of nano (Al_2O_3)_P and nano (SiC)_P based aluminum in Fao water was compared. The nanocomposites were fabrication using liquid metallurgy technique. The effect of nanoparticulates weight percentage (5%, 15% and 25%) on the corrosion was studied. The results showed that the Al reinforced with nano (Al_2O_3) composites exhibited lower corrosion rates that the Al reinforced with nano (SiC)_P composites. The corrosion rate was found to be increased by increasing of the weight percentage of the nanoparticles more than 5% nano (Al_2O_3)_P composites exhibited the highest corrosion resistance among all the investigated nanocomposites.

Keywords: Pure Al, nano alumina (Al_2O_3), nano silicon carbide (SiC), Stir casting, Corrosion rate, potentiostatic measurements, Fao water.

دراسة مقارنة معدل التآكل للمواد المعدنية المترابطة ذات اساس المنيوم المقواة بدقائق نانوية للالومينا وكاربيد السليكون في ماء الفاو

الخلاصة:

تم في هذا البحث تقييم سلوك التآكل الكهروكيميائي الساكن للالمنيوم النقي (1060) المقوى بدقائق نانوية من الالومينا وكاربيد السليكون في ماء الفاو والمقارنة بينهما. حضرت المواد المترابطة المدعمة بدقائق نانوية بتقنية ميتالورجيا الحالة السائلة حيث تم دراسة تأثير النسب الوزنية للدقائق النانوية (5% و 15% و 25%) على سلوك التآكل. اظهرت النتائج ان المادة المترابطة المنيوم- نانو الومينا اقل معدل تآكل من المادة المترابطة المنيوم- نانو كاربيد السليكون في ماء الفاو. كذلك وجد ان معدل التآكل يزداد مع زيادة النسب الوزنية للدقائق النانوية الاكبر من 5% والمقواة بدقائق الالومينا النانوية والتي ابدت اكثر مقاومة تآكل من بقية المواد المترابطة النانوية.

الكلمات المفتاحية: الالمنيوم النقي، نانو الومينا، نانو كاربيد السليكون، السبائك بالمزج، معدل التآكل، قياسات المجهود الساكن، ماء الفاو

INTRODUCTION

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Hard ceramic particle-reinforced aluminum matrix composites (Al-MMCs) have received great interest due to their mechanical and physical properties; as a result, they are widely used to fabricate diverse components for the automotive and aerospace industries [1,2]. Al-MMCs can be reinforced with various oxides, carbides, nitrides and borides, such as SiC, Al_2O_3 , B_4C , TiC, TiB_2 , MgO, TiO_2 , AlN, BN and Si_3N_4 [3,4].

Metal matrix composites (MMCs) reinforced with nano-particles, also called Metal Matrix nano-Composites (MMnCs), are being investigated worldwide in recent years, owing to their promising properties suitable for a large number of functional and structural applications. The reduced size of the reinforcement phase down to the nano-scale is such that interaction of particles with dislocations becomes of significant importance and, when added to other strengthening effects typically found in conventional MMCs, results in a remarkable improvement of mechanical properties [5].

Recently, metal matrix nanocomposites (MMNCs) have become more attractive in various applications because of their improved mechanical properties over conventional micro-particle reinforced MMCs. These materials are expected to exhibit good corrosion resistance in the aggressive environments. Therefore, determination of the corrosion resistance of composite materials reinforced with nanoceramic additives is very important.

Most studies conducted on Al matrix nanocomposites, have been focused on the corrosion susceptibility in NaCl solutions [6,7]. For example, El-Mahallawi et al.[6] studied the corrosion behavior in 3.5% NaCl solution of A356 Al alloy reinforced with nano- Al_2O_3 particulates. The results showed that the A356 the monolithic alloy exhibited high corrosion rates when compared with the nanocomposites. Durai et al. [7] studied effect of mechanical milling on the corrosion behavior of Al-Zn/ Al_2O_3 composite in NaCl solution. Results of the corrosion tests, evaluated using the potentiodynamic method, indicate that corrosion of the investigated composite materials depends on the weight fraction of the reinforcing particles. The milled composite material Al-Zn/ Al_2O_{3p} has higher corrosion resistance in the selected environment compared to unmilled composite Al-Zn/ Al_2O_{3p} . Zuhair studied corrosion behaviour of 6061/ Al_2O_3 composite with two volume fraction of reinforced were examined in 3.5% NaCl. He observed that the number of pit sites appears to increase with volume fraction of the reinforcement [8].

