Solid State Science and Technology, Vol. 16, No 1 (2008) 168-174
ISSN 0128-7389

THE EFFECT OF CERIUM ADDITION ON THE MICROSTRUCTURE OF AlSiMgCe ALLOY

Anasyida Abu Seman and Abdul Razak Daud.

School of Applied Physics, Faculty of Science and Technology,
University Kebangsaan Malaysia, 43600 Bangi, Selangor.

ABSTRACT

In this study the effect of cerium addition on the microstructure and microhardness of Al-12.5Si-4Mg alloy was investigated. Experiments have been conducted on Al–12.5Si–4Mg alloys with cerium content in the alloy was varied from 0.5 to 3wt%. The alloys were produced by casting in a permanent mould. Optical microscopy, scanning electron microscopy and energy dispersive X-Ray spectroscopy, X-ray diffractometry and Vickers microhardness were used in this investigation. The results show that the addition of 0.5 to 3.0wt% of cerium led to the formation of precipitation of Al_4Ce phase in the Al-matrix. The microhardness of as cast alloy increases with the increase in cerium content as a result of the precipitation. Heat treatment at 200ºC led to the increase in microhardness of as cast alloys due clustering of Si and precipitation of fine Al_4Ce phase.

INTRODUCTION

The need of the automotive and aircraft industries to produce cost efficiently integral components of complex geometry led to an increase in exploitation of the Al–Si– Mg cast alloys which possess excellent castability in addition to good tensile fatigue properties and corrosion resistance [1]. Increasing demands on such materials have resulted in increasing research and development for high-strength and high-formability aluminium alloys [2]. The trend of the increased use of castings in structural applications has been supported by recent advancements such as the tighter specification of composition, the higher rates of solidification and improved heat treatment conditions. The mechanical properties of an Al-Si-Mg cast alloy are mainly determined by its cast structure and the microstructural characteristics such as grain size, dendrite arm spacing (DAS), the size, shape and distribution of the eutectic silicon particles, as well as the morphologies and amounts of intermetallic phases present [3]. The fine dispersion of intermetallic compounds in aluminium alloys modifies the eutectic structure and age-hardening mechanism. Several new Al–Mg–Si alloys have been developed through alloy design and improvement of the manufacturing process.

The presence of rare earth elements was reported to increase strength and hardness of aluminium alloy at elevated temperatures [4]. By adding Ce into the alloy, the strength at room as well as high temperature increase as reported by Anru et al. [5]. Besides that, it also help to refine the eutectic structure, decrease ductility, harden by dispersion, influence the rate and precipitation of solid phases. The solubility of this element in

Corresponding Author: syida_7853@yahoo.com

aluminum usually increases with increasing temperature. The decrease in solubility from high concentrations at elevated temperatures to relatively low solubility during solidification and heat treatment results in the formation of secondary intermetallic phases. The wide variety of intermetallic phases in aluminum alloys occur because aluminium is highly electronegative and trivalent [6]. In the present experiment, the main objective is to analyze the influence of cerium addition on microstructure and microhardness of AlSiMgCe alloy.

EXPERIMENTAL METHOD

A series of Al-12.5wt%Si-4Mgwt% alloys with different percentage of Ce (0.5wt% to 3.0wt%) additions were prepared from pure Al (99.9%), Si (99.9%), Mg (99.9%) and Ce (99.9%). The melting was carried out using graphite crucible in electrical melting furnace under argon gas atmosphere. The alloys were melted at 850ºC for 30 minutes. The melt was cast in a steel mold to produce a casting 10 mm in diameter and 80 mm in length. The specimens were cut and mechanically ground using SiC papers with different grid; 400, 600, 800, 1000 and1200. Then the specimens were polished with diamond spray with 6 µm and followed by 1-µm finish and were etched in Keller's reagent. The alloys investigated were characterized by means of an Axiotech 1000HD optical microscope (model Carl Zeiss), a LEO Scanning Electron Microscope model 1450 equipped with an Energy Dispersive X-Ray Spectroscopy analyses (EDX), a Siemen D5000 X-Ray diffractometer and a Shimadzu Microhardness Tester HMV-2000.

