The Effect of (Ag,Ce) Addition on Corrosion Resistance of (Al-Si) Alloy

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Abstract

Aluminum casting alloys with silicon as the major alloying elements are the most important commercial casting alloys because of their superior casting characteristics and as it is well known that (Al-Si) alloys, which are widely applied in the aerospace and automotive industries. This research aims to study the effect of silver and cerium (2.5% Ag, 2% Ce) elements added to (Al-Si) alloy. In this research was calculated Vickers microhardness and corrosion resistance by electrochemical method to master alloy before and after the addition of silver and cerium.

The results showed that the addition of the silver element led to increase microhardness, decrease corrosion resistance, and either addition of cerium led to decrease microhardness, increase corrosion resistance and addition of elemental silver and cerium together led to increase microhardness, decrease corrosion resistance of (Al-Si) alloy. The results shown that the best corrosion resistance was in (C) alloy (Al- 6.37% Si- 2% Ce) while (B) (Al- 6.34% Si- 2.5% Ag) has better microhardness.

Keywords: (Al-Si) alloy, Alloying elements, Corrosion resistance , Microhardness.

الخلاصة

تعد سبائك الألمنيوم المسبوكة مع السليكون كعنصر سبك رئيس من أهم السبائك التجارية بسبب امتلاكها خصائص سبك فائقة ولهذه السبيكة تطبيقات واسعة في صناعة السيارات والفضاء. يهدف هذا البحث إلى دراسة تأثير إضافة عنصري الفضة والسيريوم على سبيكة (ألمنيوم–سليكون) فقد تم احتساب الصلادة الدقيقة بطريقة فيكرز ومقاومة التآكل بالطريقة الكهروكيميائية للسبيكة الاساس قبل وبعد إضافة الفضة والسيريوم. وأظهرت النتائج إن إضافة عنصر الفضة أدت إلى زيادة الصلادة الدقيقة وانخفاض مقاومة التآكل اما اضافة السيريوم فأدى الى انخفاض الصلادة الدقيقة وزيادة مقاومة التآكل. وان اضافة عنصري الفضة والسيريوم معا للسبيكة الاساس ادى إلى زيادة الصلادة الدقيقة وانخفاض مقاومة التآكل. النتائج اظهرت ان افضل سبيكة مقاومة للتأكل هي السبيكة (C) بينما السبيكة (B) تمتلك افضل صلادة دقيقة .

الكلمات المفتاحية : سبيكة (المنيوم– سليكون) ، عناصر السبك ، مقاومة التآكل ، الصلادة الدقيقة .

1. Introduction

Aluminum, the second most plentiful metallic element on earth, became an economic competitor in engineering applications as recently as the end of the 19th century [Elwin Rooy,1990]. Aluminum does not change colour as its temperature rises, non-magnetic, has a face-centred cubic crystal structure means that it does not suffer from a loss of notch toughness as the temperature is reduced [Mathers,2002]. Due to high strength to weight ratio, besides other desirable properties like appearance, high corrosion resistance, high electrical and thermal conductivities and ease of fabrication, aluminum and its alloys are used in a wide range of industrial applications, particularly in aircraft and space vehicles, construction and building, containers and packaging and in electrical transmission lines [Hossain, and Kurny, 2013]. Addition of alloying elements improve mechanical properties of aluminum and increase the aluminum response to heat treatment which improves the casting, corrosion resistance property as well as the strength of the alloy [Oladele and Omotoyinbo, 2011]. Silicon is the main alloying element. It imparts high fluidity and low shrinkage, which results in a good castability and weldability [Al-Khazraji *et al.*, 2011]. The influence of Si content in Al-Si alloy helps in the reduction of density and coefficient of thermal expansion, improvement in hardness, mechanical properties (modulus and strength) and wear resistance [Ahlatci *et al.*,2004]. Aluminum alloys with silicon as a major alloying element constitutes a class of material, which provides the most significant part of all shaped castings and they are popular for a variety many applications [Al-Khazraji *et al.*,2011]. The heat treatment is one of the important methods for improving the mechanical properties of Al alloys. This heat treatment consists of solution heat treatment, quenching, and then either natural or artificial ageing [Moldovan and *et al.*,2007]. Aluminium-Silicon (Al-Si) alloys are considered as the most important cast alloys due to their excellent casting characteristics, good corrosion resistance, and good weldability. The fluidity of the Al-Si alloy increases up to eutectic composition (12.5% Si), further, presence of Si reduces hot cracking tendencies and solidification shrinkage. The overall weight of the cast component is reduced since Si has a low density of 2.34 g/cm^3. Moreover, the solubility of Si in Al is very low and precipitates as pure Si. As a result, they are responsible for improved abrasion wear resistance [Jigajinni *et al.*,2011].