Amar studied corrosion behavior of aluminum alloy matrix reinforced by alumina composite in 3.5% NaCl, 1%HCl & 2.5% HCl. He observed that the corrosion rates increased with the increase in the concentration of acid, the corrosion rates were higher in acid medium than salt medium [9].

The aim of this work

In the present work, an effect has been made to fabrication metal matrix composites reinforced with nano (Al_2O_3 and SiC) particles containing various weight percentages of particulates(5%, 15% and 25%) and compared their to study their corrosion behavior in Al – Fao water by potentiostat and at scan rate $3 \text{ mV}.\text{sec}^{-1}$. Optical microscope were carried out to identify the corroded surface..

Experiment procedure:

Materials

Metal matrix composites containing various weight percentages of nano (Al_2O_3 and SiC) particles were produced by liquid metallurgy route. For the production of MMCs, a commercial purity aluminum (AA 1060). was used as the matrix material while Al_2O_3 and SiC particles with an average size of 30 nm were used as the reinforcement. The chemical composition of the Commercial purity aluminum (AA 1060) is shown in table 1 and the characterization of nano (Al_2O_3 and SiC) reinforcing materials is shown in table 2.

Table (1) The chemical composition of Commercial purity aluminum (AA 1060).

| Al | Si | Fe | Ti | V | Cu | Mn |
|-------|------|------|-------|-------|-------|-------|
| 99.76 | 0.08 | 0.15 | 0.001 | 0.007 | 0.001 | 0.003 |

Table (2) Alumina and silicon carbide ceramic nanopowders properties (Anhui Elite International Tradeco.Ltd China)

| properties | Alumina | Silicon Carbide |
|---------------|---|----------------------------|
| Purity | 99+% | 99+% |
| Particle size | 30 nm | 30 nm |
| Color | White powder | Green powder |
| Density | 3.69 g/cm ³ | 3.22 g/cm ³ |
| Morphology | nearly spherical | nearly spherical |
| Crystal Phase | Al_2O_3 nanopowder (α) | SiC nanopowder (β) |

Composite preparation

A stir casting setup (Figure. 1), which consisted of a resistance furnace and a stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a graphite blades stirrer, which was connected to a variable speed vertical drilling machine (speed 0 to 1000 rpm) by means of a steel shaft.

The stirrer was made by cutting and shaping a graphite block to desired shape and size manually. The stirrer consisted of three blades at angles of 120° apart. Graphite crucible of 100g capacity was placed inside the furnace. Preheating of Alumina and Silicon Carbide mixture at 750°C was done for one hour to remove moisture and gases from the surface of the particulates . The stirrer speed was then lowered vertically up to 3 cm from the bottom of the crucible. The speed of the stirrer was gradually raised to 800 rpm the preheated Alumina and Silicon Carbide particle powder was added (5%, 15% and 25%) with a spoon at the rate of 10- 20g/min into the melt.

The speed controller maintained with constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Alumina and Silicon Carbide powder, stirring was continued for 10 min. get better distribution. The melt was kept in the crucible for one minute in static condition, The slag were removed and Aluminium melt poured in the graphite moulds.

