Effect of Heat Treatment on Microstructure and Corrosion Parameters of Alloys (Al- 4%Cu) and (Al- 4.1%Cu- 0.9%Mg)

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ABSTRACT:

This work aims to study the effect of the heat treatment (precipitation hardening) on microstructure and corrosion parameters of two alloys (Al- 4%Cu) and (Al- 4.1%Cu- 0.9%Mg). They were prepared by melting and casting in a metallic mold. Hot rolling at 450C° was carried out on ingots by 50% deformation of two alloys to get sheets. Many tests were conducted on these prepared alloys of cast and wrought conditions, including microstructure and hardness and corrosion test. Precipitation heat treatment was carried out which included solution heat treatment at 515C° and aging. Two types of aging, artificial aging at 190C° for 3hr and natural aging at 25C° for 7 days were carried out on prepared alloys in order to indicate the effect of these heat treatments on the microstructure and hardness. Electrochemical corrosion test by Tafel extrapolation method was carried out on all prepared samples of alloys in sodium chloride solution of 3.5% NaCl (PH=8.2) to determine corrosion parameters. such as corrosion potential (Ecorr.),corrosion current (Icorr.) and corrosion rate (mpy). The results show that the corrosion rate of cast samples and homogenized treated was lower than that of wrought samples of two alloys (Al- 4%Cu) and (Al- 4.1%Cu- 0.9%Mg) in salt solution at room temperature. Precipitation heat treatment and artificial aging at 190C° for both cast and wrought conditions lead to increase corrosion rate. The results also show that the addition of Mg to (Al-4%Cu) alloys reduce corrosion current density(I_{corr}.) and corrosion potential (E_{corr}) shifts to more noble direction in 3.5% NaCl solution for two alloys in cast and wrought conditions.

تاثير المعاملة الحرارية على البنية المجهرية وعوامل التأكل للسبيكتين

(Al-4%Cu) و (Al-4.1%Cu-0.9%Mg)

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ملخص البحث

يهدف البحث الى دراسة تأثير المعاملة الحرارية (الاصلاد بالترسيب) على البنية المجهرية وعوامل التأكل للسبيكتين(Al-4%Cu) و (Al-4.1%Cu-0.9%Mg). وتم تحضير السبيكتين بعملية الصهر والصب في قوالب معدنية. وتم أجراء عملية التشكيل على الساخن بنسبة ٥٠% في درجة حرارة 450C° لغرض الحصول على عينات مشكلة. وقد أجريت أختبارات عديدة شملت فحص البنية المجهرية ، الصلادة الدقيقة وأختبار التأكل. وأجريت المعاملة الحرارية بالترسيب (الأصلاد بالترسيب) لكل من العينات المسبوكة والمشكلة والتي تتضمن المعاملة الحرارية المحلولية في 515C° والتعتيق. حيث أجري التعتيق على نوعين ، التعتيق الصناعي في 190C° لمدة ٣ ساعات والتعتيق الطبيعي في 25C° لمدة ٧ أيام لجميع العينات المحضرة لبيان تاثيرها على البنية المجهرية والصلادة.

أجري أختبار التأكل الكهروكيمياوي باستعمال طريقة تافل لأسنكمال منحنيات الأستقطاب لجميع العينات المحضرة في محلول ملحي من كلوريد الصوديوم(3.5% NaCl) ذو دالة حامضية (PH=8.2) لغرض تحديد عوامل التأكل وهي جهد التأكل (.Ecorr) ،تيار التأكل(.Icorr) ومعدل التأكل (mpy).

أوضحت النتائج أن معدل التأكل للعينات المسبوكة والمجانسة حراريا كان أقل مما هو هي في حالة العينات المشكلة ولكلأ السبيكتين (Al-4%Cu) و (Al-4.1%Cu-0.9%Mg) في المحلول الملحي. وكذلك وجد ان المعاملة الحرارية بالترسيب والتعتيق الصناعي في 190C° ولكلأ الحالتين المسبوكة والمشكلة أدت الى زيادة معدل التأكل. وأوضحت النتائج ايضا ان أضافة المغنيسيوم الى السبيكة (Al-4%Cu) أدى الى تقليل كثافة تيار التأكل وميل جهد التأكل (Ecorr) بالأتجاه الأكثر نبلأ (الأقل ساليبة) في محلول (3.5% NaCl) ولكلأ السبيكتين في الحالتين المسبوكة والمشكلة.

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1- Introduction

The corrosion resistance of aluminum and most of its alloys is high. This is due to the dense impervious oxide film (Al_2O_3) prevent further oxidation[1].The alloys containing copper are the least resistance to corrosion, but this can be improved by cladding[2]. Al-Cu alloys are at one time widely used for gears-boxes ,sumps and other automobile casting for cases for switch gear, for industrial fitting[3]. Aluminum alloys can be divided into two groups cast alloys and wrought alloys .The aluminum alloys can be heat treated to improve mechanical properties and to changing the corrosion resistance.

Muller and Galvele [1977][4] first studied the effect of copper on Eb (breakdown potential) value for aluminum in different concentration of NaCl solution. They found that the presence of copper in solid solution in aluminum shifts Eb to more noble values.

Boger R.K [2003][5] reported that the aged specimens are more susceptible to pitting corrosion than that of solution heat treated ones. They attributed these results to the weak passive film formed on Al_2CuMg, the strengthening phase in the aged alloyed.

Zlaticanin B. et al [2003][6] they studied the microstructure and properties of alloys(Al-Cu-Mg)with chemical composition of (1-5%Mg) and (4.9-5.3%Cu).They concluded the addition of Magnesium allows the formation of more intermetallic compounds such as Al_2CuMg ,AlCuMg an $AlCu_6Mg_2$ in the microstructure and the strength was improved.

Srinivasa Rao and Prasad Rao[2004][7] they studied the mechanism of pitting corrosion of heat treatable Al–Cu alloys. Pitting corrosion involves three stages, pitting initiation ,metastable pitting and pitting growth.

The aim of this work is to study the of effect of precipitation heat treatment with different aging on microstructure and corrosion parameters in 3.5%NaCl solution of prepared alloys (Al-4%Cu)and (Al-4.1%Cu- 0.9%Mg) in cast and wrought conditions.

2- Experimental Works

2-1 Alloys Preparation

       Two alloys of (Al –4% Cu) and (Al –4.1% Cu – 0.9%Mg) were prepared by casting process which is involved melting and pouring the melt in steel mould in following steps:

1- specified known weight of pure aluminum (99.99% purity) was melted in an alumina crucible in an electric furnace (Carbolite made in Japan) checking the temperature of the furnace by thermocouple (Type K) at temperature of 750 C°. The specified weight of pure copper with (99.95%) purity (12 gm) was added to molten aluminum with hand stirring of melt with stainless steel rod and adding 2% flux (CaF_2) to melt.