In this paper we studied the effect of silver and cerium (Ag, Ce) elements which added to (Al-Si) alloy where was calculated Vickers microhardness and corrosion resistance by electrochemical method to base alloys before and after the addition of (Ag, Ce) and microstructure .

2. Experimental Procedures

2.1 Specimens Preparation

The (Al-Si) alloys were prepared using high purity elements, aluminum (99.89 wt.% purity), silicon (99.95 wt.% purity) , silver (98.6 wt.% purity) and cerium (99.9 wt.% purity). The melting was carried out using graphite crucible at (850 ºC) in electrical melting furnace. Then the alloying elements were added in the required weight percentages where remained for (5-10) minutes after each element added. During the addition of alloying elements, there must be continuous mixing by using a graphite stirring rode to ensure a best mixing and dissolution of alloying elements and to avoid segregation defects. All alloying elements are packing with Al-foils to avoidance of oxidization . For removal of gases from molten, flux cleaner (KCl) was added. The melt was poured in a steel mould to produce a casting of (15mm) in diameter and (150 mm) in length. The chemical composition of prepared alloys as shown in table (1).A homogenizing of samples has been at (500 ^{o}C) temperature for three hours**.**

Table (1) Chemical composition of prepared alloys.

Code of alloy	Al (Wt. %)	Si (Wt. %)	Ag (Wt. %)	Ce (Wt. %)
A	93.5	6.5	-	-
B	91.16	6.34	2.5	-
C	91.63	6.37	-	2
D	89.29	6.21	2.5	2

2.2 Corrosion Test

Electrochemical method was used to found the corrosion current and corrosion potential by using Tafel method. This tester consists of electrochemical cell and its electrodes ,the cell made from glass and contains three electrodes are reference electrode (saturated -calomel electrode), auxiliary electrode (platinum electrode), and working electrode contains the specimens. The anodic and cathodic polarization curves are plot automatically, the solution used for the test was sea water, which was prepared from (3.5%) of pure sodium chloride salt added to distilled water.

2.3 Microhardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may be also refer to resistance of bending, scratching and cutting. Hardness tests are very simple to perform and they can be performed on production parts as quality control checks without destroying the parts. They depend on measuring the amount of deformation caused when a hard indenter is pressed into a surface with a fixed force. [F. William Hosford,2005]. In this test uses Vickers device ,this test uses a pyramidal indenter with a square base, made of diamond. The angle between the faces is (136°). Microhardness test is widely used to study fine scale changes in hardness.

2.4 Microstructure of Alloys

Microstructure of alloys were appeared after homogenization at (400X) by using (SIMRAN optical microscope made in USA). All the specimens were grinding and polishing before procedure any test. The grinding process is the abrading of the specimens by using aluminum oxide paper of grit size (180, 400, 600, 800, 1200 and 2000) and water where the grinding was done on an electric rotary wheel type (Hergon). The polishing process was done by the same electric rotary wheel by using cloth polishing and diamond paste, the specimen surface was etched to reagent solution which consists of (99.5% distilled water, 0.5% HF), then the specimen washes by distilled water and alcohol.