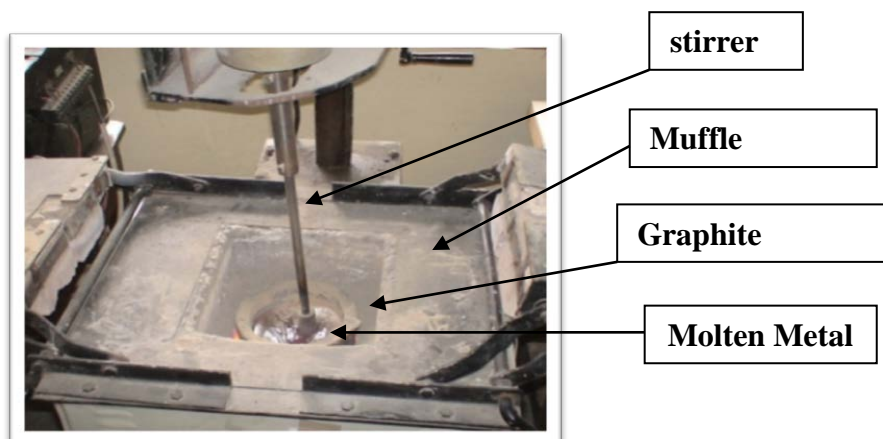


Figure (1) Stir casting set up.

Specimen Preparation for corrosion measurement

Mountin

The mounting process was performed by using XQ-2B mounting press, where the specimen was placed with phenolic resin in mold and heated up to 140°C under pressure of 3500 – 4000 psi, for 5 – 10 minutes. For electrochemical studies, suitable provision was made on the other side for electrical contact.

Grinding and Polishing

The mounted specimens were ground with SiC emery papers in sequence of 400, 600, 800, 1000, and 2000 grit to get flat and scratch- free surface.

The specimens were polished using polish cloth and alpha alumina $0.5\mu\text{m}$ and $1\mu\text{m}$, and then washed with distilled water. The polished specimens were degreased with acetone, dried and used for microstructure evolution and electrochemical investigation.

Polarization Test

All experiments were carried out using a three electrode cell with saturated calomel electrode (SCE) as reference, platinum electrode as counter electrode and the cylindrical specimens of the composite with active flat disc of (0.78 cm^2) as the working electrode. The SCE was connected via Luggin capillary, the tip of which was held very close to the surface of the working electrode to minimize the IR drop. Open circuit potential (OPC) measurements were recorded for 15 minutes, the time necessary to reach quasi stationary state for open circuit potential, Followed by polarization measurements at a scan rate of 3 mV/s for Tafel plots.

Figure (2) shows the experimental arrangements for electrochemical measurement.

All test were carried out at room temperature. Table (3) shows the compositions of Fao water.

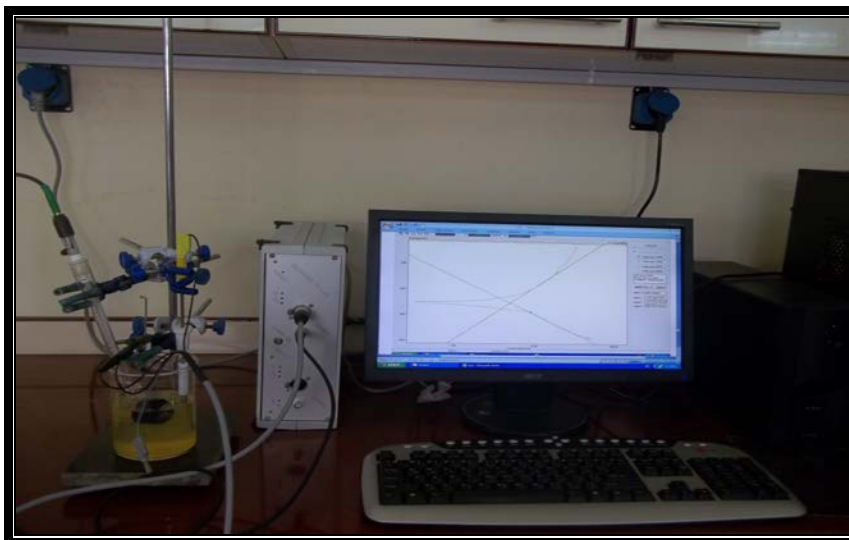


Figure (2):experimental arrangements forelectrochemical measurement.

In order to find corrosion rate from the following equation [10]:

$$\text{Corrosion rate (mm/y)} = \frac{3.27 \times 10^{-3} \times i_{\text{corr}} \times EW}{D} \dots\dots(1)$$

Where ,

i_{corr} in (A/cm²) is the corrosion current density
corroding species, and D in (g/ cm³) is the density of the corroding species.