2- A specified weight percentage (1.0 %) of magnesium as master alloy (Al – 2.2 % Mg) was added to the aluminum melt (or molten aluminum).

3- Passing pure argon gas into the melt for five minutes and finally the melt was poured in the steel mold which was designed for this purpose and it was left to cool down in the air.

4- Ingots of aluminum alloys (Al-4%Cu) and (Al-4.1%Cu-0.9%Mg) were prepared in dimensions of (40*50*150) mm. The chemical composition analysis was carried

out of two groups of prepared alloys by using spectral analysis device of spectrometer type ARL. Results of the analysis are shown in **Table (1).**

5- Homogenization treatment was carried out at 350C° for 2hr in electric furnace for two ingots to stress relive and to obtain uniform microstructure of cast alloys (A and B) [8].

6- Metal forming process by hot rolling at 450 C° carried out on produced alloys of 50% reduction (using rolling machine) to eliminate the defect which may result from casting of ingots(A and B). The thickness of produced specimen after rolling was 2mm,

7- Precipitation heat treatment included of solution heat treatment and aging was made for both alloys A(Al-4%Cu) and B(Al-4.1%Cu-0.9%Mg) in electric furnace at temperature 515C° for 30min ,15 min for casting and wrought alloys respectively, and quenching in water was followed by aging process at 190C° for 12hr and 3hr for casting and wrought alloys respectively. Solution heat treated at 515 C° for 15 min then followed natural aging at room temperature for 7days was carried out on two wrought specimens of alloys group A(Al- 4% Cu) and group B (Al – 4.1%Cu – 0.9%Mg) alloys[8]. **Table (2)** Shows classification of cast and wrought specimens

2-2 Specimens Preparation for Microstructure and Hardness test

The preparation for microstructure test was carried out by wet grinding by grinder machine (Metarix made in Japan) with using emery papers with (220, 320, 500 & 1000) grades respectively under the running tap water. Polishing process by polishing machine (Muramoto Vogyo Japan- Kaisha) by using of (Al_2O_3 solution) with special cloth.and washing the specimens under the tap water and with distilled water, and dried by drying machine. Etching process by killer's solution (1 ml HF + 1.5 ml HCl +2.5 ml HNO_3 + 95 ml distilled water) was carried out for inspection the microstructure of specimen[9]. The computerized optical microscopy (Type MeF_2) and digital camera was used to examine the microstructure of all prepared specimens of alloys group A (Al- 4%Cu and group B(Al- 4.1%Cu-0.9%Mg) at different conditions of heat treatments .

Hardness test was carried for all prepared polished specimens by using Vickers's hardness machine. The applied load (300gm) was kept for 20 second for each reading the Vickers hardness (HV) was calculated [9].

2-3 Corrosion Test

The corrosion tests were done to measure the corrosion rate for two groups (A and B) by Tafel Extrapolation method in solutions of 3.5% NaCl solution (0.6 M NaCl).with molecular weight 58.59g / mol and purity 99.99%.

2-3-1 Specimens Preparation

Piece of (1cm *1cm) dimensions of specimen was cut from the alloys in order to fit the specimen in cold mounting (Akcryckral) and in-cold setting resin. Hardener introduced fine copper wire for electrical connecting which is designed for electrochemical studies. The surface to be tested was ground with emery paper of grades (220, 320, 500 and 1000) respectively, then process was followed by polishing with special cloth and aluminum solution of particles 5 μm in the first stage while the second stage was employed by the use of 0.5 μm.

2-3-2 Electrochemical Corrosion cell (Polarization Cell)

The three electrodes cell is the standard laboratory apparatus for the quantitative investigation of the corrosion behavior of materials .The three electrodes cell, can be used in many different types of corrosion experiments.

1. The working electrode is the name given to the specimen being used investigation. It is designed to have a surface area of (1 cm^2).

2. The counter (auxiliary) electrode-platinum electrode.

3. The reference electrode, saturated calomel electrode (SCE) is used in such an experiment.

The three electrodes are usually placed in a suitable glass vessel of capacity about (1) liter containing the chosen electrolyte.

Before polarization the open circuit potential was measured out by using 3.5%NaCl solution for corrosion test (solution of pH 8.2) . After the supplying the solution 0.6M NaCl to the cell , the free-corrosion potential is measured with respect to (SCE) with switch time using the digital millimeter (Vc8135 No.2). E$_{corr}$ value is recorded, till it reaches steady state value. This steady state value can be considered the actual E$_{corr}$ in this environment**.**

2-3-3 Polarization Measurements by Tafel Extrapolation Method

The polarization was carried out in one Liter breaker consisting of working electrode، counter electrode (pt-electrode) and reference electrode (calomel electrode) as shown in **Figure(1)**. The working electrode is aluminum alloy with surface area of (1 cm ^{2}) hold by fine copper wire for electrical connection which is designed for electrochemical studies. The counter electrode is a platinum seated directly opposite to working electrode. The reference electrode bridged by a Laggin – Haber probe. The distance between the electrode surface and the Laggin – Haber capillary is set at about the optimum value of 1 mm to minimize the experimental error due to IR drop[10].

For the cathodic polarization the potential is E_{corr} and change ± 10 mv/2 min for each step and current is measured by an ammeter. After allowing time for equilibrium, the potential is recorded then its considered that a steady state is achieved. However, it was noted 2 minutes after each step.

3- Results and Discussion

3-1 Effect of Heat Treatment on Microstructure and Hardness

Figures (2) and (3) show the microstructure of alloys A_1 (Al-4% Cu) and B_1 (Al-4.1% Cu- 0.9% Mg) as cast and homogenized . Homogenization was made to stress relief and reduce residual stress after casting and to distribute uniformly the impurities and undissolved phase or particles. The alloys were homogenized at (350C°) for 2hr to reduce segregation at grain boundaries and remove low melting non equilibrium phases and improve workability.

Figures (4) and **(5)** show the microstructure of alloys A_2 (A1 – 4%Cu) and B_2 (A1- 4.1%Cu- 0.9%Mg) as cast. They were homogenized and solution treated at (515C°) for 0.5 hr and aged at (190C°) for (12) hr. The microstructure consists of solid solution of Cu in A1 (α) and particles Al_2Cu, ($\emptyset$), but when the heating rate is high much of the (Al_2Cu) remains undissolved .

Alloys A_3(Al- 4%Cu) and B_3 (Al- 4.1%Cu- 0.9%Mg) as wrought solution treated at (515C°) for 15 min and aged at (190C°) for 3hr. Those heat treatments are used for mill products to increase hardness and strength. This is due to precipitation of hard phase or particles (Al_2Cu), (Al_2CuMg) in the matrix of alloy (Al-4%Cu) and (Al-4.1%Cu -0.9% Mg) respectively as indicated by X-ray diffraction analysis (see Appendix A). These results are in agreement with those of other researchers [11] .

