Diyala Journal of Engineering Sciences

ISSN 1999-8716

Printed in Iraq

Vol. 02 , No. ٠١ , pp. 96-108 , June 2009

STUDY THE EFFECT OF (Ti) ADDITION ON THE MICROSTRUCTURE OF EUTECTIC Al-12%Si ALLOY

Mustafa Ahmed Rijab

Technical Institute – Baquba / Mechanical Department.
(Received:26/10/2008 ; Accepted:18/4/2009)

ABSTRACT - The aim of this research is to investigate the effect of addition of titanium (0.05 and 0.1) % on the microstructure of AL – 12% Si alloy, as well as the effect of long term homogenization (525 ^{o}C) on the developed microstructures.

The microstructure results showed that the addition of 0.05% Ti exhibited a partial modification of the microstructure, while the addition of 0.1% Ti to the alloy showed a marked effect on the modification. Also the results showed that the transformation of silicon (Si) from needle or fibrous shape to spheriodal shape was observed during homogenization of the alloys. The spheroid shape of silicon (Si) particles was obtained via five different stages, namely; growth, fragmentation, spherodization, growth and stabilization of the spherodized silicon.

1. INTRODUCTION

Aluminum casting alloys are gaining wide popularity, as they combine several attractive properties such as low density, high stiffness, good casting characteristics, as well as improved properties if the alloy microstructure is refined or modified.

Al-Si casting alloys are particularly of great importance as they offer good casting properties, good corrosion resistance, in addition to improved wear resistance(1,2). However, the morphology of Si eutectic in these alloys is of great significance on controlling their properties, as it is usually grows in lamellar or fibrous or spheroidized form(3). When Al-Si alloys are solidified the eutectic silicon is seen to consist of coarse plates in the sharp edges. These are detrimental to the mechanical properties. However, soon afterwards the effect of modification was found. The addition of elements like Na, Sr, Sb, and Ti was found to induce an effect on the microstructure of the eutectic alloy depending on their addition procedure and amount. Both modes of refinement of (Ti) and modification of Na, Sr, Sb have an effect on microstructure, but in a rather different way, as the first control the nucleation rate rather than the morphology of the second phase (4), while modification alters the shape of the Si phase. Some other external factors like vibration or rapid solidification cause an alternation in the morphology of the Si eutectic (5,6).

Homogenization treatments, originally designed for Al-Si cast alloys, also has an effect on the Si particles morphology, as it changes their shape from lamellar to spheroid .

Al-Si casting alloys are known for their good casting properties and a great number of researches have been conducted on their refining and/or modification to optimize its mechanical properties(7,8). The eutectic morphology ranges from plate-like to lamellar like in as cast condition to a circular like after modification or rapid cooling(9).

The effect of modification has been attributed to both affecting nucleation and Si morphology through prohibiting its growth(10).

In many situations, like those in Iraq have gone through, when shortage of fresh Al happens, remelting of scrapped castings becomes unavoidable to obtain new castings. However, non homogenous microstructure and low mechanical properties are characteristic of these castings obtained by remelting, especially when the scrapped materials are made from modified alloys(11)

2. EXPERIMENTAL PROCEDURE:

The experimental program of this work consisted of producing a number of castings (5) by remelting scrapped castings made of Al-12%Si alloy in a gas furnace. The melt was refined by adding Ti in the range 0.05-0.1% Ti. The melt composition was controlled by adding fresh Al. the Ti was added in an elemental form, weighted and wrapped with Al foil.

The Ti-wrapped in foil was laid in the bottom of an alumina crucible and the molten metal was poured over it. The whole melt was held afterwards for 10 min in the gas furnace for melt homogenization. The molten metal was poured at 700 ^{o}C in a preheated steel mould.

The cast pieces were homogenized at 525 ^{o}C for different durations 1, 3, 5, 20, 40 ,100 & 150 hrs.

Table(1): shows the chemical composition of the five cast alloys.

