EFFECT OF VOLUME FRACTION ON AGING PROCESS OF SiC PARTICLE DISPERSED Al-Mg-Si ALLOY BASED COMPOSITE MATERIALS

Masahiro ARAKI*, Susumu IKENO, Kenji MATSUDA****
Fujio SHINAGAWA and Yasuhiro UETANI*****

***Graduate School, Toyama University, Toyama city, Toyama, 930-8555, Japan**
**** Faculty of Engineering, Toyama University, Toyama, 930-8555, Japan**
***** Research Institute for Technology, Toyama Prefectural University, Toyama 939-0398,Japan**

ABSTRUCT

Aging process of Al-1.0mass%Mg_2Si alloy composite materials with 4vol% and 8vol%SiC particles was investigated by micro-Vickers hardness measurement and transmission electron microscopy.

When SiC particles are dispersed into the Al-Mg-Si alloy, aging time to reach the maximum hardness is shortened at 473K. The over-aged composite material with 4vol%SiC includes four kinds of metastable phase; namely β' phase, the TYPE-A, TYPE-B and TYPE-C precipitates of which crystal structures are different to each other.

Fraction of these three kinds of metastable phase in the composites are the same as in the matrix alloy containing 0.2mass% excess Si.

The composite material with 8vol% SiC particles contains the TYPE-A, TYPE-B and TYPE-C precipitates, but is free from β' phase precipitates. The existence of those precipitates has correspondingly been observed in the matrix alloy containing 0.4mass% excess Si

Keywords: *Composite material, SiC, Al-Mg-Si alloy, metastable phase, transmission electron microscopy*

1.INTRODUCTION

Ceramics particles dispersed aluminum alloy based metal matrix composite has been studied by many works[1~3], and the effect of dispersed ceramic particle on aging process has been also reported [3,4]. We sequence the aging process of SiC, TiC and Al_2O_3 particle dispersed aluminum matrix composite materials. Made clear the effect of ceramic particles on aging process [5~7], chemical reactions occurred between ceramics and matrix alloy, due to ceramics particles decompose. And a part of element which makes ceramics particle soluble for matrix. Change aging process like trace amounts of elements add matrix alloys.[7]Since aging process of composite materials is more complex than mother alloy, must be turned out exactly the effect of a trace amount of added element on aging process of matrix alloy[8~11] which is able to investigate in detail amount of release element from particle.

This study compared with aging process of SiC particles dispersed Al-Mg-Si alloy based composite materials and in it is already turned out exactly excess Si contain Al-Mg-Si alloy, and report effect of soluble Si on aging precipitates in Al-Mg-Si/SiC composite.

2.EXPERIMENTAL PROCEDURE

The matrix alloy is Al-1.0mass% Mg_2Si alloy it makes pure Al (99.99mass%), pure Mg and pure Si (99.9mass%) dissolve in air. Average SiC particle diameter is 1.1 μ m. The SiC/Al-Mg-Si composite fabricated pre-pack press method [12].

Composition of mother alloy in excess Si alloy are given in Table 1. Cylindrical samples, 30mm in diameter and 50mm in length were heat extruded to rod of diameter 7mm, Hardness test and TEM specimens were cut from rod. Mother alloy and composites were solution treated as long as 3.6ks at 848K and quenched to iced water. Afterward aging at 473K. TEM investigation were taken in TOPCON EM-002B microscopy at 200kV.

Table 1 chemical analysis of the specimens used (mass%)

	Si	Fe	Cu	Ti	Mn	Mg	Cr	Zn	Mg_2Si	ex.Si
matrix alloy	0.35	0.01	0.00	0.00	0.00	0.63	0.00	0.00	0.96	0.00
0.1% ex. Si	0.46	0.01	0.00	0.00	0.00	0.62	0.00	0.00	0.98	0.10
0.2% ex. Si	0.57	0.01	0.00	0.00	0.00	0.63	0.00	0.00	0.99	0.21
0.4% ex. Si	0.73	0.01	0.00	0.00	0.00	0.62	0.00	0.00	0.98	0.37

3.RESULTS AND DISCUSSIONS

Fig.1 is age herdening curves of matrix alloy, 4vol% and 8vol% SiC composites aged at 473K. The value of hardness of composites at as quenched state is higher than matrix alloy. Hardness tendency of to higher with composite ratio high, and each composite have shorter peak age time and effect of particle was observed obviously. Wang et al [13] also suggested reaction between SiC particles and Al in the matrix.

$$4Al + 3SiC \rightarrow Al_4C_3 + 3Si \quad (1)$$

thus exist Al_4C_3 phase and released Si in matrix and SiO_2 layer have been formed beforehand, and it is reacting to melt.