Figures (6) and (7) show the microstructure of alloys (A$_4$ and B$_4$) as wrought solution treated at (515C°) for 15 min and aged at room temperature for (7) days. This heat treatment improves the properties and increase the hardness to value (100 Hv), (128Hv) for alloy (Al- 4%Cu) and B$_5$ (Al- 4.1%Cu- 0.9%Mg) respectively. See the **Table (3)** This result is in agreement with those other researchers [12]

It was found that the microstructure examination of two alloys (Al- 4%Cu) and(Al- 4.1%Cu-0.9%Mg) proves clearly the presences of precipitated particles ,(Al$_2$Cu) and (Al$_2$CuMg) in alloys after precipitation heat treatment in cast and wrought conditions as indicated by X-ray diffraction analysis.

3-2-1 Open Circuit Potential Measurements.

The variation in the open circuit potential (OCP) of alloy A$_1$(Al- 4%Cu) (as cast) and alloy B$_1$(Al- 4.1%Cu- 0.9%Mg) (as cast) in 3.5%NaCl solution at room temperature has been measured as shown in **Figure (8).** The potential generally changes from an initial negative value(-1500mV) (SCE), to the positive direction (-819mV) (SCE), (-811mV) (SCE) within about (120) minute, for alloys (A$_1$ and B$_1$) respectively after that the potential remains constant.

Sherif and Narayan [13] have suggested in their study that the open circuit potential

of aluminum, like those of other corroding metals, is a mixed potential. Equilibrium that control this mixed potential include:

1. Cathodic Reactions:

a. Reduction of dissolved oxygen,

$$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^- \text{ (neutral solution)} \ldots\ldots \text{ (1)}$$

b. Reduction of H ions, (acid solution) .

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O \qquad \ldots\ldots \text{ (2)}$$

C. Reduction of H+   ions,

$$2H^+ + 2e^- \longrightarrow H_2\uparrow \qquad \ldots\ldots \text{ (3)}$$

11- Anodic Reactions:

a. $Al \longrightarrow Al^{+3} + 3e^-$ \qquad .... (4)

b. $Al + 3OH^- \longrightarrow Al\,(OH)_3 + 3e^-$ \qquad ....(5)

c. $Al + 3Cl \longrightarrow AlCl_3 + 3e^-$ \qquad ....(6)

d. $2Al + 3H_2O \longrightarrow Al_2O_3 + 6H^+ + 3e^-$ \qquad ....(7)
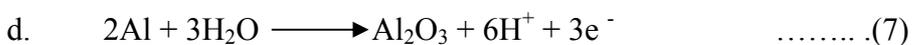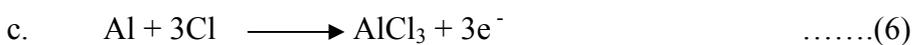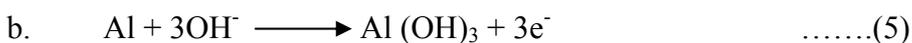
    In Figure (8) the potential was measured every two minutes for the first ten minutes and then five minutes for the remaining time. This continuous increase in corrosion potential was most likely the result of oxide film build up or formation of corrosion products on surface. The variation of open circuit potential with time depends on many parameters such as chemical composition, surface treatments, oxygen content …etc) [13]

Dibari and Read [14] found that the presence of oxygen in NaCl solutions of pH = 4 shift in the corrosion potential of about 70 mV .The open circuit potential depends also on the presence of chloride ions but not to a great extent on the concentration .All alloys in this study behave similarly where open circuit potential goes rapidly in the active direction from the moment of immersion until it reaches a steady state at value which remains constant with time .

3-2-2 Tafel Extrapolation Measurements Method

    Corrosion tests were performed on the tested samples of alloys (Al- 4%Cu), (Al- 4.1%Cu- 0.9%Mg) in 3.5%NaCl solution .The typical polarization curves are reported in **Figures (9) and (10)**. The current density values (Icorr.) calculated from Tafel Extrapolation are listed in **Table (4).** The corrosion rate (mpy) was determined by using equation as follow [10]:

mpy = 0.13 Icorr. * e/ρ   …………………(8)

Where:

e: equivalent weight   e = 9.42 for alloy (Al-Cu-Mg)(2024 alloy)

ρ: relative density of metal (gm/cm^3)

Icorr. : Current density ($\mu m/cm^2$)

3-3 Effect of precipitation Heat Treatment On Corrosion Parameters

    In order to study the effect of heat treatments on the corrosion parameters (Icorr. and Ecorr.) of two alloys (Al- 4%Cu), (Al- 4.1%Cu- 0.9%Mg) in cast and wrought conditions, polarization curves are reported for this purpose and the current density value (Icorr.) and corrosion potential (E_{corr}) determined from Tafel Extrapolation and drawing the cathodic and anodic polarization curves for each alloy(A_1, A_2, A_3 ,A_4) and((B_1, B_2, B_3, B_4) in 3.5% NaCl solution are listed in **Table (4).** It was found that the corrosion potential (E_{corr}) of both (A_1 and A_2) before and after precipitation heat treatment and aging at (190C°) for 3hr,were -819 mV (SCE), -825 mV(SCE) of cast

alloys respectively. It was found that E_{corr} appears shifted to less noble (more active) potential by about 6mV. With respect to alloy(A_3)(as wrought) precipitation heat treatment and aging at 190Cº for 3hr. E_{corr} was (– 840 mV)(SCE) in 3.5% NaCl solution. This is due to wrought alloy that the condition of wrought surface is more active and catalytic to the H_2 evolution reduction than of cast surface of cast alloys[15].

The anodic part of the polarization curves shown in (B2)alloy (as cast) solution treated and aged at (190Cº) is very important to compare the pitting potential of alloy B1 (A1- 4.1%Cu-0.9%Mg) because the presence of copper in solid solution (α) and formation of the intermetallic compounds of phase Al2CuMg in structure rises the potential more positive than E_{corr} =(- 811 mV) and current density deceases. Corrosion rate of the alloy A1 (Al- 4%Cu) also is increased to value higher than that of alloy B1,and the Ecorr. potential is made more noble as indicated in **Table (4).**

The presence of alloying element in the (Al-4%Cu) such as magnesium improves the hardness of the alloy by precipitation of phases (Al_2CuMg), (Al-4.1%Cu-0.9%Mg) in matrix of alloy. In addition of hardening phase (Al_2Cu) reduce slightly corrosion resistance , this is due to coherency strains and stresses in matrix solid solution (α) when precipitates (second phase particles) segregate on grain boundary which are considered high energy regions and are highly susceptible to intergraunlar corrosion[15].