3. The Results and Discussion

3.1 Corrosion Results

From table (2) and figures (1,2,3,4) we show that the addition of silver leads to increase of corrosion current and this means decrease of corrosion resistance of (Al-Si) alloy because sliver tends to precipitate at grain boundaries, these sliver rich zones are more noble/catholic than the surrounding aluminum matrix and act as preferred sites for corrosion through galvanic coupling. Sliver precipitates dissolve in the anodizing electrolytes leaving holes in the oxide, and solute sliver migrates under the high electric field towards the aluminum/oxide interface compromising the anodic film properties . Addition of cerium leads to decrease of corrosion current and this means increase of corrosion resistance and addition of silver, cerium together leads to increase of corrosion current and this means decrease of corrosion resistance of (Al-Si) alloy. The corrosion current of (C) alloy improved by (18.2 %), while the best voltage of corrosion in (D) alloy by (8.42 %) of base alloy. The addition of (Ce) improves the corrosion uniformity of the anode due to the fine equiaxed grains and grain boundaries where (Ce) particles uniformly distributed. The results indicate that the microstructure, electrochemical characteristics and corrosion uniformity can be improved significantly after adding (Ce). Cerium has low resistivity coefficients and atomic radii that are relatively different from that of aluminum. These characteristics cause solute element to react with crystal defects such as dislocations and grain boundaries and enhance the mechanical properties of the base metal [Sakr and *et al*.,2010].

Table (2) Value of the corrosion current, corrosion potential

Code of alloy	$I_{corr.}$(µA/cm^2)	$E_{corr.}$(mV)
A	12.32	-820
B	24.27	-768.3
C	10.08	-755.3
D	14.69	-751