	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Ni	Pb	Sn	AL
AL	0.114	0.327	0.009	0.003	0.008	0.028	0.008	0.001	0.00	0.001	0.00	99.51
AL-13%Si	13.00	0.279	0.021	0.172	0.007	0.027	0.00	0.018	0.007	0.013	0.005	86.40
AL-12%Si	12.25	0.266	0.020	0.187	0.005	0.026	0.035	0.012	0.006	0.012	0.002	87.21
AL-12%Si-0.05%Ti	12.12	0.264	0.022	0.185	0.007	0.030	0.045	0.014	0.007	0.013	0.003	87.34
AL-12%Si-0.1%Ti	12.13	0.262	0.021	0.192	0.007	0.030	0.108	0.015	0.007	0.013	0.003	86.08

3- RESULTS AND DISCUSSION

3.1. Microstructural Observations Of as Cast Condition

Figure 1 shows the as cast microstructure of the Al-12%Si cast alloys without Ti and with 0.05%Ti & 0.1%Ti, respectively. The microstructure is seen to consist of two phases mainly, which are primary α- Al and eutectic Si. Adding the 0.05%Ti is seeing to modify the Si-eutectic morphology slightly but has no effect on refining the primaryα. While, 0.1%Ti modifies the Si-eutectic morphology greatly and changes the primary α to have a fine dendritic structure. This effect is believed to be due to the role of Ti in reducing the melting point of the alloy, thus giving a higher chance for nucleation of the primaryα Al relative to the Si-eutectic, this is in turn refines the primary (α) phase and inhibits the Si growth.

3-2- Microstructural Observations Of Homogenized Conditions

Figures (2→5) shows the microstructure of the studied alloys after homogenization at 525 oC for 1, 3, 5, 20, 40 ,100 & 150 hrs respectively. The different surging times of heat treatment aims to detecting the changes that happens with the microstructure refinancing . The depicted changes in microstructure reveals that the Si-eutectic changes its morphology by heating at 525oC through five stages; nucleation, fragmentation, spherodization, growth, and finally stabilization.

The first stage, as seen in fig (2) after 1 hr, is a stage where growth of the Si starts by diffusion of Si from the matrix to the particles. After 3 hrs the Si starts to diffuse out of the Si-eutectic particles and fragmentation of these particles happens changing their morphology. After that, as seen in fig. (3), the Si particles becomes spheroidized for both alloys without Ti and with 0.1%Ti, where as, only partial spherodization happens in the alloy containing 0.05%Ti. The spherodized particles start to grow, growth of the Si particles proceed with holding time till these grown particles reach a stable state of their size and changes only happen to their shape.

It is worth noticing that the time necessary for stabilization changes from alloy to alloy, as stabilization happens after 40 hrs for the alloy without Ti & with 0.1%Ti, while it happens after 150 hrs for the alloy containing 0.05%Ti (fig 5). This stable size of the Si-particles ranges from 4-14 μm.

3.3. Hardness Of The Alloys:

The measured hardness of all the studied alloys in as cast and homogenized conditions are given in fig 6. The data shows that adding Ti to Al-Si eutectic cast alloys increase their hardness in as cast condition. This effect might be explained by an increase in the eutectic content or the formation of (TiSi) particles(11), which is not investigated in this study. Homogenization, of these alloys cause a significant drop in hardness of all alloys and this drop continues with homogenization time. The possible causes behind this drop in hardness are stress-relief and change in Si-eutectic morphology.

It is a worth mentioning that recent references(11, 12)have pointed out that the addition of Titanium in various forms to aluminium Alloys have a strong effect on nucleating the primary aluminum phase. These studies have shown that Ti in solution in the liquid metal even below the 0.15% , determined by equilibrium data from the phase diagram, and as low as 0.01% would be expected to precipitate (TiAl3), which is an active nucleus for aluminum. However, these studies have recorded that (TiAl3) was present on (TiB2) crystals at the lower levels of Ti than that expected from the phase diagram (0.15%Ti)(11). Some of these studies reported a poisoning effect of Si on the grain refinement action of Ti when Si% is high due to the possibility of formation of TiSi(12).

4. CONCLUSIONS

1. Adding elemental Ti (.05%) to Al-12%Si alloy causes partial modification of the Si eutectic, and as Ti content reaches 0.1% maximum modification is gained.
2. Adding Ti to Al-12%Si cast alloys causes an increase in their hardness.
3. Homogenization treatment of Al-12%Si cast alloys with or without Ti causes a modification in the Si eutectic morphology through 5 stages; growth, fragmentation, spherodization, growth, and finally stabilization.
4. The stabilization state is reached after (150) hrs. for the alloy with 0.05%Ti, while it is reached after (40) hrs. for the alloys without or with 0.1% Ti.
5. When Ti content reaches 0.1% the mechanisms for modification of Si eutectic through homogenization becomes similar to those of the alloy without Ti.