3-4 Microstructure of Alloys after Corrosion

Figures(11)and (12) show the pitting formed on the cast alloy A1(Al-4%Cu),and alloy B1(Al-4.1%Cu-0.9%Mg) after homogenization heat treatment the dark region represent pits in the surface after electrochemical corrosion in 3.5%NaCl and pits grow to larger size until they cover most of surface with increase potential. **Figures (13)** and **(14)** show the pits are indicated at weak points such as scratches, defects, precipitates and other particles on surface. **Figures (15) and (16)** show the micrographs of the alloyA3(Al-4%Cu) and B3(Al-4.1%Cu-0.9%Mg), suffer from pitting corrosion in as wrought condition after precipitation heat treatment and artificial aging, the number of pits increased ,the pits developed on the surface did not have any particular shape and different sizes. This behavior can be attributed to the microstructure of alloy which consists of single homogenous phase (α) since solution

heat treated and aging lead to the formation of (Al_2Cu) precipitates on the grain boundaries whose E_b is less noble than the grain boundaries regions leading to the preferential attack of the grain boundaries regions[5],

Figures(17) and (18) show photomicrographs of alloy (A4) and (B4)surface after the potentiostatic polarization test in 3.5%NaCl solution , the pits developed are less in number and smaller size than that of alloy A3 and B3. But the presence deformation lines on the wrought alloy (A4) surface encourage the pitting corrosion and it was much severer than that of cast alloy A2 because those regions were high energy surface area when the passive film was weakened by those defects[15]. **Muller and Galvele** (1977)[4] have also observed that the aging of (Al-4%Cu) alloys which are susceptible to intergraunlar corrosion is attributed to precipitates of second phase particularly (Al_2Cu) (θ) that can lead to the creation of copper. depleted zones.

4-Conclusions

1- Precipitation heat treatment increases the hardness of (Al -4% Cu) and (Al - 4.1%Cu- 0.9%Mg)alloys in cast and wrought conditions.

2- Precipitation heat treatment has significant effect on corrosion rate by Tafel Extrapolation method, corrosion rates for cast alloys are less than those of the wrought alloys in 3,5%NaCl solutions.

3- Artificial aging treatment increases the corrosion rate to higher values in comparison with natural aging treatment .

4- It was found corrosion potential (E corr.) of wrought specimens was less noble (more negative in direction) than that of cast specimens.

5- Wrought aluminum alloy and precipitation heat treated are subjected to pitting corrosion more severe than that of cast and precipitation heat treated.

6- It was found the addition of (Mg) to (Al-4%Cu) shifts the Ecorr for more noble direction .

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Table (1) The chemical composition analysis of prepared alloys used in this study

Element wt %	Cu	Mg	Fe	Si	Mn	Ti	Al
Alloy A	4.08	0.09	0.3	0.21	0.01	0.003	Rem.
Alloy B	4.1	0.9	0.3	0.21	0.01	0.003	Rem.

Table (2) Shows classification of specimens used in this study

Alloy	Composition	Condition	Head treatment
A1	Al-4%Cu	As cast	Homogenization at 350C° for 2hr
A2	Al-4%Cu	As cast	Homogenization + S.T. 515 C° for 30 min. +Aging at 190 C° for 12hr
A3	Al-4%Cu	As wrought	S.T. 515 C° for 15min +Aging at 190 C° for 3hr
A4	Al-4%Cu	As wrought	S.T. 515C° for 15min +Aging at R.T. C° for 7days
B1	Al-4.1%Cu-0.9%Mg	As cast	Homogenization at 350C° for 2hr
B2	Al-4.1%Cu-0.9%Mg	As cast	Homogenization + S.T. 515 C° for 30 min. +Aging at 190 C° for 12hr
B3	Al-4.1%Cu-0.9%Mg	As wrought	S.T. 515 C° for 15min +Aging at 190 C° for 3hr
B4	Al-4.1%Cu-0.9%Mg	As wrought	S.T. 515 C° for 15min +Aging at R.T. C° for 7days

Table (3) The results of hardness of different studied alloys.

Samples		Hardness kg/ mm^2	Samples		Hardness kg/ mm^2
Cast	A$_1$	46	Cast	B$_1$	55
	A$_2$	89		B$_2$	110
Wrought	A$_3$	92	Wrought	B$_3$	121
	A4	100		B4	128

Table (4) The results of corrosion rates (mpy) , Icorr. (μA/cm²) and Ecorr (mV) of different studied alloys in solution 3.5 %NaCl

Samples	Ecorr (mV)	Icorr (μA /cm²)	Mpy
A1	-819	15	6.52
A2	-825	19	8.208
A3	-840	25	10.8
A4	-830	20	8.64
B1	-811	6	2.59