□ EW is the equivalent

Table (3). shows the characterization of Fao water.

| | | |
|-------------------------|-------------------------------|-------------|
| Anions g/L | Cl ⁻ | 7.04 |
| | SO ₄ ²⁻ | 1.27 |
| pH | | 7.6 |
| Electrical conductivity | | 19.92 mS/cm |

Optical Microscopic

The specimens were etched by etchant reagent used for aluminum (killers' reagent (composition: 95ml water, 2.5ml HNO₃, 1.5ml HCL, 1.0ml HF)), the reagent stay on the specimen surface for 10 second then clean by water and dry.

RESULTS AND DISCUSSION

Corrosion Behavior in Fao water

The corrosion parameters of composites in Fao water are given in Table(4) . The corrosion current density i_{corr} , increases with increase of Al₂O₃ and SiC content in the composites, corroborating the results that additives fillers with ceramic does influence and increase the corrosion rate of the aluminum matrix

Table (4) Corrosion parameters of Al reinforced with nano (Al_2O_3 and SiC) composites in Fao water

| COMPOSITE | WEIGHT% | FAO WATER | | |
|--|---------|--|------------------------|-----------------------|
| | | i_{corr} (A/cm^2) | E_{corr} (mV) | Corrosion Rate (mm/y) |
| Al/nano(Al_2O_3) particles | 5% | 4.12 | -661.3 | 0.0412 |
| | 15% | 5.23 | -627.0 | 0.0523 |
| | 25% | 5.63 | -741.8 | 0.0563 |
| Al/nano(SiC) particals | 5% | 5.40 | -621.4 | 0.0450 |
| | 15% | 9.14 | -723.2 | 0.0914 |
| | 25% | 9.33 | -664.7 | 0.0933 |

Polarization curves for Al reinforced with nano (Al_2O_3 and SiC) composites are shown in Figures (3) to (8). The Al reinforced with nano (Al_2O_3) composites however, had better resistance to corrosion in Fao water in comparison with the Al reinforced with nano (SiC) composites possibly due to the inhomogeneous structure of an aluminum metal matrix composite which must be considered in designing a corrosion protection system. So due to alumina has larger electrical resistance than silicon carbide, besides the Al- Al_2O_3 has more compatibility than Al-SiC.

For all the investigated nanocomposites, there is a trend of increasing of the corrosion rate with the increase of the Al_2O_3 and SiC nanoparticulates weight percentage. The Al/5% Al_2O_3 exhibited higher corrosion resistance than the Al/ Al_2O_3 and Al/SiC nanocomposites. Both SiC and Al_2O_3 nanoparticulates are ceramic materials and they remain inert. The corrosion behavior of nanocomposites depends weight percentage of the additives fillers.