5. REFERENCES

1. R.A.Higgins , 1983 , “ Engineering Metallurgy , Part 1 , Applied Physical Metallurgy ” , Holder and Stoughton (London) .
2. Metals Hand book , 1979 , Vol.2 , “ Properties and Selection : Non Ferrous Alloys and Pure Metals ” , American Society for Metals , Metals Part , Ohio .
3. B.F. Yilmaz , 1988 , “ Silicon Crystals in Aluminum – Silicon alloys ”, Aluminum, Vol. 64 , P.1047
4. Y. Shimizu , y. Kato , S. Hashimoto and N.Tsuchiya , 1986 , “ Influence of Phosphates and Sodium Halides on the Structure of Hyper Eutectic AL-Si Casting Alloys ” , Aluminum , Vol. 62 , P . 276 .
5. Schatterjee and A.A.Das , 1973 “Some Observations on the Effect of the Pressure on the Solidification of AL-Si Eutectic Alloys ” , Brit . Foundry man ,Vol. 66, P.118 .
6. S.Shivkumar , L.Wang and D.Apelian , 1991 , “ Molten Metal Processing of Advanced Cast Aluminum Alloys ” , J. Met . Jan , P 26 .
7. T.V. Rajan C.P. Sharma and A Sharma , 1997 , “ Heat Treatment : Principles and Techniques ” , Prentice Hall of India , Private Ltd .
8. R.N. Grugel , 1992 , “ Evaluation of Primary Dendrite Trunk Diameters in Directionally Solidified AL-Si alloys ”, Mater . Character . Vol. 28 ,P.213 .
9. Somi Reddy , B.Npramila Bai , K.s.s Murthy and S.K.Biswas , “ Mechanism of Seizure of Aluminum Silicon Alloys Sliding Against Steel ” , Wear ,Vol. 181 , P.658 .

10. S.F.Mustafa , 1995 , " Wear and Wear Mechanisms of AL –22%Si/AL2O3 Composite ", Wear ,Vol. 185 , P.189 .
11. Campbell, J., (2003), Castings, London: Butterworth, Heinemann, pp. 149-153.
12. Neff, V. D., Nonferrous Molten Metal Processes, ASM Handbook, Vol. 15, (1998), USA: pp. 476-477.