B2	-827	7	3.041
B3	-835	13	5.65
B4	-805	9	3.91
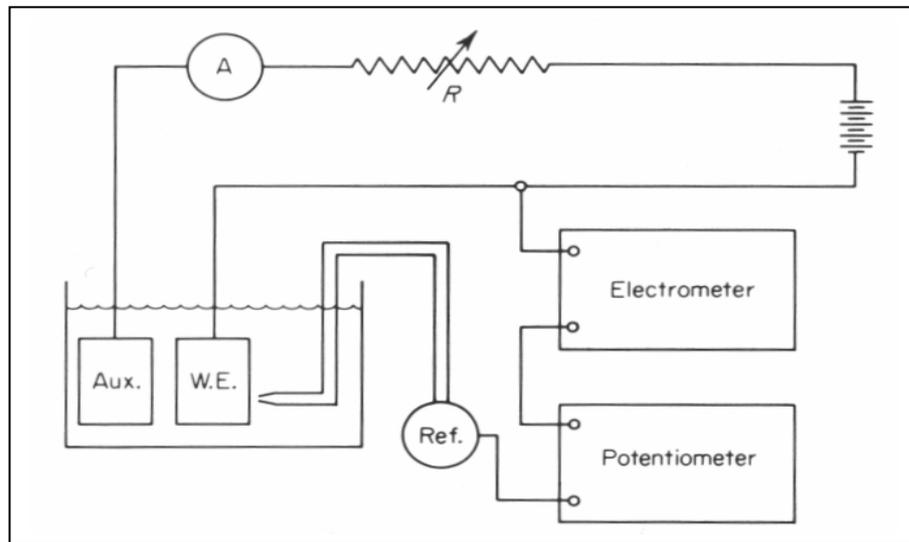
Figure (1)The electrical circuit connection for electrochemical test
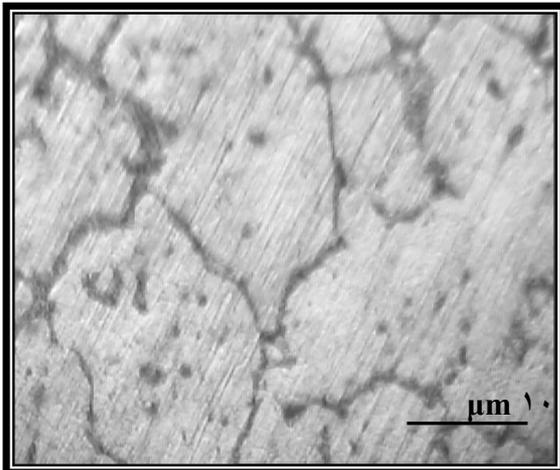
Figure (2) The microstructure of alloy A_1 (Al-4%Cu) (as cast + homogenized)
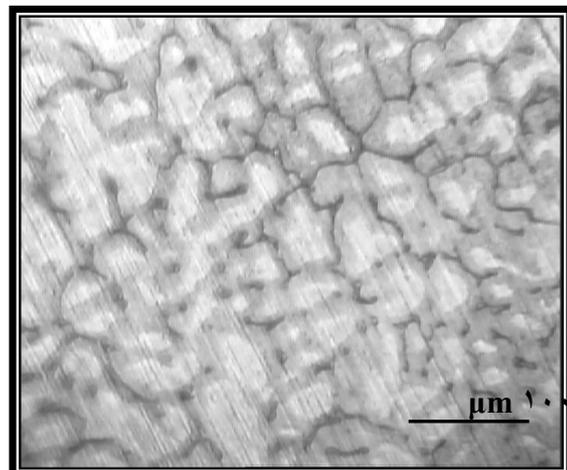
Figure (3) The microstructure of alloy B_1 (Al-4.1%Cu-0.9%Mg) (as cast+ homogenized)
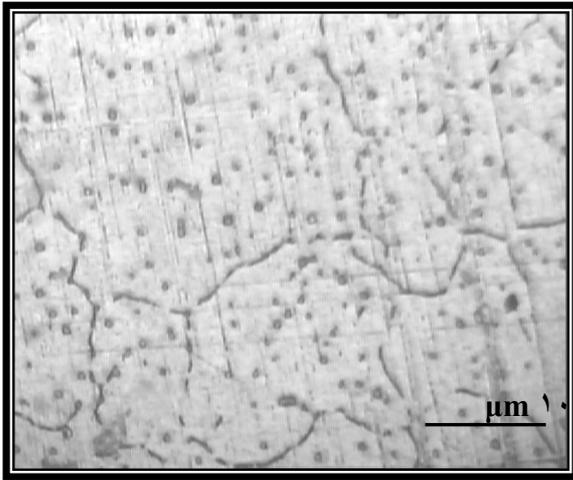
Figure (4) The microstructure of alloy A₂ (Al-4%Cu) (as cast +S.T+ Aging at 190 Cº for 12hr)
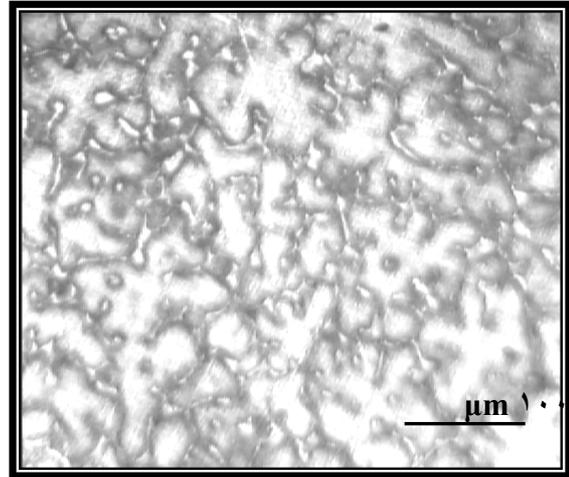
Figure (5) The microstructure of alloy B₂ (Al-4.1%Cu-0.9%Mg) (as cast +. S.T+ Aging at 190 Cº for 12hr)
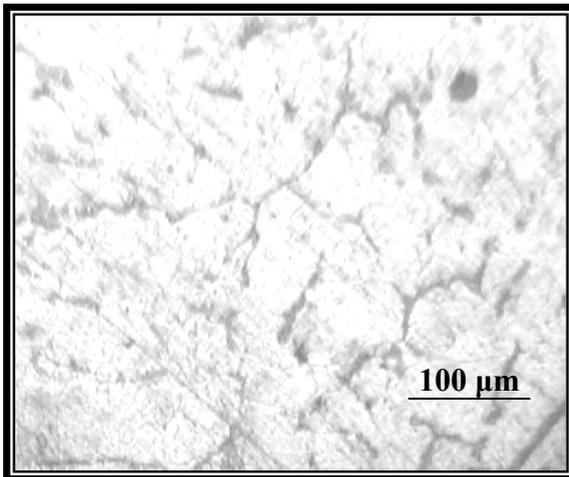
Figure (6) The microstructure of alloy A₄ (Al-4%Cu) (as wrought +S.T+ Aging at 25 Cº for 7 days)