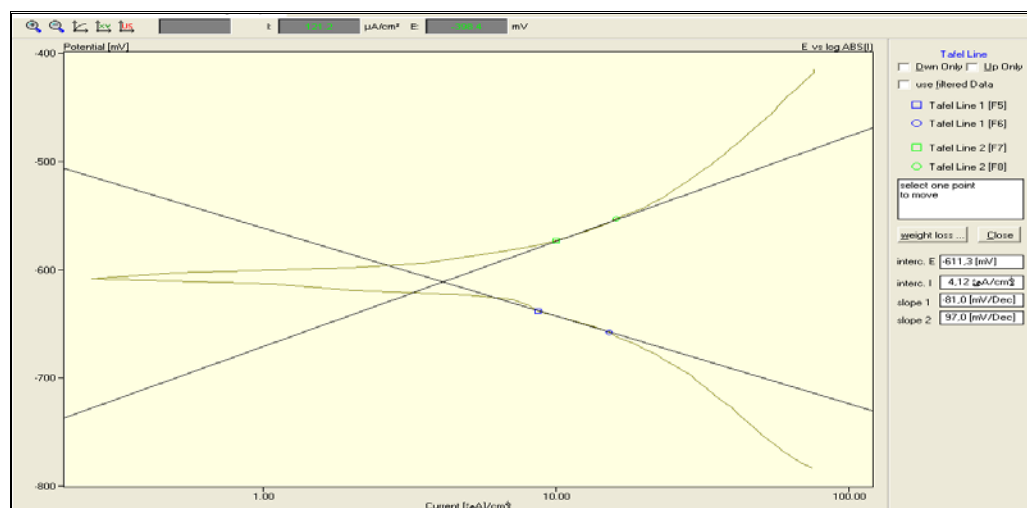


Figure (3) polarization curve for Al/ 5% nano Al_2O_3 composites

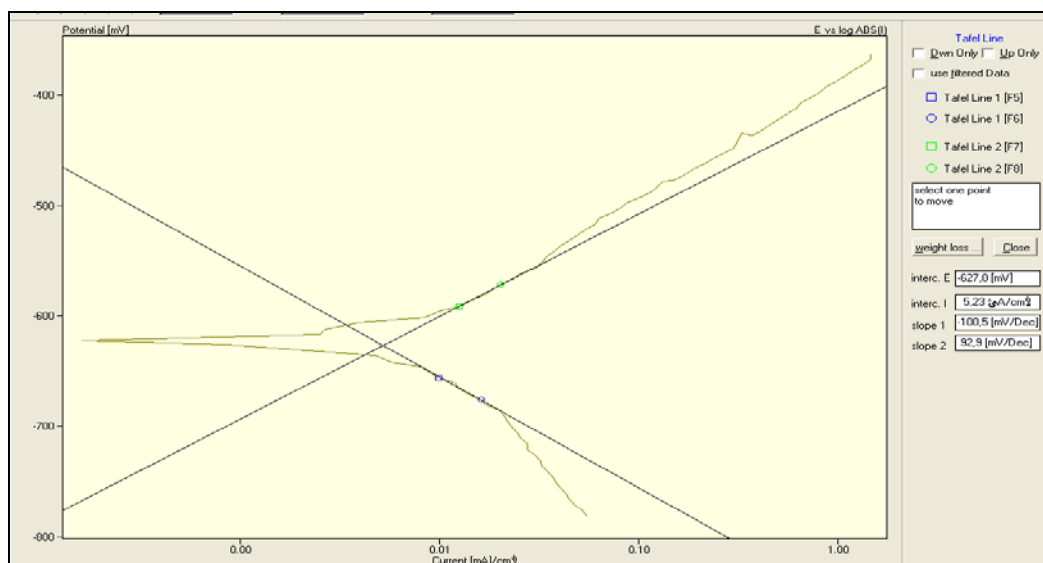


Figure (4) polarization curve for Al/15% nano Al_2O_3 composites

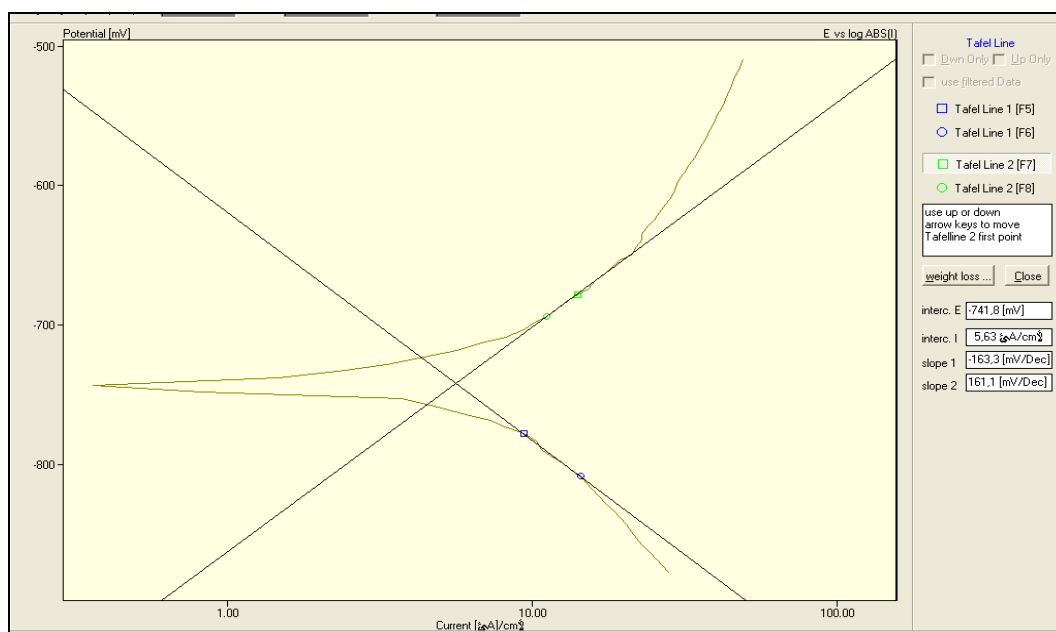


Figure (5) polarization curve for Al/25% nano Al_2O_3 composites

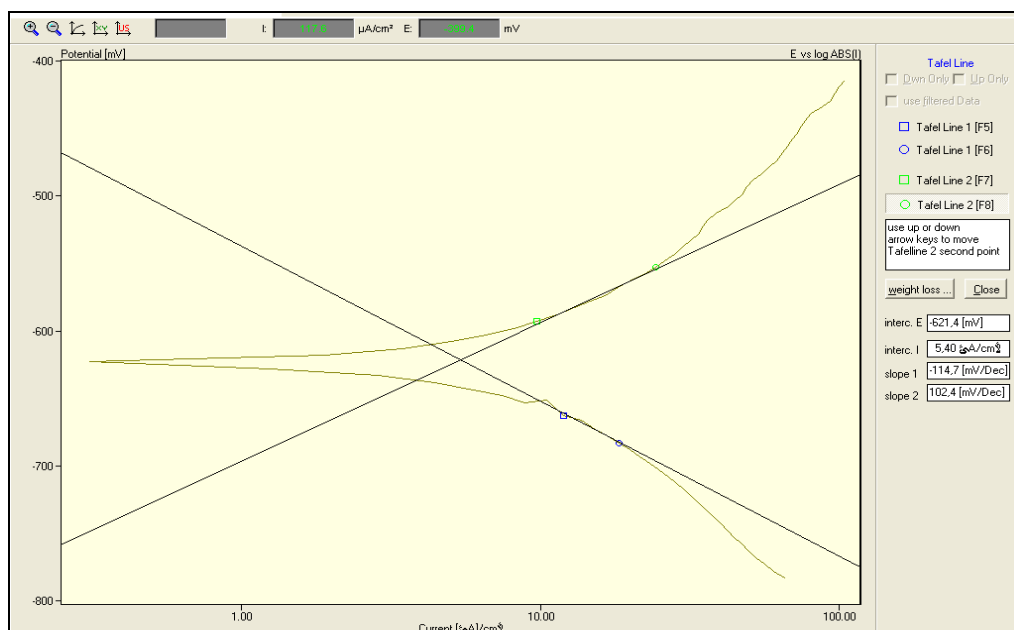


Figure (6) polarization curve for Al/ 5% nano SiC composites

