EFFECT OF HOMOGENIZING TREATMENT ON Al-Fe-Si INTERMETALLIC PHASES IN A 6063 ALUMINUM ALLOY

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ABSTRACT The effect of homogenizing treatment on occurrence of Al-Fe-Si intermetallic compound particles in a 6063 aluminum alloy was investigated using X-ray diffraction and transmission electron microscopy (TEM). The intermetallic phases were extracted from the ingot by the thermal phenol method. In the 0.1mass%Fe as-cast ingot at the casting cooling rate of 0.06K/s, the most of the β-AlFeSi phases (monoclinic : a=b=0.612nm, c=4.15nm, β=91°) observed. Similarly, in the 0.5mass%Fe as-cast ingot at the casting cooling rate of 50K/s, the most of the α-AlFeSi phases (cubic : a=1.252nm or 1.256nm) observed. To clarify the effect of homogenizing treatment on these intermetallic phases, each ingot was homogenized at 858K for 54ks and 2400ks, and Al-Fe-Si intermetallic phases in these ingots were investigated. When these ingots were homogenized at 858K for 2400ks, the α'-AlFeSi phase (hexagonal : a=1.23nm, c=2.62nm) was mainly observed, and the α-AlFeSi phase and the β-AlFeSi phase could not be observed.

Keywords : *6063 aluminum alloy, Al-Fe-Si intermetallic phase, homogenizing treatment, TEM*

1. INTRODUCTION

Al-Fe-Si intermetallic phases exist in a 6063 aluminum alloy used as aluminum sashes, which contain the α-AlFeSi phase and the β-AlFeSi phase. It is said that the platelet β-AlFeSi phase is harmful to extrusion. It had been reported that the β-AlFeSi phase formed in the as-cast ingots transformed to the rounded α-AlFeSi phase by applied heat treatment[1,2]. However, there is few systematic investigations about these intermetallic phases change on heat treatment correspond to crystal system change.

The present investigation was carried out to clarify the effect of homogenizing treatment on Al-Fe-Si intermetallic phases in a 6063 aluminum alloy by transmission electron microscopy (TEM).

2. EXPERIMENTAL DETAILS

Four varieties alloys used in this work were prepared using 99.99%Al, 99.9%Mg, and 99.9%Si ingots and Al-50mass%Fe mother alloy by melting. The chemical compositions of these alloys are given in Table 1.

Table 1 Chemical composition of specimens (mass%)

	Mg	Si	Fe	Cu	Ti	Mn	Cr	Zn	Al
0.1%Fe alloy	0.49	0.43	0.09	0.002	0.001	0.001	0.000	0.001	bal.
0.2%Fe alloy	0.49	0.42	0.18	0.001	0.001	0.001	0.000	0.001	bal.
0.3%Fe alloy	0.49	0.42	0.33	0.001	0.001	0.000	0.000	0.002	bal.
0.5%Fe alloy	0.52	0.40	0.50	0.002	0.000	0.003	0.000	0.001	bal.

These ingots were casting at cooling rate of 0.06, 5.0 and 50K/s, and then homogenized at 858K for 54ks and 2400ks. The Al-Fe-Si intermetallic phases extracted from the matrix by the thermal phenol method were investigated using X-ray diffraction and TEM. Specimen for X-ray diffraction was prepared by the thermal phenol method, which used as dried powder. The extracted AlFeSi phases on glass were measured by using Cu K α X-ray diffraction (RINT 1100 X-ray Diffractmeter RIGAKU). The extracted Al-Fe-Si phase on the microgrid for TEM observation was also prepared by the thermal phenol method. A TEM is the EM-002B type (Topcon co.ltd.) equipped with an energy dispersive X-ray spectroscopy (EDX, EDAX inc.)