In this way, following there reactions bring

$$3SiO_2 + 4Al \rightarrow 2Al_2O_3 + 3Si \quad (2)$$

$$SiO_2 + 2Mg \rightarrow 2MgO + Si \quad (3)$$

$$2SiO_2 + 2Al + Mg \rightarrow MgAl_2O_4 + 2Si \quad (4)$$

In any event, be produce release Si. We have reported that Si released from SiC particle in composite apparently soluble into the in matrix and aging process change like an Al-Cu-Mg alloy added only Si. We speculated this case, which Si is supplied for four reaction. But Al_4C_3, Al_2O_3, MgO and $MgAl_2O_4$ could not been confirmed by TEM observation.

It is difficult to speculate that Si solubles in the matrix, although only the age-hardening curve is similar to excess Si alloy. The case of Al-Mg-Si based SiC particle composite is also difficult to confirm Al_4C_3, Al_2O_3, MgO and $MgAl_2O_4$ by TEM observation.

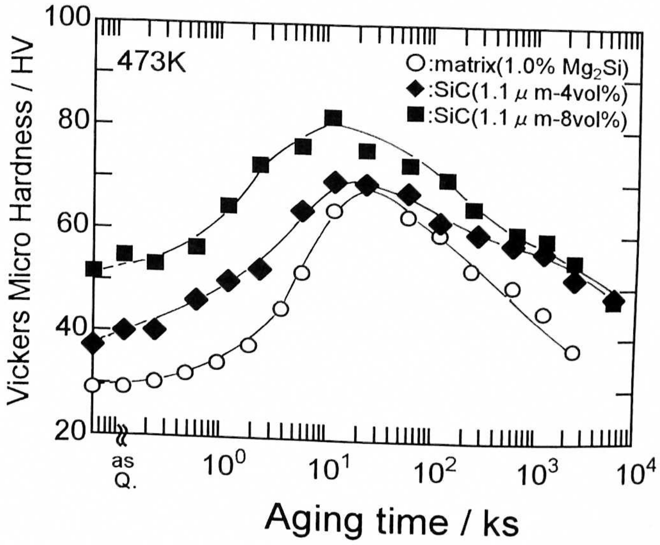

Fig.1 Micro-Vickers hardeness as a function of aging time for the matrix alloy, 4vol% and 8vol% SiC/Al-1.0mass%Mg_2Si alloy composite aged at 473K.

The aging sequence of this alloy have been clarified and the effect of excess Si content on the various kind of metastable phase and their crystal structures have been proposed by our recent works. It is expected that the amount of excess Si in this composite will be confined by the classification of the types of metastable phase in this composite.

Fig.2 is TEM micrographs for each specimens aged at 473K for 600ks. Fig.2(a) show a typical rod shape metastable phase along the ⟨001⟩ directions of the matrix in the matrix alloy. Fig.2(b) and (c) have shown similar precipitates in each composite materials. There were no different features from precipitates in each specimen.

Fig.3 is one example of the first type of precipitate in 4vol%SiC composite. The spacing of 0.203nm corresponding to (200) plane of the aluminum matrix is observed and there is the hexagonal network of bright dots having the spacing of 0.71nm in this precipitate. This precipitate has a crystal lattice of hexagonal and its lattice parameters are a=0.705nm c=0.405nm. This precipitate has same the structure of the metastable phase commonly observed in the matrix alloy.

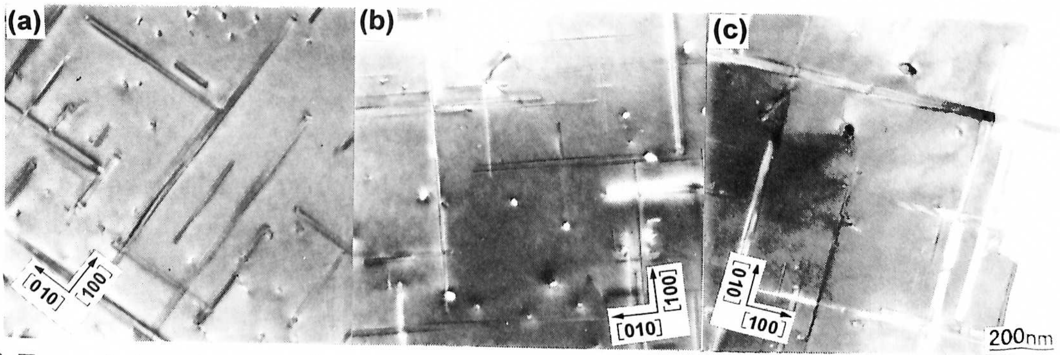

Fig.2 Transmission electron micrographs for the matrix alloy (a), 4vol% and 8vol% SiC/ Al-1.0mass%Mg_2Si alloy composite ((b),(c)) aged at 473K for 600ks.