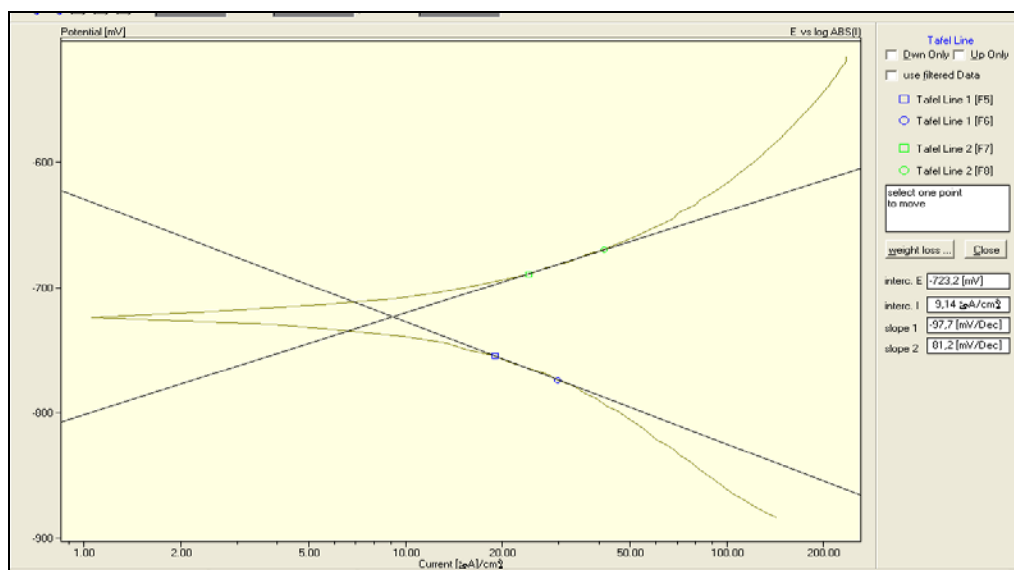


Figure (7) polarization curve for Al/15% nano SiC composites

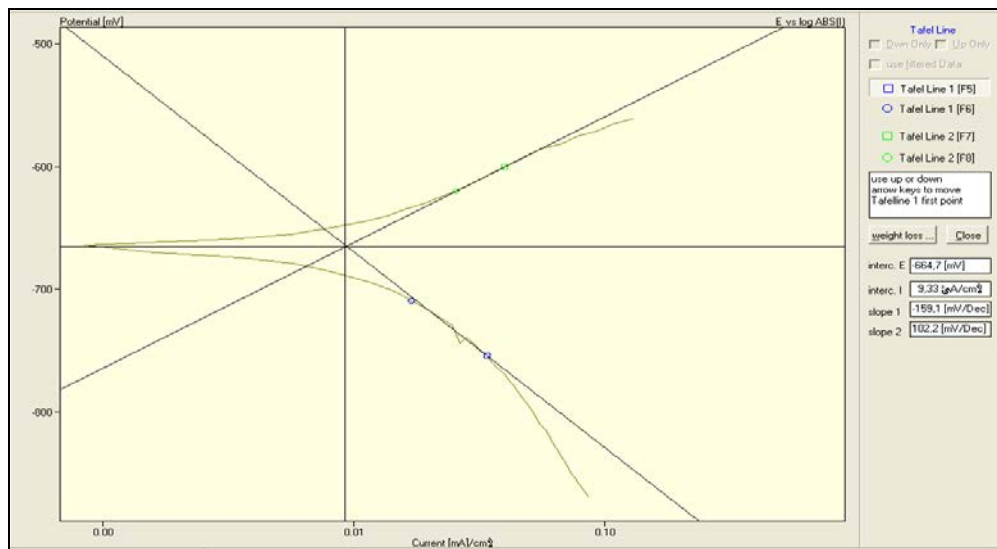


Figure (8) polarization curve for Al/25% nano SiC composites

Microstructure

The microstructure of as polished Al reinforced with nano (Al_2O_3 and SiC) composites with (5, 15 and 25) weight percentage fabricated by liquid metallurgy. Etching in Keller's reagent did not reveal additional