3. RESULTS AND DISCUSSION

Fig.1 shows the relationship between the iron content and the casting cooling rate for the intermetallic phases formation in the as-cast ingots. It had been reported that the β-AlFeSi phase formed in the as-cast ingots [1,2]. However, in this study, when the iron content and the casting cooling rate changed, the α-AlFeSi phase and the α'-AlFeSi phase were observed in addition to the β-AlFeSi phase. In the 0.1%Fe as-cast ingot at the casting cooling rate of 0.06K/s, the most of the β-AlFeSi phase was observed. Similarly, in the 0.5%Fe as-cast ingot at the casting cooling rate of 50K/s, the most of the α-AlFeSi phase was observed. To clarify the effect of homogenizing treatment on the type of these intermetallic phases, each ingot was homogenized at 858K for 54ks or 2400ks, and Al-Fe-Si intermetallic phases in these ingots were investigated.

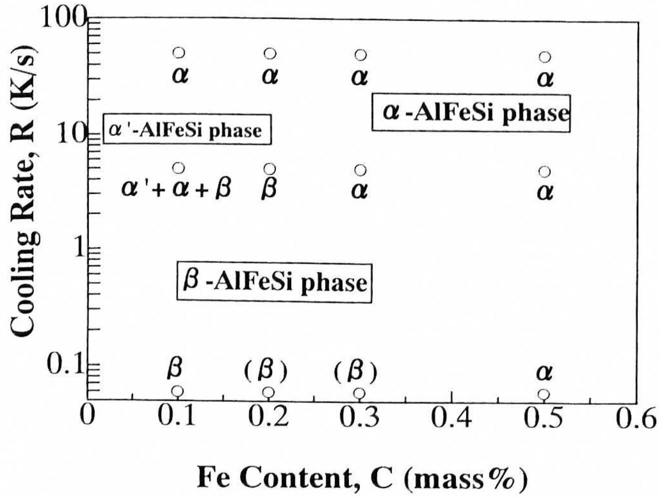

Fig.1 The relationship between the iron content and the casting cooling rate of intermetallic phase formation in the as-cast ingots.

Fig.2 shows an example of TEM image of the Al-Fe-Si intermetallic phase in the 0.1%Fe ingot homogenized at 858K for 2400ks at the casting cooling rate of 0.06K/s. The shape of this phase was polygonal, and Al, Fe and Si peaks were detected from them by the EDX analysis. This phase was identified as the α'-AlFeSi phase by the selected area diffraction pattern (SADP) and EDX.