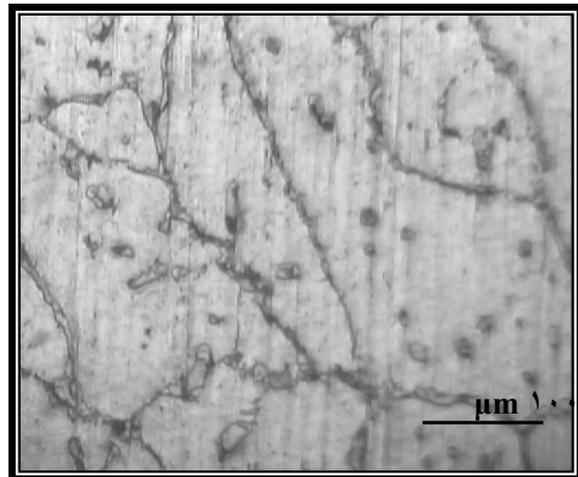
Figure (7) The microstructure of alloy B4 (Al-4.1%Cu-0.9%Mg) (as wrought +S.T+ Aging at 25 Cº for 7 days)
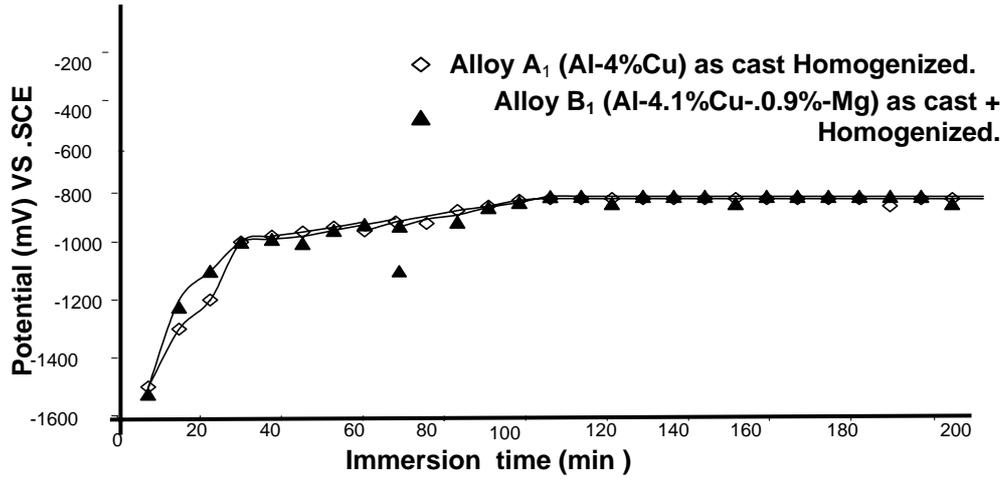
Figure (8) open circuit potential of alloy A1 (Al-4%Cu) as cast +homogenization and Alloy B1 (Al- 4.1% Cu - 0.9Mg) as cast + homogenization in 3.5% NaCl solution at as function of immersion time .
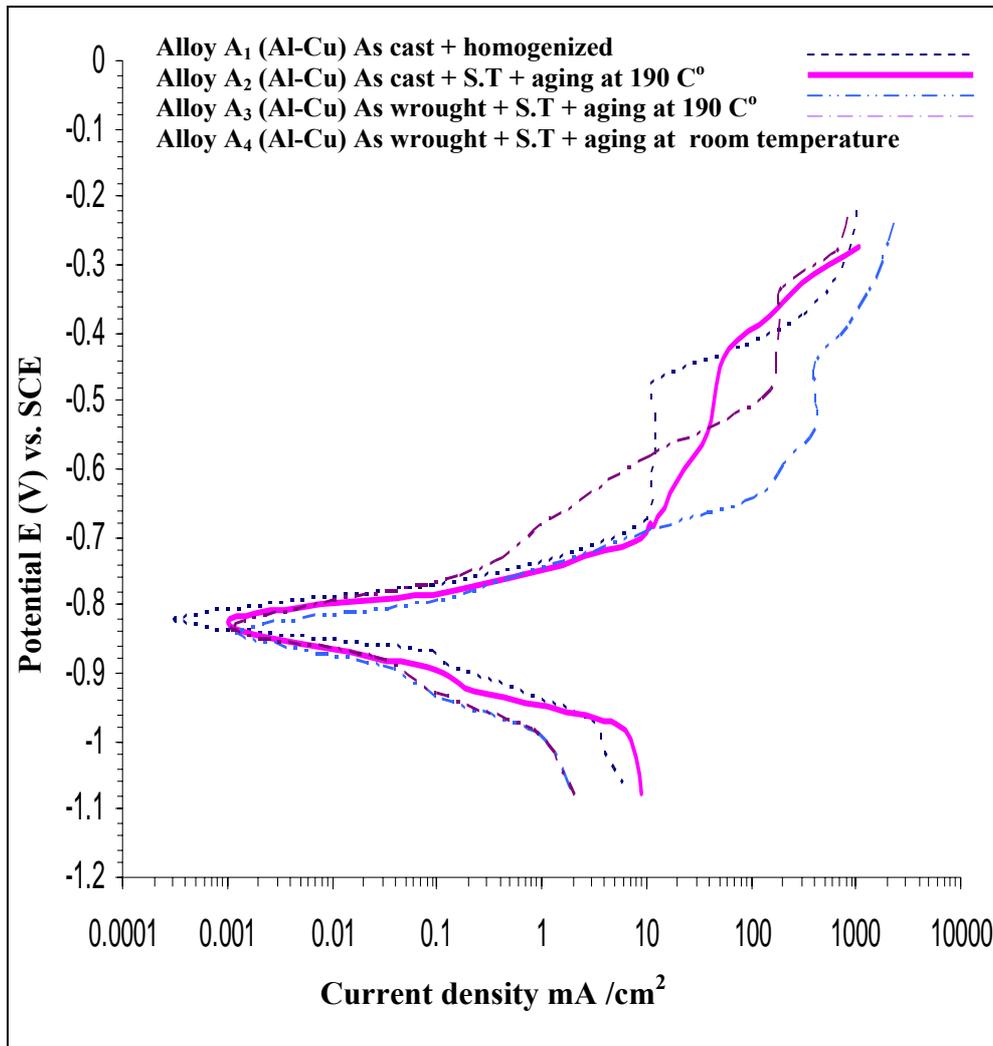
Figure (9) Polarization curves of alloys group A (Al-4%Cu) after different heat treatments in 3.5 % NaCl solution
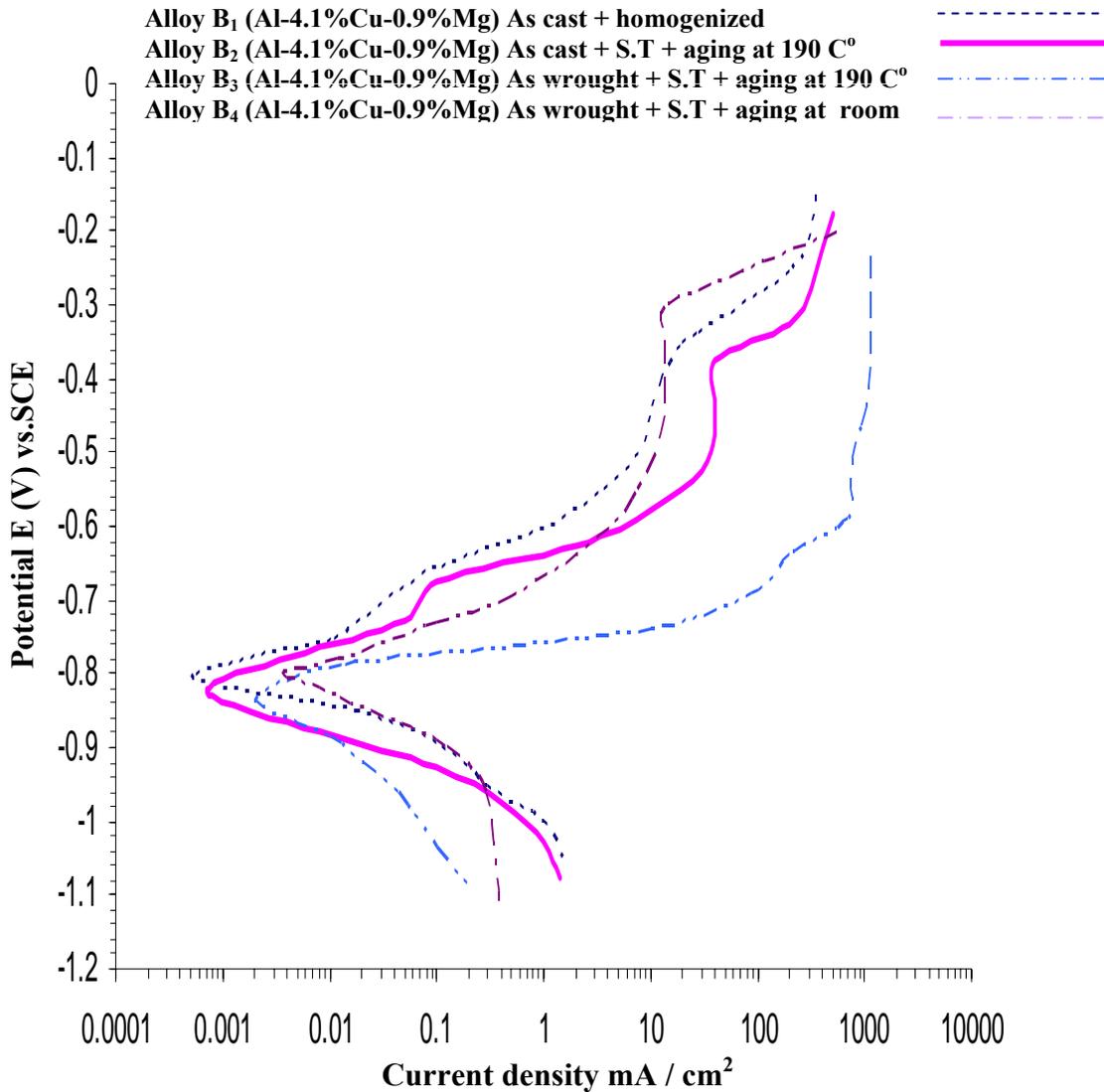
Figure (10) Polarization curves of alloys group B (Al-4.1%Cu-0.9%Mg) after different heat treatments in 3.5% NaCl solution.
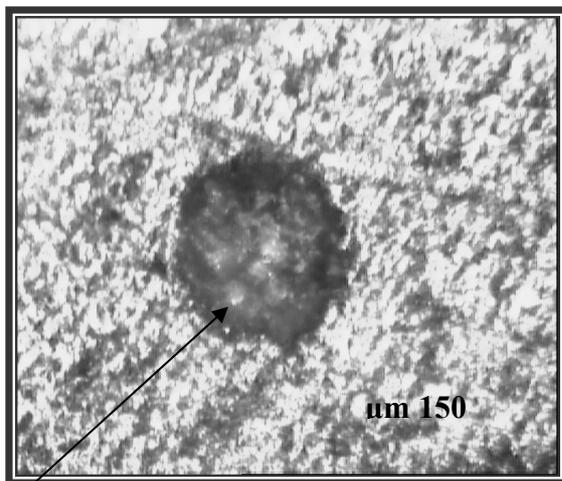