RESULT AND DISCUSSION

Microstructure

Figure 1 shows the optical micrographs of the as cast alloy comprising an α-aluminum dendritic network with the acicular eutectic silicon particles segregated into the interdendritic region. Due to the relatively high cooling rates in open air achieved using a permanent mould, fine Si particles are obtained. The aluminum phase was rounded, the silicon particles are smaller shape, and the intermetallic phases in rod like form, distributed around the aluminum globules. In the figures, the eutectic and primary silicon particles are light gray. The intermetallic phases are concentrated mainly in the interdendritic spaces and are dark gray in color, with the exception of Mg_2Si (β) [7] which is black. The Mg_2Si (β) precipitate phase appears in two morphologies: large particles and fine lamellar plates, as shown in figure 1(e) and (f). With the addition of cerium, some rod-like intermetallic phases were observed in figure 1(a) to figure (f). The addition of cerium refined the phase and formed more continuous phase on the grain boundaries. With increasing cerium content, the amount of the dark gray intermetallic increased and it coarsened.

Corresponding Author: syida_7853@yahoo.com

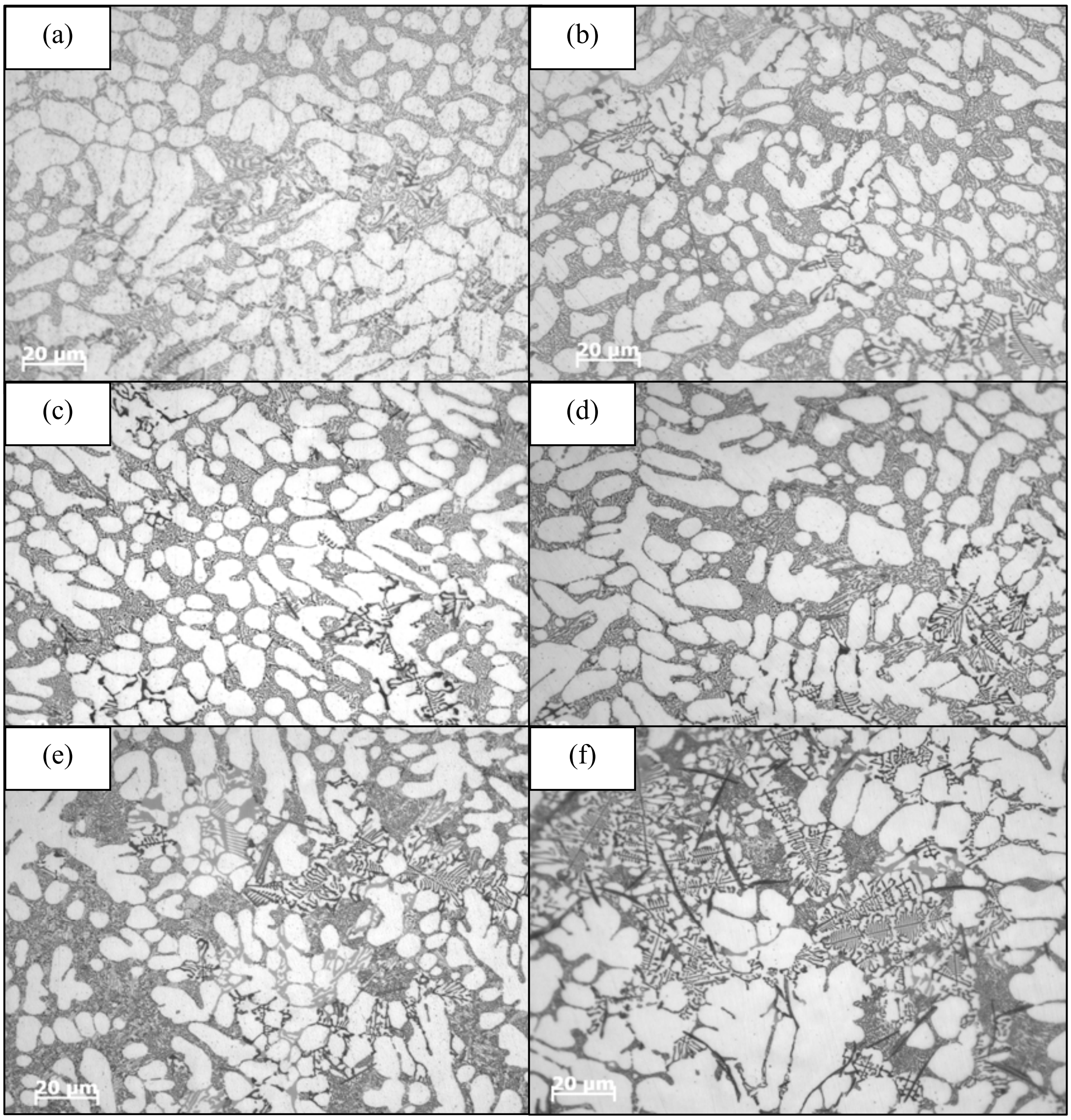


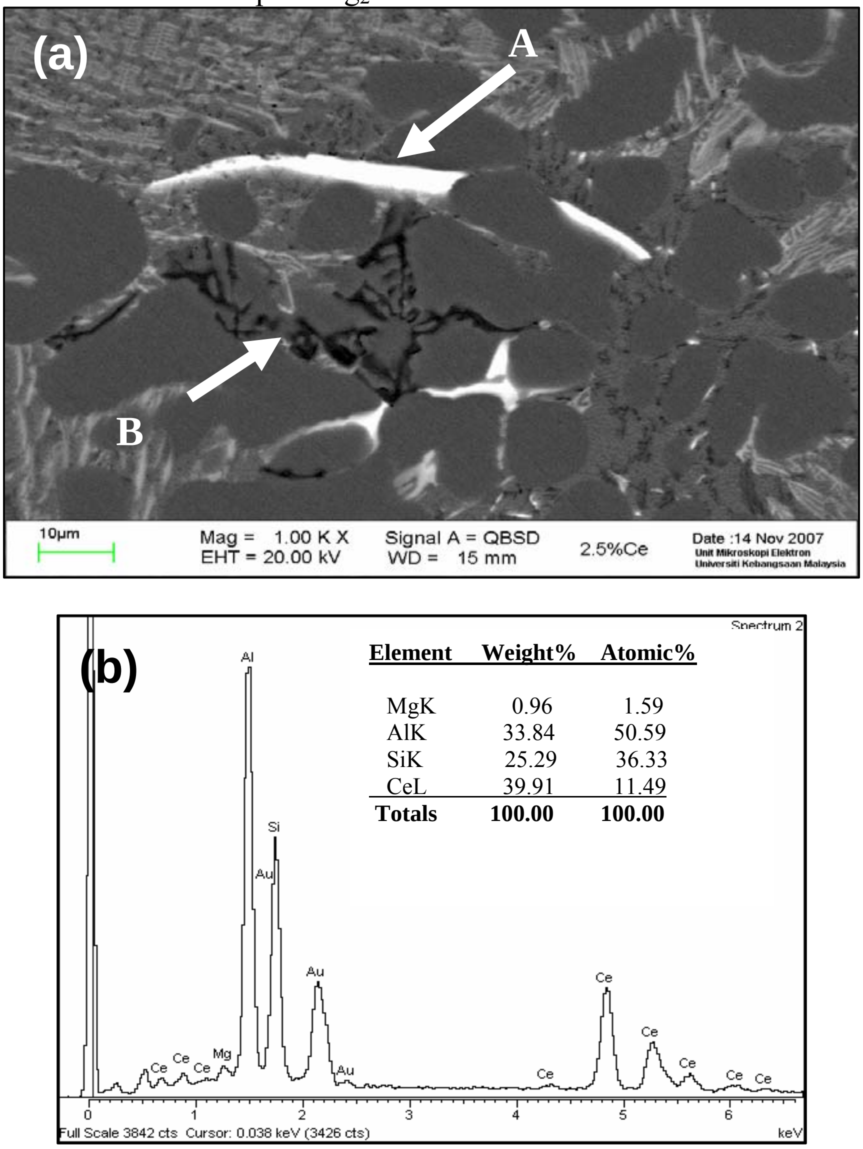
Figure 1 : Microstructure of Al –12.5Si– 4Mg alloys (a) 0.5wt%Ce (b) 1.0wt%Ce (c) 1.5wt%Ce (d) 2.0wt%Ce (e) 2.5wt%Ce (f) 3.0wt%Ce