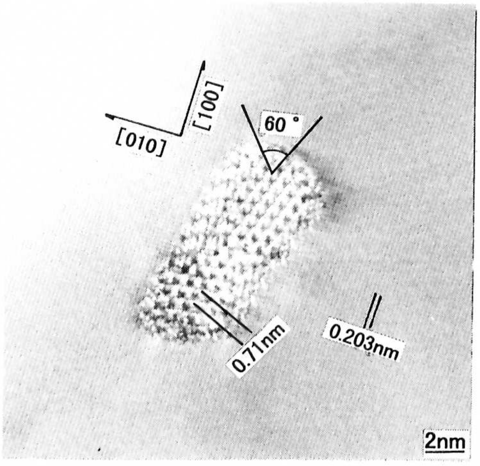

Fig.3 High resolution electron micrograph of the transverse section of a metastable phase (β 'phase) precipitate in the 4vol% SiC/ Al-1.0mass%Mg_2Si alloy composite aged at 473K for 600ks

Fig.4 are precipitates observed only composite materials. Fig.4 (a) show second type of metastable phase in the 8vol% SiC composite. In this case, the rectangular arrangement of bright dots in the precipitate have the spacing of 0.35nm and 0.67nm.

This is a typical metastable phase in the Al-Mg_2Si alloy containing Si in excess. We proposed as the TYPE-A precipitate [11]. The TYPE-A precipitate have a hexagonal lattice with a=0.405nm, c=0.67nm and this phase consists of Al, Mg and Si [9].

Fig.4 (b) show the third type of the metastable phase in the 8vol% SiC composite. It is same type of metastable phase as the TYPE-B precipitate in the excess Si alloy. Bright dots in this phase arrange the rectangular network having spacings of 0.68nm and 0.79nm.The crystal lattice of the TYPE-B precipitate is an orthorhombic and its lattice parameters are a=0.683nm, b=0.794nm and c=0.45nm. The TYPE-B precipitate also consists of Al, Si and Mg as the same as the TYPE-A precipitate. This metastable phase is smaller than the TYPE-A precipitate and there is a lot of the TYPE-B precipitate in the excess Si alloy aged at 523K up to peak [10].

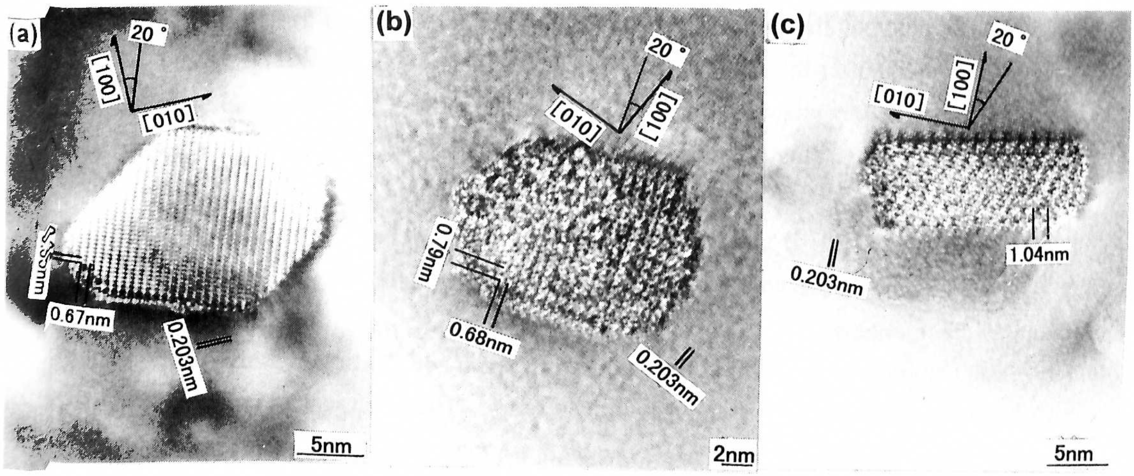

Fig.4 High resolution electron micrograph of the transverse section of a metastable phase, (a) The TYPE-A precipitate, (b) The TYPE-B precipitate, (c) The TYPE-C precipitate, in the 8vol% SiC/ Al-1.0mass%Mg_2Si alloy composite aged at 473K for 600ks