contrast. The light area denotes the aluminum matrix, while the black colored bodies are alumina and silicon carbide particles seem to be distributed uniformly except some clusters, before and after corrosion are as shown in figures (9-12).

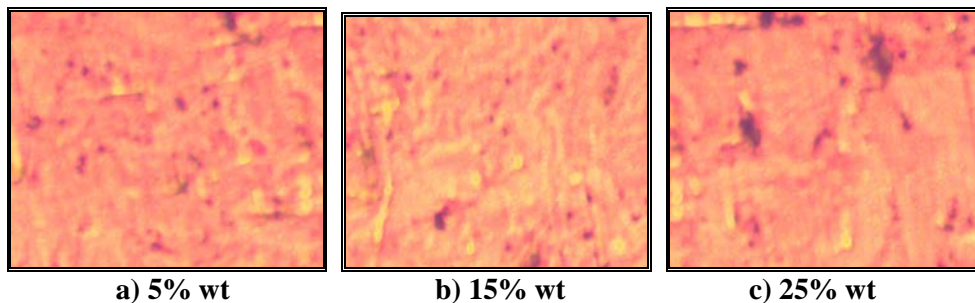


Figure (9) Microstructure of alumina particles before corrosion at different weight percent of nano Al_2O_3 particulates in Al- matrix (X40).