Figure(11) Micrograph of alloy A1 after exposed to the solution of 3.5% in NaCl

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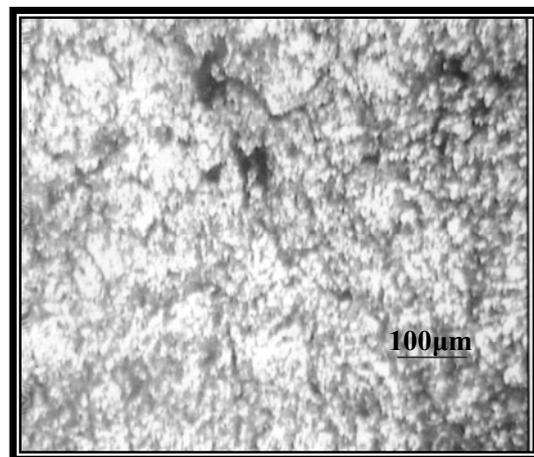
Figure(12) Micrograph of alloy B1 after exposed to the solution of 3.5% in NaCl
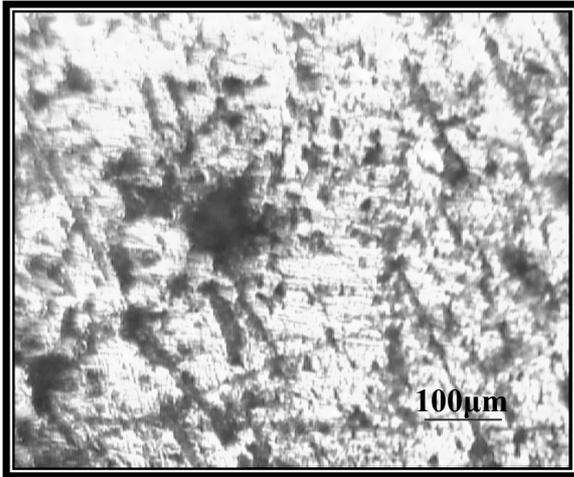
Figure(13) Micrograph of alloy A2 after exposed to the solution of 3.5% in NaCl
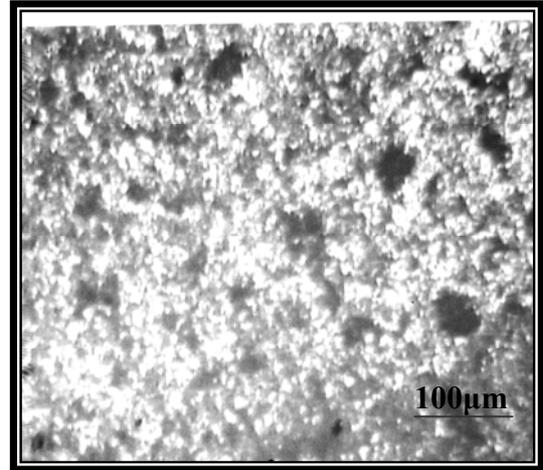