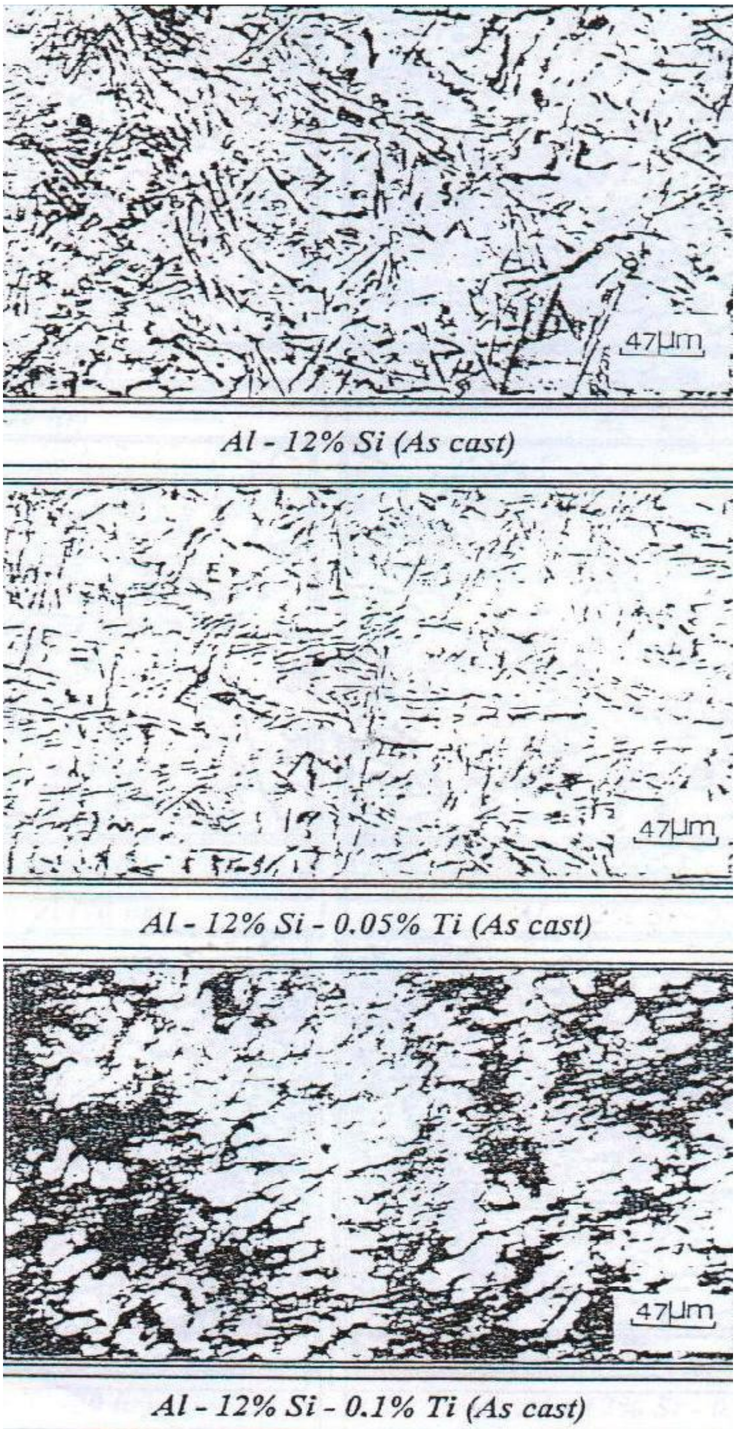

Fig.(1): Microstructure of As Cast and Modified Alloys.