Fig.4 (c) is the forth type of metastable phase in 8vol% SiC composite. This metastable phase is "The TYPE-C precipitate", we proposed [11]. Bright dots arrange a hexagonal network having the spacing of 1.04nm.The chemical composition of this phase could not been detected by EDX, because this precipitate could not been extracted from the matrix. The crystal lattice of the TYPE-C precipitate is a hexagonal (a=1.04nm and c=0.405nm). In this way, the β'phase, the TYPE-A, the TYPE-B and the TYPE-C precipitates observed in the composites.

According to results of TEM in the composite materials, it is considered that the SiO_2 layer on the particle surface reacts with molten aluminum and MgO or $MgAl_2O_4$ are formed at the interface between the SiC particle and the matrix.

Thus, the concentration of Mg in the matrix alloy decreases and the chemical composition of the matrix alloy becomes excess Si, because this reaction produces the released Si in the same time.

The aging process of composite materials becomes the same as that of the excess Si alloy.

Based on our HRTEM observation, it is presumed that amounts of released Si from the SiC particle in 4vol% and 8vol% SiC composites are 0.1~0.2mass% and 0.2~0.4mass%, respectively. It is estimated that SiO_2 layer on the SiC surface is maximum about 17nm.

4.CONCLUSION

The aged SiC particle dispersed Al-1.0mass%Mg_2Si alloy based composite materials, were investigated to understand the effect of released Si from SiC particle on aging process. The summary of this study are as follows.

(1) The time to achieve the maximum value of hardness in the 4vol% and the 8vol% SiC composites were shorter than that of the matrix alloy.

(2) Many β' metastable phase, a few the TYPE-B and the TYPE-C precipitates existed in the 4vol% SiC composite. This tendency is similar to that of the matrix alloy containing 0.2mass% Si in excess.

(3) The TYPE-A, the TYPE-B and the TYPE-C precipitates exist in 8vol% SiC composite. But the β' phase was not observed. This results is similar to that of the matrix alloy containing 0.4mass% Si in excess.

(4) The present study have found that the released Si from SiC particle dissolve in the matrix in the SiC dispersed Al-Mg-Si alloy and Mg forms oxide. The chemical composition of the matrix changed from the Al-1.0mass%Mg2Si alloy to excess Si and the aging process of this composites become just like that of the matrix alloy containing Si in excess.

REFERENCE

[1] S. I. Hong, G. T. Gray III and J. J. Lewandowski : Acta Metall. Mater., 41 (1993), 2337.

[2] M. P. Thomas and J. E. King : J. Mater. Sci., 29 (1994), 5272.

[3] G. M. Janowski and B.J. Pletka : Metall. Mater. Trans. A, 26 (1995), 3027.

[4] D. Yu and T. Chanadra : Mater. Trans. JIM., 12 (1993), 1184.

[5] S. Ikeno, K. Horie, K.Matsuda, Y.Uetani, H.Anada, S.Tada : J. Jpn. Inst. Light Metals, 43 (1993), 465

[6] S. Ikeno, K. Furuta, K.Matsuda, H.Anada, Y.Uetani, S.Tada : J. Jpn. Inst. Light Metals, 45 (1995), 249

[7] S. Ikeno, K. Furuta, T.Teraki, K.Matsuda, H.Anada, Y.Uetani : J. Jpn. Inst. Light Metals, 46 (1996), 9

[8] K.Matsuda, S. Ikeno, S.Tada : J. Jpn. Inst. Metals, 57 (1993), 1107.

[9] K.Matsuda, S.Tada, S. Ikeno, T.Sato and A.Kamio : Scripta Met. Mater., 32 (1995), 1175.

[10] K.Matsuda, S. Ikeno, T.Sato and A.Kamio : Scripta Met. Mater., 34 (1996), 1797.

[11] K.Matsuda, S. Ikeno, T.Sato and A.Kamio : Proceedings of ICAA 5, 2 (1996) 707.

[12] S. Ikeno, K. Kawashima, K.Matsuda, H.Anada, S.Tada : J. Jpn. Inst. Light Metals, 41 (1991), 752

[13] N.Wang, Z. Wang and G.C. Weatherly: Metall. Trans. A, 23 (1992), 1423