Figure(14) Micrograph of alloy B2 after exposed to the solution of 3.5% in NaCl
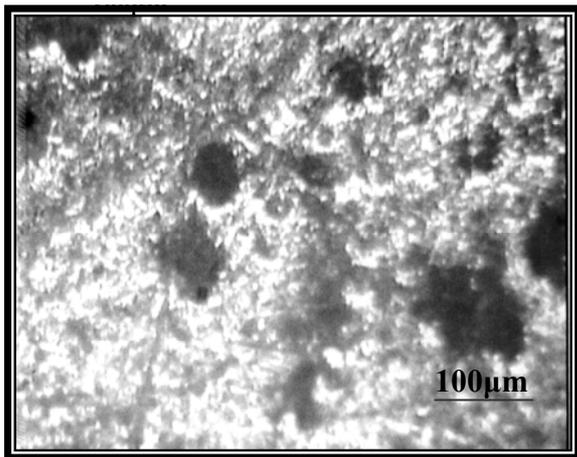
Figure(15) Micrograph of alloy A3 after exposed to the solution of 3.5% in NaCl
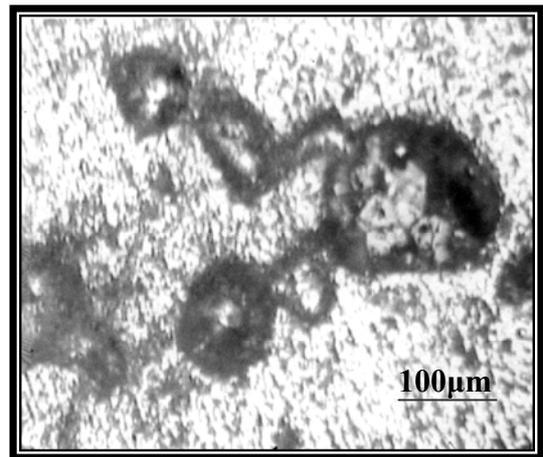
Figure(16) Micrograph of alloy B3 after exposed to the solution of 3.5% in NaCl
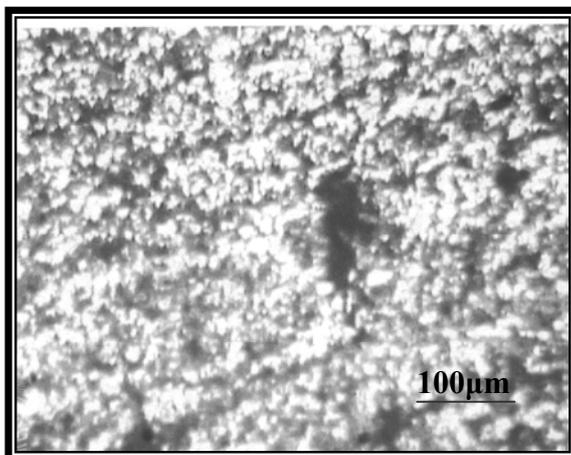
Figure(17) Micrograph of alloy A4 after exposed to the solution of 3.5% in NaCl
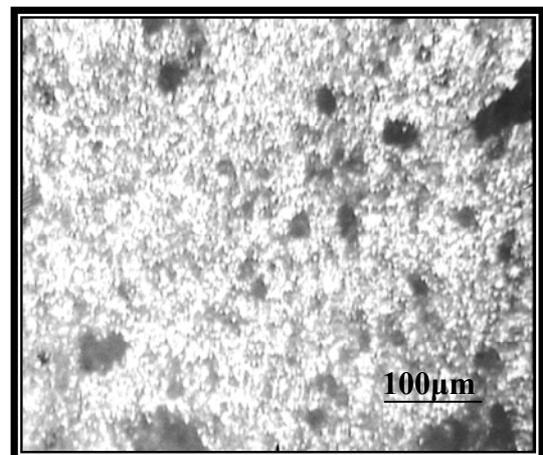
Figure(18) Micrograph of alloy B4 after exposed to the solution of 3.5% in NaCl

Effect of Heat Treatment on Microstructure and
Corrosion Parameters of Alloys (Al- 4%Cu) and
(Al- 4.1%Cu- 0.9%Mg)

Dr. Muna Khedier Abbas
Suhayla Noori Gareab
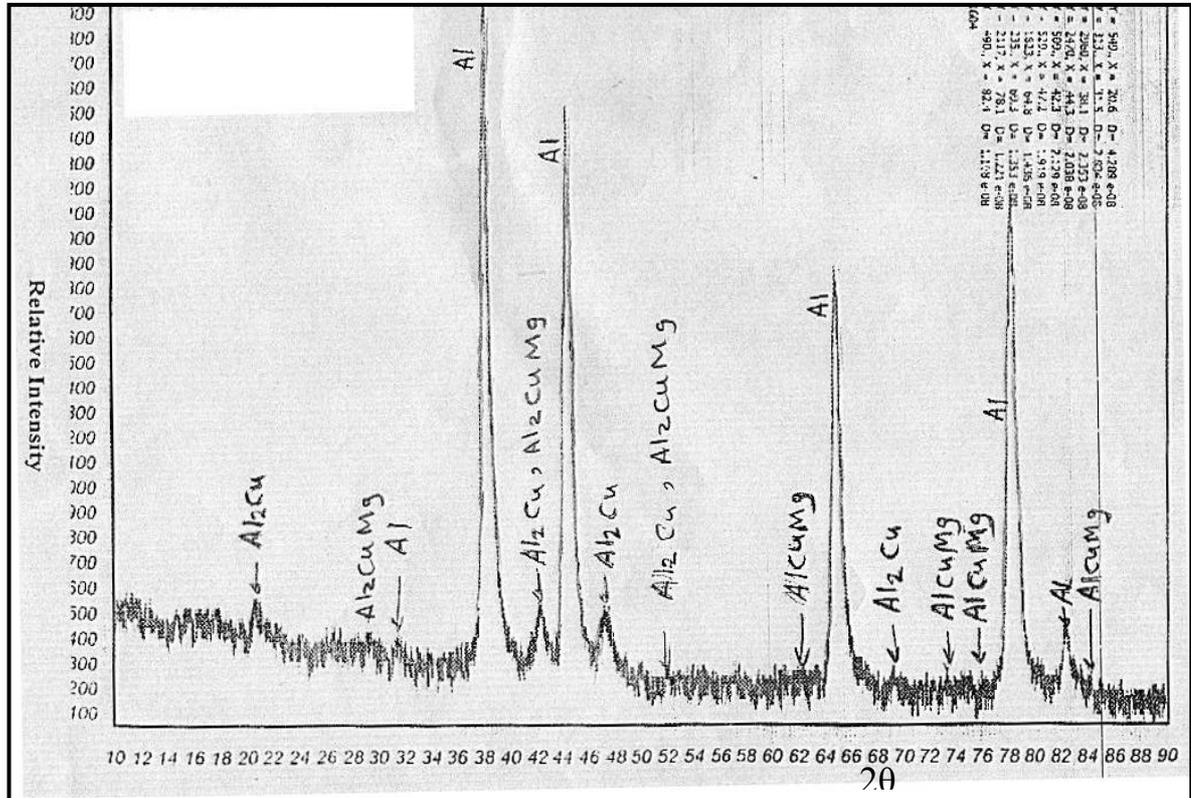
Appendix (A) X-ray diffraction analysis of wrought alloy(Al-Cu-Mg) after solution treatment and aging at 190 ºC for 3hrs