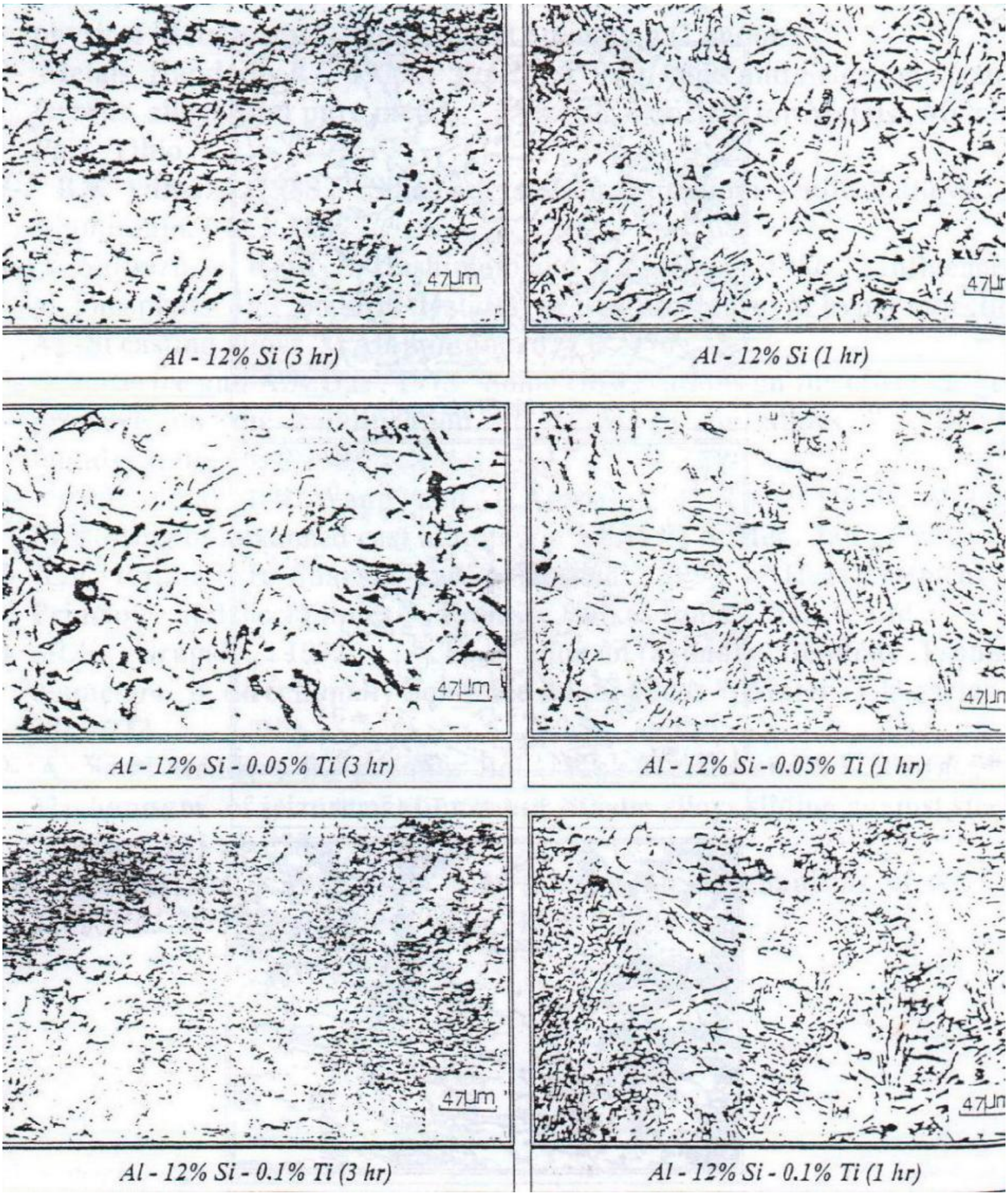

Fig.(2): Microstructure of Homogenized Alloys with(1)and(3)hrs. at 525°C

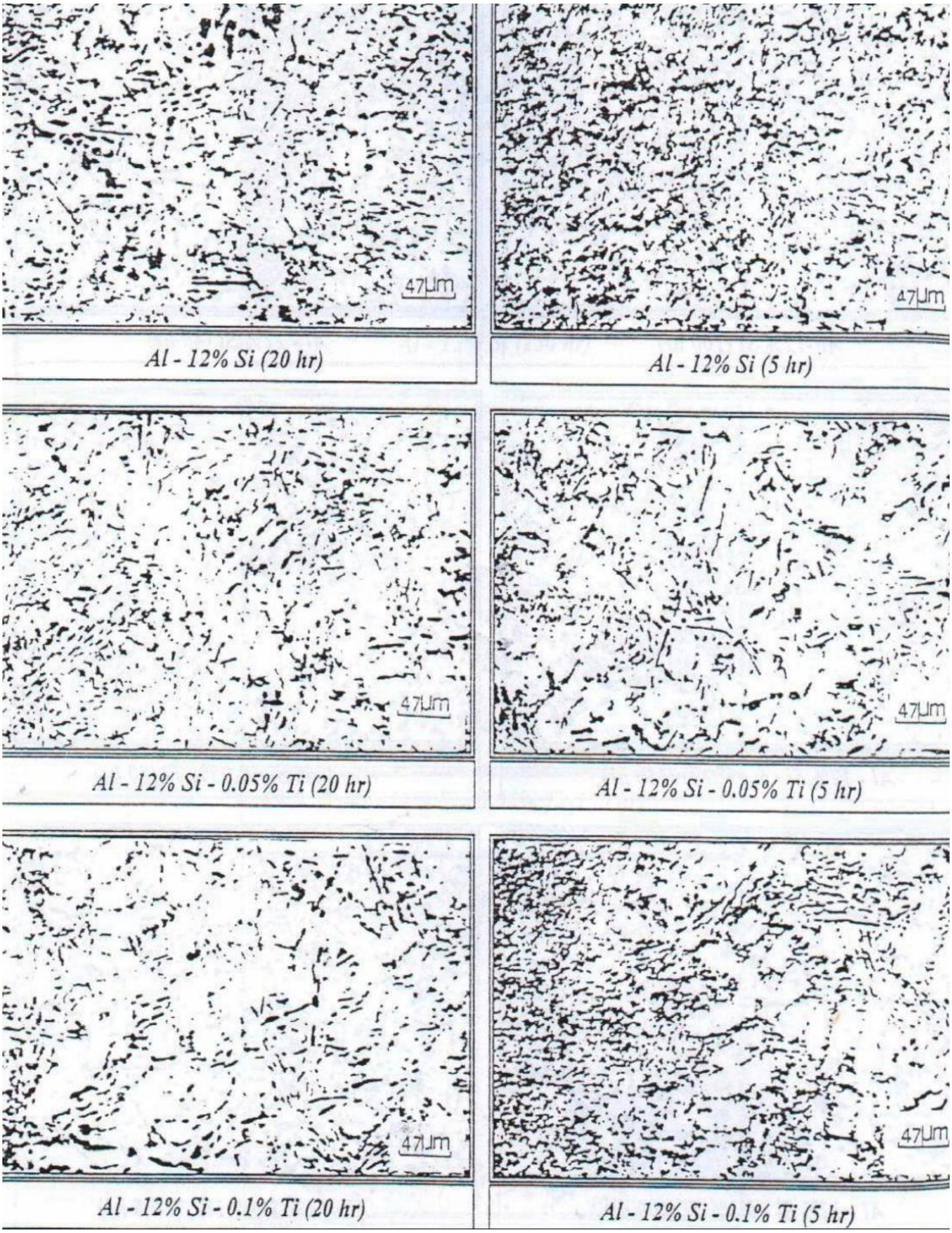

Fig.(3): Microstructure of Homogenized Alloys with (5)and(20)hrs. at 525° C

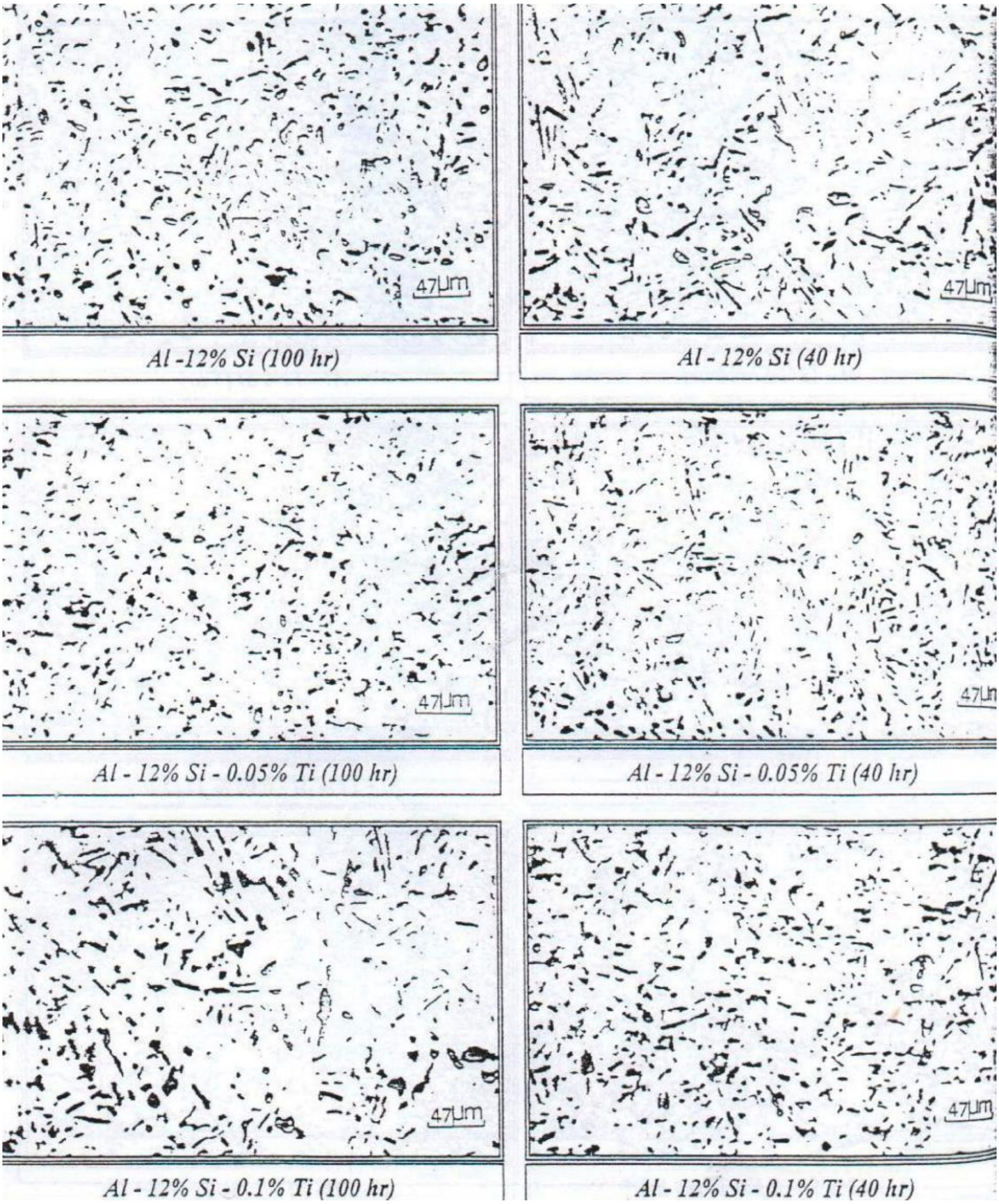

Fig.(4): Microstructure of Homogenized Alloys with(40 , 100)hrs. at 525 °C