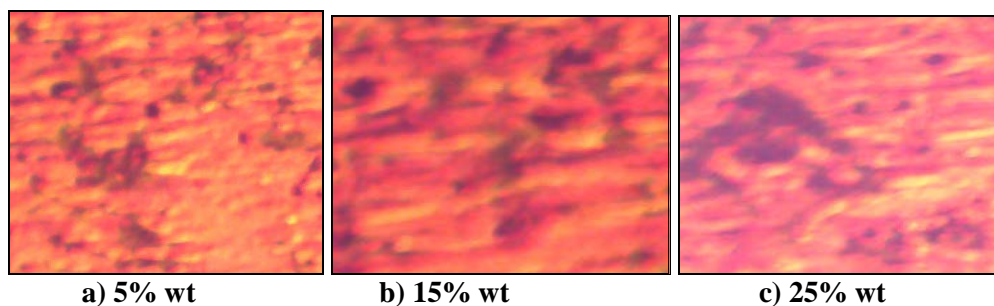
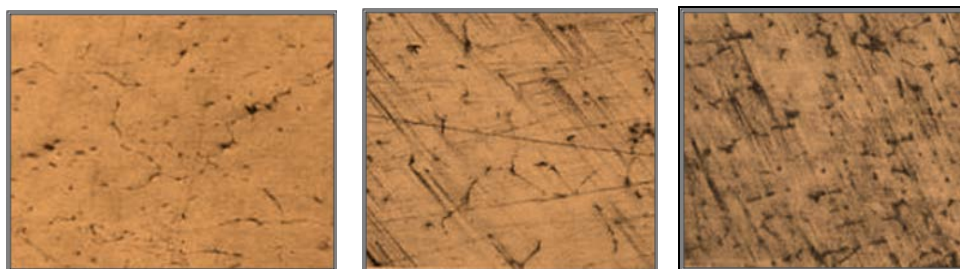


Figure (10)) Microstructure of alumina particles after corrosion at different weight percent of nano Al_2O_3 particulates in Al- matrix (X40).

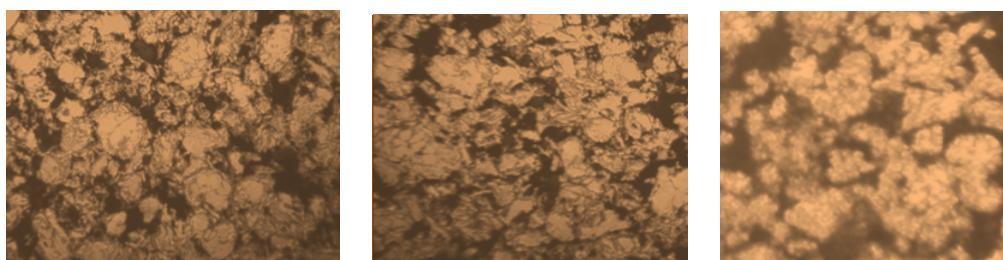


a) 5% wt

b) 15% wt

c) 25% wt

Figure (11)) Microstructure of alumina particles before corrosion at different weight percent of nano SiC particulates in Al- matrix (X40).



a) 5% wt

b) 15% wt

c) 25% wt

Figure (12)) Microstructure of alumina particles after corrosion at different weight percent of nano SiC particulates in Al- matrix (X40).

Conclusions

According to the results obtained from the current investigation, the following conclusions can be pointed out:

- The corrosion rate increases with increasing the weight percentage of the nanoparticles for Al_2O_3 and SiC.
- The Al/ Al_2O_3 nanocomposites exhibited lower corrosion rates in Fao water than the Al/SiC nanocomposites. The Al/5% Al_2O_3 exhibited the best corrosion resistance among all the investigated nanocomposites; and Corrosion current values (i_{corr}) increase with increase in Al_2O_3 and SiC content in the composites in Fao water.

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