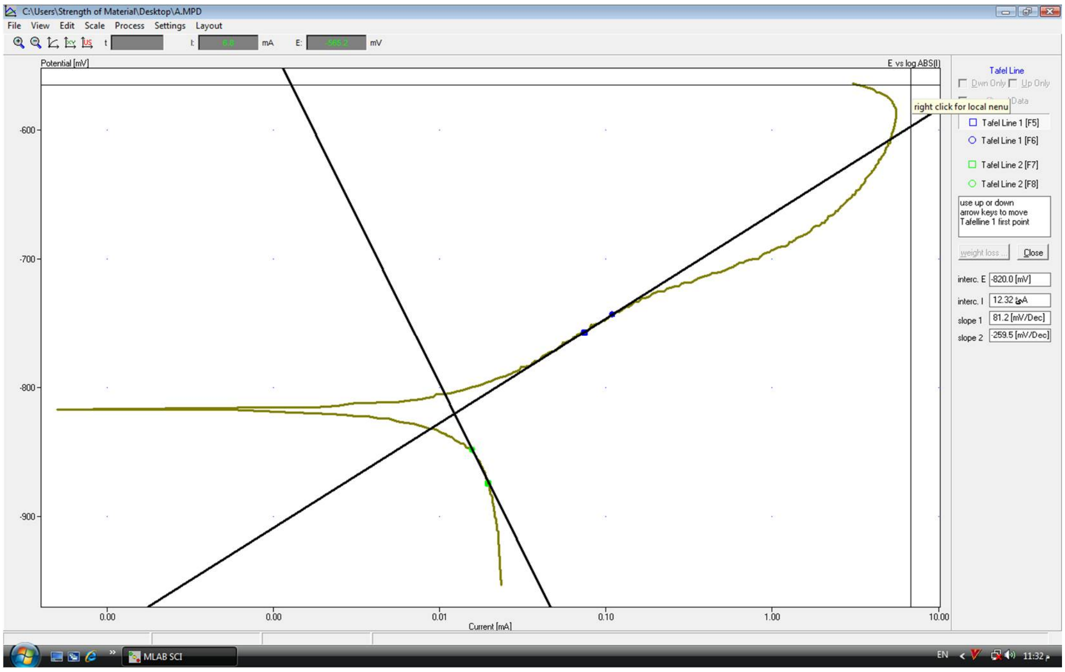

Fig.(1) Tafel curve of (A) alloy

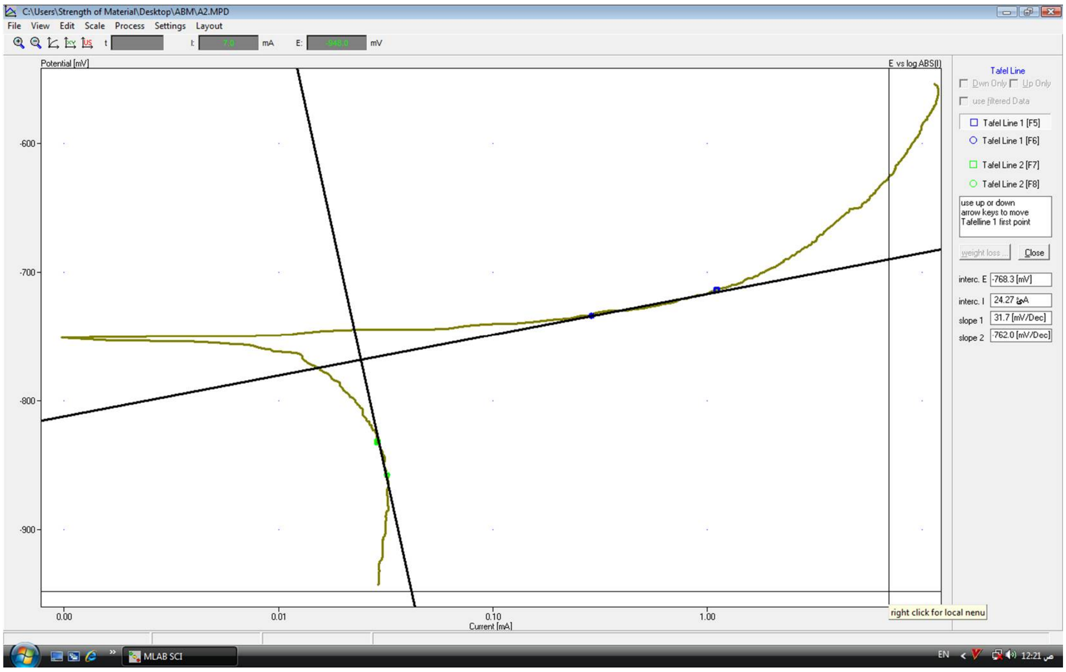

Fig.(2) Tafel curve of (B) alloy

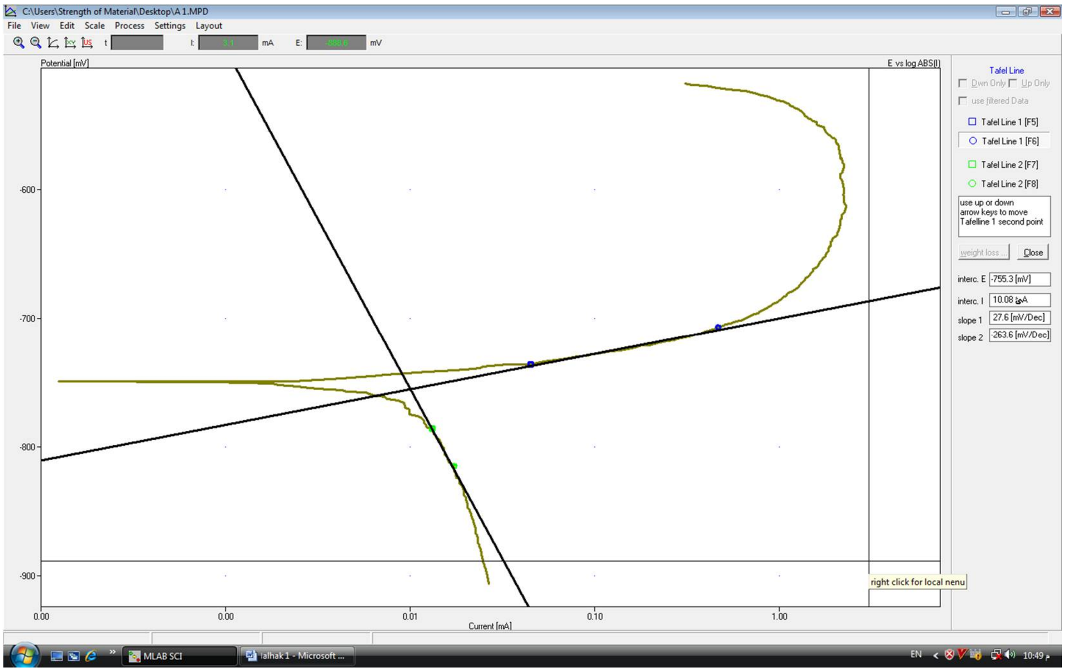

Fig.(3) Tafel curve of (C) alloy

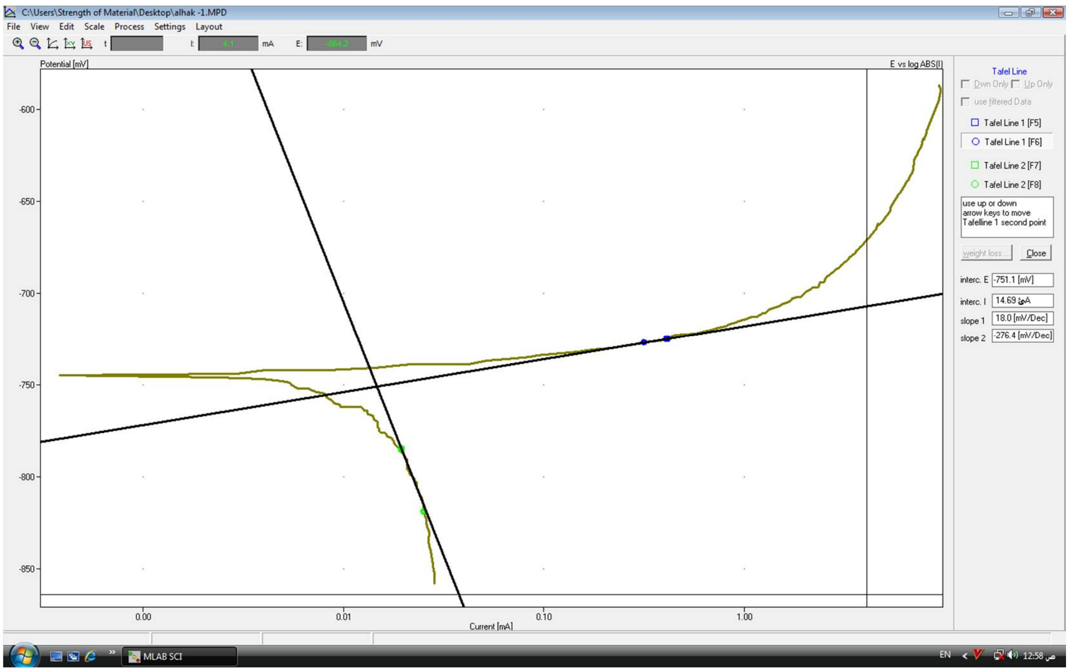

Fig.(4) Tafel curve of (D) alloy

3.2 Microhardness Results

Table (3) shows that addition of silver leads to increase microhardness, addition of cerium leads to decrease microhardness and addition of cerium with silver together leads to increase microhardness to master alloy because the alloying element (Ag) accelerated and refined the precipitates which formed previously in base alloy (A) alloy. The addition of sliver is very effective in refining the particles, and dispersed more uniformly near the grain boundary. Silver additions also bring about greater hardening response and therefore facilitate. Nucleation of the precipitates in a finely divided state.

Table (3) Microhardness of the alloys as homogenized

Code of alloy	Vickers microhardness (HV) (Kg/mm^2)
A	55.2
B	71.6
C	50.9
D	60.55

3.3 Microstructure Results

The microstructures were different, where figure (5) shows light areas with rounded particles (aluminum) are crystallized, which are surrounded by networked structure of dark fine areas, and revealed the presence of α-Al dendrites and eutectic silicon. Also this Figure shows non-uniform distribution of acicular needles-like Si particles in the matrix of α-Al. Un-modified (Al–Si) cast alloys, the eutectic Si particles have a coarse, acicular and polyhedral morphology and the final mechanical properties of an alloy is characterized by their distribution in the microstructure [F. Grosselle and *et al*, 2009].The eutectic structure is refined by addition of (Ag) and (Ce) .The changes in the morphology of eutectic silicon would effect on the hardness and corrosion resistance. Figures (6,7,8) show that silver and cerium addition lead to refine grains of alloys. Cerium will modify Si phase from acicular need. The addition of cerium resulted in the formation of (Al-Ce) and (Al-Si-Ce) intermetallic phases which led to the improvement of hardness and wear resistance. It has also been reported that (Ce) reduced interdendritic spacing of the alloy which can resist the movement of dislocation. In addition, the strengthening effects of (Ce) atoms segregated at the grain boundary have the contribution of keeping the highest tensile properties. That is, to say, the main reason that makes the segregation of (Ce) atom at grain boundary increases the sliding resistance of the grain boundary increase the mechanical properties [Sakr *et al.*,2010].