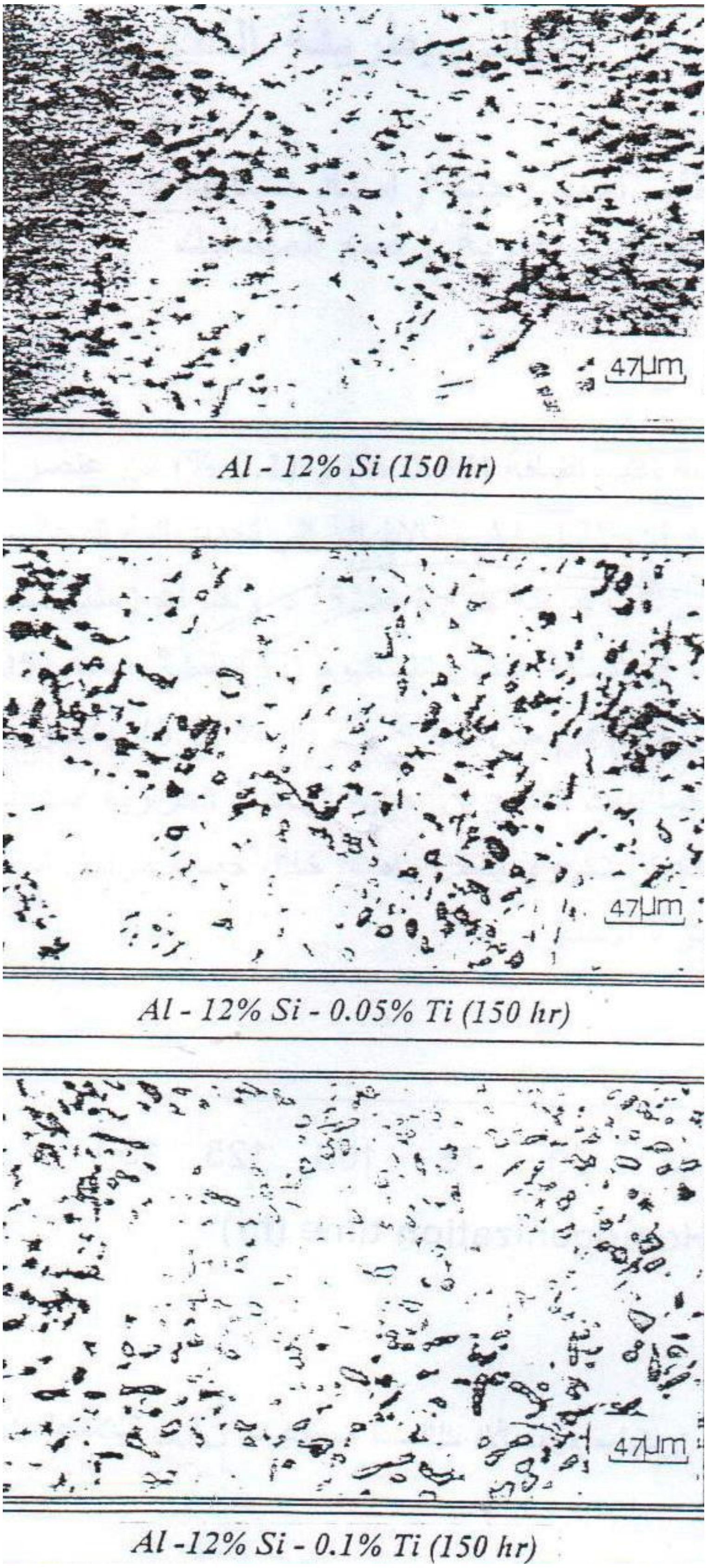

Fig.(5): Microstructure of Homogenized Alloys with (150)hrs. at 525 °C

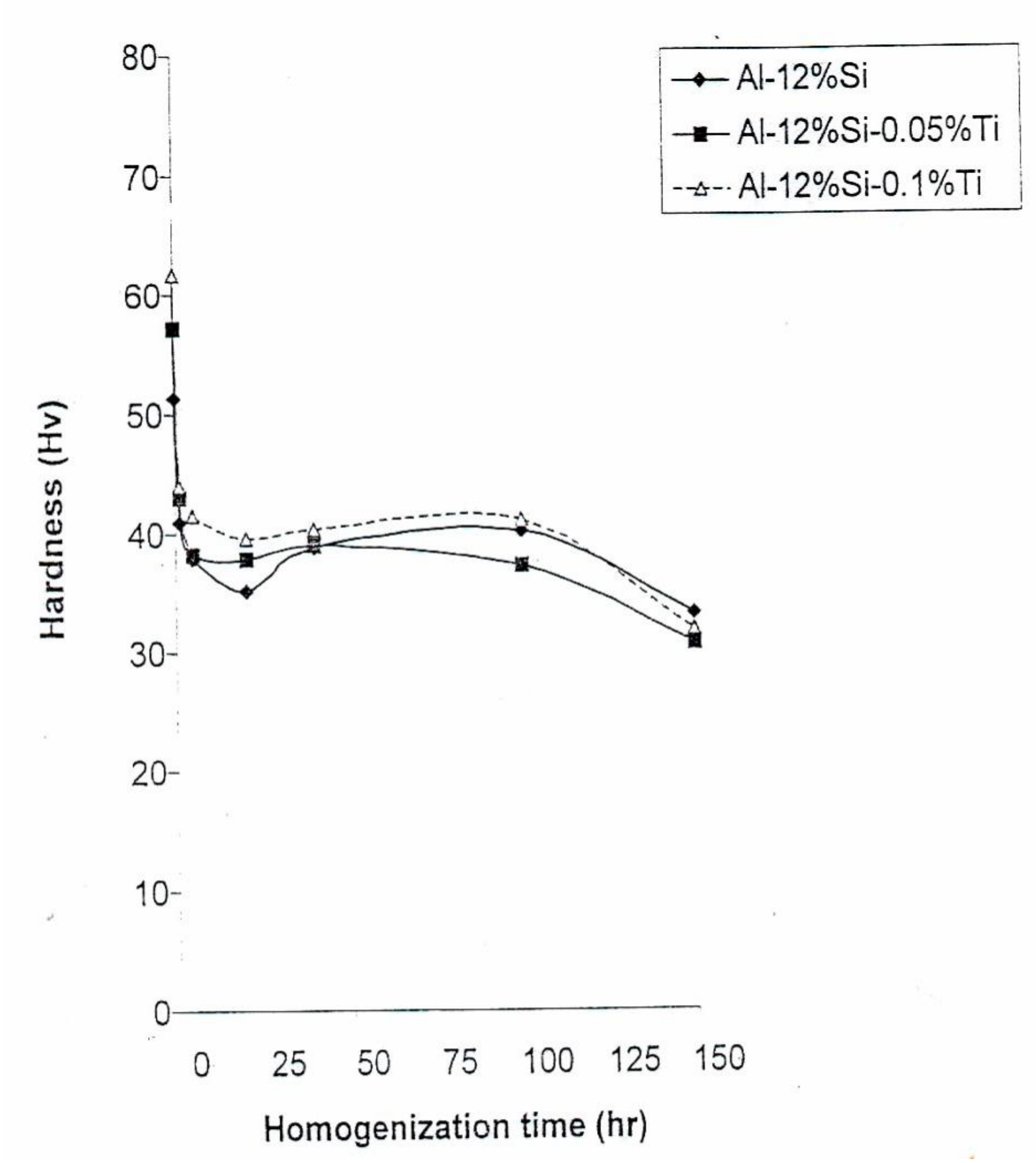

Fig.(6): Relationship Between The Hardness and Homogenization Time of Al-Si Alloy

دراسة تأثير إضافة التيتانيوم على البنية المجهرية لسبيكة الألمنيوم ١٢ % سيليكون اليوتكتيكية

د. مصطفى احمد رجب

أستاذ مساعد

المعهد التقني/بعقوبة . هيئة التعليم التقني

الخلاصة :

يهدف البحث إلى دراسة تأثير إضافة (٠.٠٠٥ %) و (٠.٠١ %) من عنصر التيتانيوم على البنية المجهرية لسبيكة Al-12%Si ، بالإضافة إلى تحديد آلية المجانسة الحرارية وتأثيرها على البنية المجهرية ، والتي تمت بدرجة حرارة (٥٢٥) °م .

أوضحت نتائج البنية المجهرية ، إن إضافة عنصر التيتانيوم (Ti) بنسبة (٠.٠٠٥ %) يؤدي إلى تحوير جزئي للبنية المجهرية في حين عند إضافة Ti % (٠.٠١) يكون كافيا لحصول عملية التحوير بشكل فعال . كما بينت النتائج أن المجانسة تغير شكل السليكون الابري أو الليفي إلى الشكل الكروي بشكل واضح خلال مجانسة السبائك. وأن الشكل الكروي لجسيمات السيليكون تم الحصول عليه خلال خمسة مراحل أساسية متمثلة بالنمو ، التكسر ، التكور ، النمو ،والاستقرار .