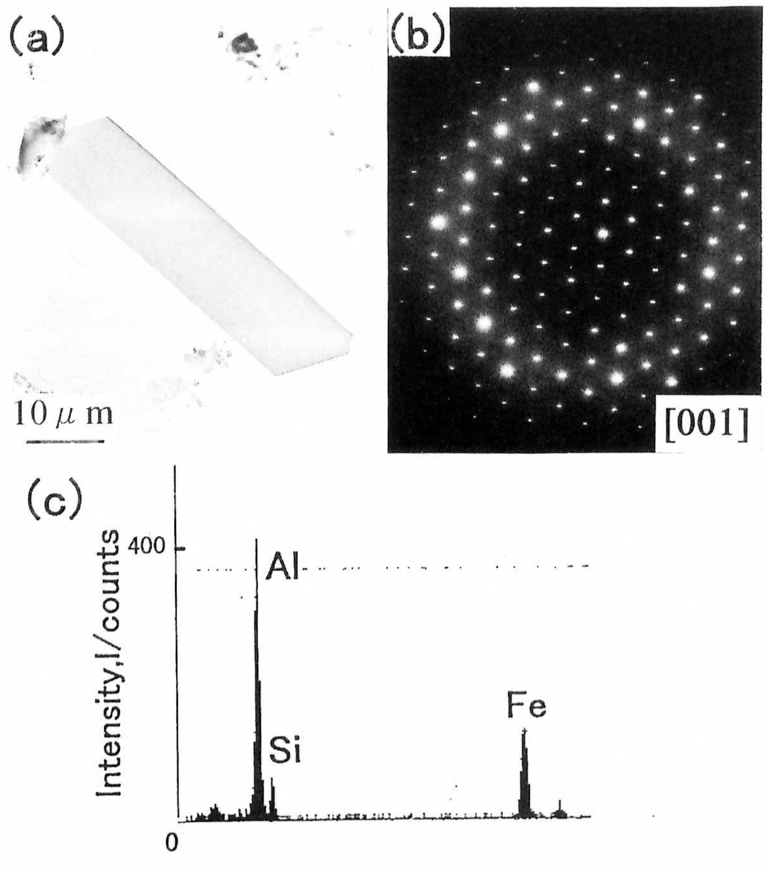

Fig.2 A TEM image of the Al-Fe-Si intermetallic phase in the 0.1%Fe ingot homogenized at 858K for 2400ks at the casting cooling rate of 0.06K/s. The phase is supported on a microgrid. (a) bright field image, (b) selected area diffraction pattern showing [001] zone of hexagonal α-AlFeSi phase and (c) EDX spectrum.

In this way, three types of the Al-Fe-Si intermetallic phases in those ingots were classified by TEM and this result was summarized in Fig.3. Fig.3 shows the changes of the relative frequency of three types of the Al-Fe-Si intermetallic phases to homogenizing treatment time in the 0.1%Fe ingots at the casting cooling rate of 0.06K/s. A large amount of the β-AlFeSi phase was observed in the as-cast ingot, but the β-AlFeSi phase was little observed in the ingot homogenized at 858K for 2400ks. The amount of the α'-AlFeSi phase tended to increase with increasing heating time. When those ingots were homogenized at 858K for 2400ks, most Al-Fe-Si intermetallic phases were the α'-AlFeSi phase.

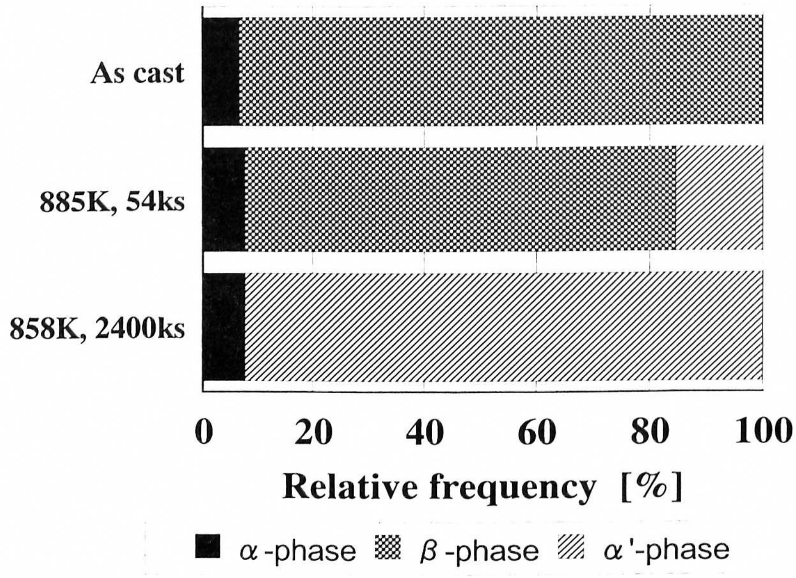

Fig.3 The changes of the relative frequency of the Al-Fe-Si intermetallic phases to homogenizing treatment time in the 0.1%Fe ingots at the casting cooling rate of 0.06K/s.

Fig.4 shows the changes of the relative frequency of the Al-Fe-Si intermetallic phases to homogenizing treatment time in the 0.5%Fe ingots at the casting cooling rate of 50K/s. Almost the Al-Fe-Si intermetallic phases were the α-AlFeSi phase in the as-cast ingot, but the amount of the α-AlFeSi phase in the homogenized ingot at 858K for 54ks decrease to 95 %. When this ingot was homogenized at 858K for 2400ks, the α-AlFeSi phase was little observed. The amount of the α'-AlFeSi phase tended to increase in this ingot with increasing heating time, too. When this ingot was homogenized at 858K for 2400ks, most Al-Fe-Si intermetallic phase was the α'-AlFeSi phase. It was found that both the amount of the α-AlFeSi phase and the β-AlFeSi phase tended to decrease and that of the α'-AlFeSi phase tended to increase with increasing heating time.