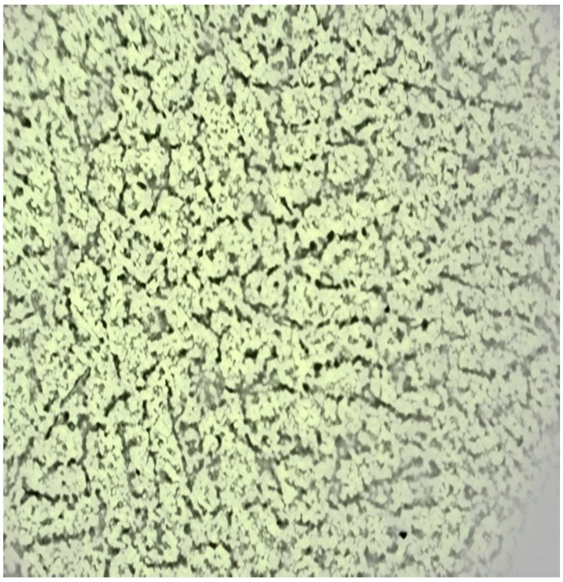

Fig. (5) Microstructure of (A) alloy

Fig. (6) Microstructure of (B) alloy

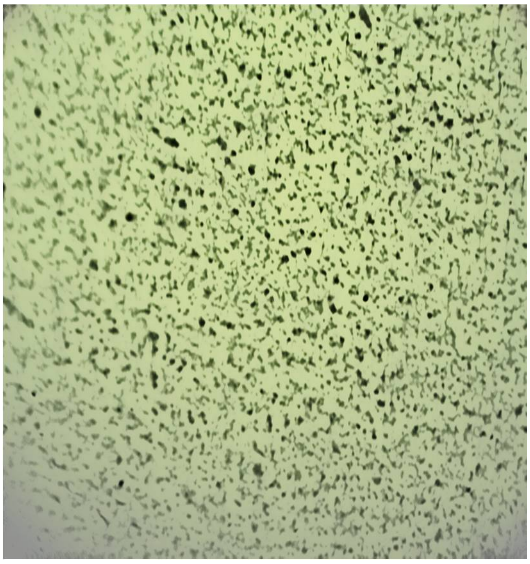

Fig. (7) Microstructure of (C) alloy

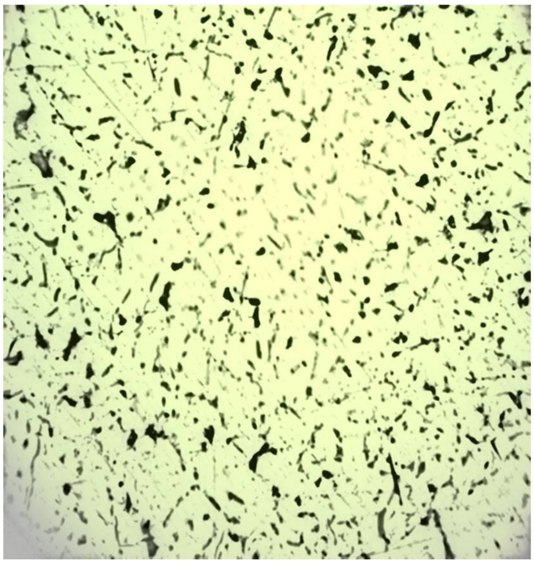

Fig. (8) Microstructure of (D) alloy

4. Conclusions

The aluminum alloys are important in many industrial applications because of their light weight and good mechanical properties. The results of present work refer to:-

- Addition of sliver to base alloy leads to improve microhardness by (29.7%) and decrease corrosion resistance.
- The addition of cerium improves corrosion resistance where corrosion current of (C) alloy improves by (18.2 %) but leads to decrease microhardness.

- The addition of sliver with cerium together to base alloy leads to improve microhardness by (9.7%) and decreases corrosion resistance but less than from addition of sliver alone.
- The best corrosion resistance is in (C) alloy.
- The best microhardness is in (B) alloy.
- The best voltage of corrosion is in (D) alloy by (8.42 %) from base alloy.
- The addition of sliver and cerium leads to refine grains of alloys.

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