By analyzing the SEM micrograph "A" phase in Figure 2(a) and EDX results in figure 2(b), it was found that the rod like intermetallic phases was Al_4Ce [8]. It is reported by Chang et al. [9] that RE elements can easily form an intermetallic compound with Al and Si. Cerium can form a number of intermetallic compounds with aluminium and silicon such as Al_4Ce, Al_2Ce, SiCe and $SiCe_4$ [10]. Because of the high chemical stability of Al_4Ce phases, cerium is combined with Al and form Al_4Ce until all the available cerium is used [11]. The formation of this intermetallic compound begins below the solidus temperature of Al-Si alloy, and therefore does not contribute to the heterogeneous nucleation of primary Si. These elements reduce the contents of gases

Corresponding Author: syida_7853@yahoo.com

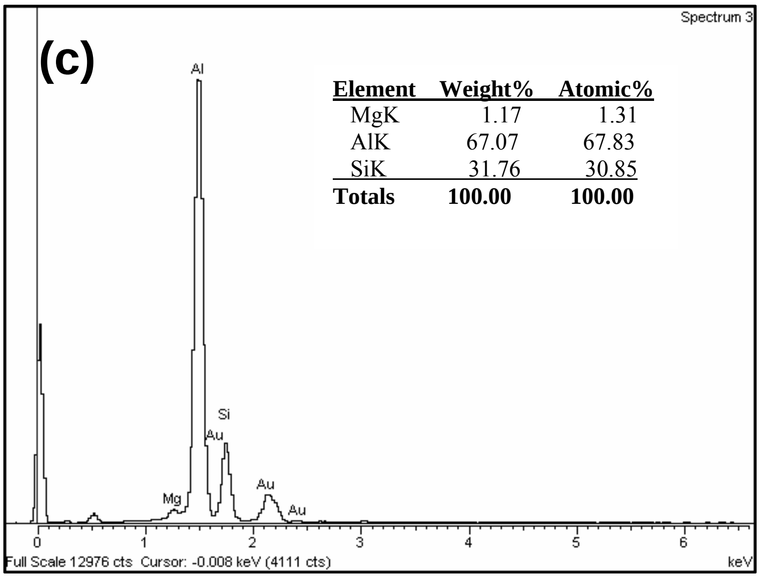
Solid State Science and Technology, Vol. 16, No 1 (2008) 168-174
ISSN 0128-7389

and some impurities and the spacing between secondary dendrite arms. The addition of rare earth (RE) is favorable to the formation of fine equiaxial grains, so that casting characteristics and microstructure of aluminium alloy can be effectively improved. The results of SEM micrograph "B" phase in Figure 2(a) and EDX results in Figure 2(c) indicated that the Chinese script is Mg_2Si.