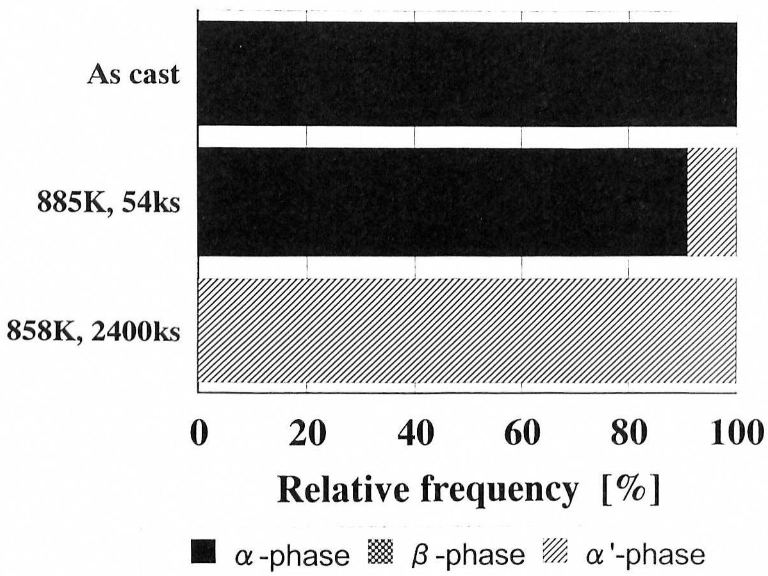

Fig.4 The changes of the relative frequency of the Al-Fe-Si intermetallic phases to homogenizing treatment time in the 0.5%Fe ingots at the casting cooling rate of 50K/s.

Fig.5 shows the relationship between the iron content and the casting cooling rate of the Al-Fe-Si intermetallic phases in the homogenized ingots. When the casting cooling rate of the ingots was 50K/s, the main phase in as-cast ingots was the α-AlFeSi phase regardless of the iron content, while the main phase in the ingots homogenized at 858K for 54ks was also the α-AlFeSi phase regardless of the iron content (Fig.5 (a)). On the other hand, the main phase in the ingots homogenized at 858K for 2400ks was the α'-AlFeSi phase regardless of the iron content (Fig.5 (b)). When the casting cooling rate of the ingots was 5K/s, the α-AlFeSi phase, the β-AlFeSi phase and the α'-AlFeSi phase were observed in the 0.1%Fe as-cast ingot. In the 0.2%Fe as-cast ingot, the β-AlFeSi phase was mainly observed. In the 0.3 and 0.5%Fe as-cast ingot, the α-AlFeSi phase was mainly observed. However, the main phase in the ingots homogenized at 858K for 2400ks changed from the α-AlFeSi phase to the α'-AlFeSi phase regardless of the iron content (Fig.5 (b)). When the casting cooling rate of the ingots was 0.06K/s, the main phase in the 0.1%Fe as-cast ingot was the β-AlFeSi phase, and the β-AlFeSi phase decreased and the α-AlFeSi phase increased with increasing the iron content up to 0.5%. On the other hand, the main phase in the ingots homogenized at 858K for 2400ks changed the α'-AlFeSi phase regardless of the iron content (Fig.5 (b)). It is not correct that the β-AlFeSi phase transformed to the α-AlFeSi phase simply. It was found that the α-AlFeSi phase and the α'-AlFeSi phase existed in addition to the β-AlFeSi phase in as-cast ingots dependent on the iron content and the casting cooling rate, while that the main phase in the ingots homogenized at 858K for 2400ks changed the α'-AlFeSi phase regardless of the iron content and the casting cooling rate.