Element	Weight%	Atomic%
MgK	0.96	1.59
AlK	33.84	50.59
SiK	25.29	36.33
CeL	39.91	11.49
Totals	**100.00**	**100.00**

Corresponding Author: syida_7853@yahoo.com



Element	Weight%	Atomic%
MgK	1.17	1.31
AlK	67.07	67.83
SiK	31.76	30.85
Totals	**100.00**	**100.00**

Figure 2. (a) SEM micrograph of as-cast alloy Al –12.5Si– 4Mg-2.5Ce (b) EDX of the "A" phase (c) EDX of the "B" phase

Microhardness

The Vickers microhardness test was carried out using Shimadzu Microhardness Tester HMV-2000. The specimens were metallographically polished and opposite sides were made perfectly parallel before the hardness measurement. A load of 100 g was applied for 15 s. Fives hardness readings were taken on each sample and the average value was reported. Figure 3 shows the effect of cerium addition on microhardness of Al-12.5Si-4Mg. The microhardness of the as cast alloy increased with cerium addition. The increase in the microhardness of the as cast alloy resulted in the refinement of eutectic structure and grain size. An increase in Ce content also leads to the precipitation of intermetallic Al_4Ce, thus increase the microhardness. Our results agreed well with the finding by Karen and Daud [12].

Corresponding Author: syida_7853@yahoo.com

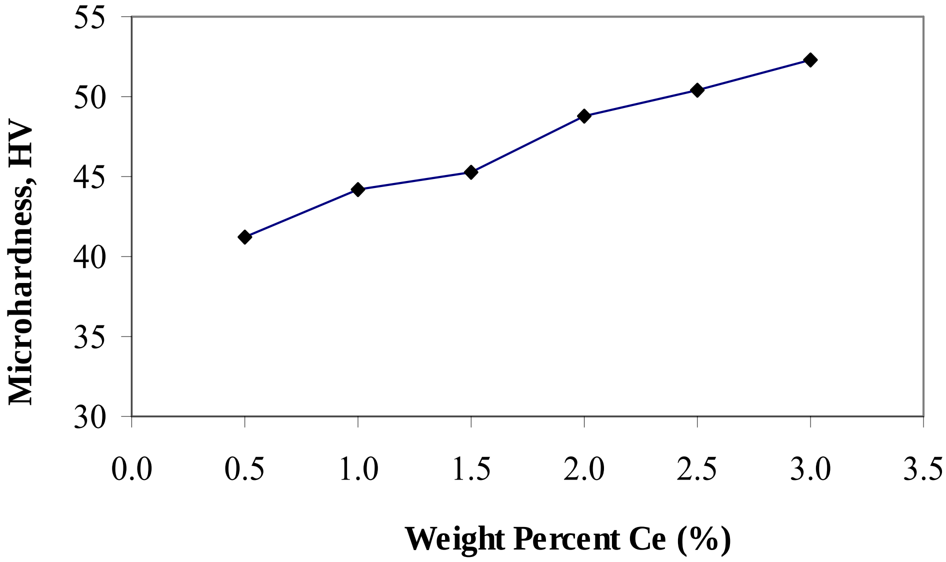


Figure 3.Effect of Ce additions on the microhardness of Al –12.5Si– 4Mg.

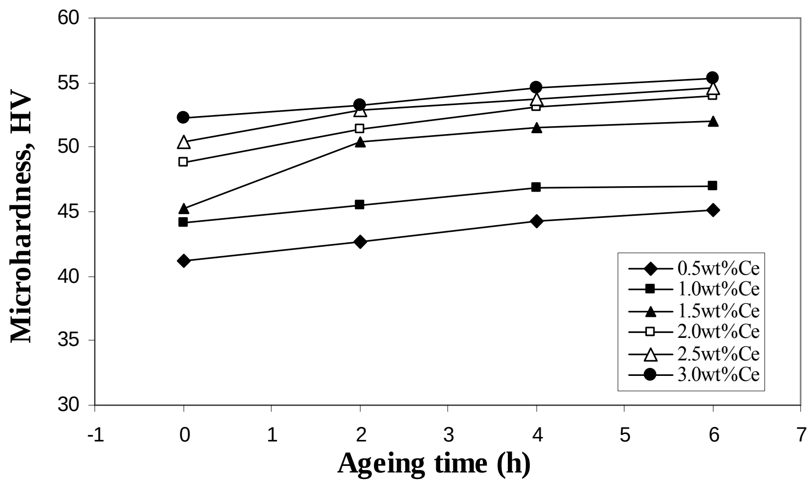


Figure 4. Microhardness change of as cast alloys heat treated at 200 °C.

The effect of heat treatment at 200 °C on the microhardness of the alloys was presented in Figure 4. Alloy heat treated at 200ºC show some response to age hardening and the microhardness increased slightly. Heat treatment at 200°C may induce the diffusion of Si leading to clustering of Si particles which contribute to an in increase in the microhardness of the alloy [13]. Besides clustering of Si particles, ageing at 200 °C may leads to precipitation of fine intermetallic phase Al_4Ce. These fine particles will contribute to an increase in the microhardness. The increase of hardness during ageing with increase of Ce content also may results of solid-solution strengthening of Ce on a

Corresponding Author: syida_7853@yahoo.com

Al matrix. The Al and Si atoms distributed homogeneously within the solid solution take the energy need for performing fine precipitations with heat. Distribution of precipitations in the form of small particles and their prevention from dislocations are other reasons for the increase in microhardness.

CONCLUSIONS

The results show that the addition of 0.5 to 3.0wt% of cerium led to the formation of fine cells dispersed in the Al-matrix. These fine cells consist of a mixture of α-Al, eutectic Si and intermetallic Al_4Ce phase. The microhardness of as cast alloy increases with the increase in Ce content as a result of the precipitated phase. Ageing at 200ºC seems to induce the diffusion of Si and Ce, leading to clustering of Si and precipitation of fine Al_4Ce phase which contribute to the increase of the microhardness of the as cast alloy.

REFERENCES

[1]. N.D. Alexopoulos and Sp.G. Pantelakis, (2004); *Materials and Design*, **25**, 419–430.
[2]. Y.L. Liu, S.B. Kang and H.W. Kim, (1999); *Materials Letters*, **41**, 267–272.
[3]. M.A.Moustafa, F.H. Samuel, & H.W.Doty, (2003); *Journal of Material Science*, **38**, 4507 – 4522.
[4]. F. Rosalbinoa, E. Angelinia, S. De Negrib, A. Sacconeb and S. Delfinob, (2003); *Intermetallics,* **11**, 435–441.
[5]. WU Anru, XIA Changqing and WANG Shaowu, (2006)*Rare Metals*, **25**, 371-376.
[6]. Y.Haizhi, (2003); *Journal of Materials Engineering and Performance,* **12**, 288-297.
[7]. L. Lasa and J. M. Rodriguez, (2004); *Journal Of Materials Science*, **39**, 1343 – 1355.
[8]. Y.Fan, G.Wu and C.Zhai, (2006); *Materials Science and Engineering A*, **433**, 208–215.
[9]. J.Y.Chang, G.H.Kim, I.G..Moon and C.S.Choi, (1998); *Scripta Materialia*, **39**, 307-314.
[10]. M.Harun, L.A. Talib and A.R. Daud, (1996);*Wear*, **194**, 54-59.
[11]. W.Guohua, Y.Fan, G.Hongtao, Z.Chunquan and P.Z.Yan, (2005); *Materials Science and Engineering A,* **408**, 255–263.
[12]. A.R. Daud, K.M.C.Wong, (2004); *Materials Letters*, **58**, 2545– 2547.
[13]. N.Saheb, T.Laoui, A.R.Daud, R.Yahya and S.Radiman, (2001); *Philosophical Magazine A,* **82**, 803-814.

Corresponding Author: syida_7853@yahoo.com