FORMATION CHARACTERISTICS OF Al–Cu–Fe–Mg QUASICRYSTALS①

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ABSTRACT

Several Al–Cu–Fe–Mg powders were produced by rapid solidification. The powders are crystalline at room temperature, bút start to be transformed into quasicrystals when being heated to 600 ℃ and almost transformed to single icosahedral phase quasicrystals at about 800 ℃, and then, transformed into crystalline materials again at about 900 ℃. In this paper, the phase structural changes during heating, the composition range and formation characteristic of the Al–Cu–Fe–Mg quasicrystals are reported.

Key word: powders rapid solidification quasicrystals

1 INTRODUCTION

When searching for new quasicrystalline alloys, the authors suggested a principle of composition additivity in the quasicrystal constitution[1,2], which means that some new quasicrystalline alloys can be constituted by adding several quasicrystalline alloy compositions, and these alloys can be obtained by means of rapid solidification. Guided by this principle, the authors have discovered several quasicrystalline alloys. In this work, the authors found that the Al–Cu–Fe–Mg powders, constituted by adding $Al_{65}Cu_{20}Fe_{15}$ and $Mg_{32}(Al, Cu)_{49}$ are crystalline at RT. When being heated, these powder start to be transformed into quasicrystals at about 600 ℃ and almost wholly transformed to icosahedral quasicrystals at about 800 ℃. The present paper gives the details.

2 EXPERIMENTAL PROCEDURE

Some Al–Cu–Fe–Mg alloys were formulated according to the compositions listed in Table 1; chemical analysis indicated that nominal compositions are satisfactorily consistent with the analysis results. In addition, some other alloys were formulated by adjusting the compositions listed in Table 1. These powders were made with a RS powder-making device developed by the authors[3]. The cooling rate of the device reaches $10^5 \sim 10^7$ K / s; the obtained powders have a production rate of 1～1.5 kg / min. The metallic melt were first atomized with a nozzle with gas pressure 0.5～1.5 Mpa; then, the droplets were centrifugally pulverized by a high velocity rotating disc and subsequently cooled by the jetted water. The detail of the device can be seen in literature [4]. The raw powders and the heat treated powders

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(in the protection of inert gas) were detected with H–800 Transmission Electronic Microscope (TEM) and SIMENS D5000 X–ray diffracometer (XRD) and Differential Thermal Analyzer (DTA); EDAX was employed to determine the composition of the phases, because of the copper microgrid used to suport the particles in the TEM observation, the composition results is qualitative. In the elevated temperature X–ray diffraction (HXRD), N_2 was used to prevent the sample from oxidizing.

Table 1 Formulation of the Al–Cu–Fe–Mg alloy

Sample NO.	$Al_{65}Cu_{20}Fe_{15}$:Mg_{32} (Al, Cu)$_{49}$* (mass ratio)	composition(wt.–%) Al	Cu	Fe	Mg
1	2:1	37.6	39.2	14.5	8.7
2	1:1	33.7	42.4	10.9	13.0
3	1:2	29.8	45.7	7.2	17.3

* Here we have $Mg_{32}Al_{24.5}Cu_{24.5}$

3 RESULT AND DISCUSSION

3.1 *The Phase Structural Transitions of* Al–Cu–Fe–Mg *Alloys During Annealing*

DTA, XRD HXRD and TEM were used to analyze the phase transformation of the powders during heating proccess. The results showed that at RT, the powders have crystalline structures; at about 600 ℃, these crystalline phases start to be transformed into quasicrystalline phases; at about 800 ℃, the powders almost transform into icosahedral quasicrystals wholly; then at about 900 ℃, the icosahedral phase transforms back into crystalline phases. Fig.1 shows the XRD pattern of the Al–Cu–Fe–Mg powder (sample No.3). Comprehensive TEM observation indicated that the phase structures of the powders at room temperature are crystalline. Fig.2 presents the DTA curve of the Al–Cu–Fe–Mg powder (sample No.1). Fig.3 shows the HXRD patterns of the Al–Cu–Fe–Mg powder. Fig.4 demonstrates the TEM diffraction patterns of the heat treated powder (800 ℃, 0.5 h) which possesss 5–3–2 fold symmetry. These facts describe the phase transformation characteristics of the Al–Cu–Fe–Mg powders during annealing process, that is, from crystalline structure to quasicrystalline structure.

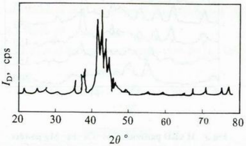

Fig.1 XRD pattern of Al–Cu–Fe–Mg powder (sample No.3)

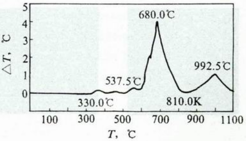

Fig.2 DTA curve of Al–Cu–Fe–Mg powder (sample No.1, heating rate: 10 ℃ / min)

3.2 *The Composition Range of* Al–Cu–Fe–Mg *Quasicrystalline Alloys*

The Al–Cu–Fe–Mg quasicrystals can be formed in a wide composition scope, the ratio of their components can be adjusted in some limit. The powders with the composition listed in Table 1 can form quasicrystals when being heated. This work shows that the composition of the quasicrystals (wt.–%) can be varied as

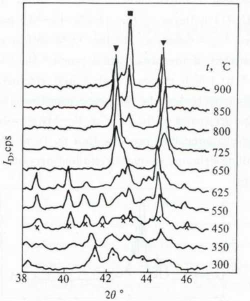

Fig.3 HXRD patterns of Al–Cu–Fe–Mg powder sample No.1, heating rate : 5 ℃ / min

▼— quasicrystalline phase; ● l and ■ — crystalline phase

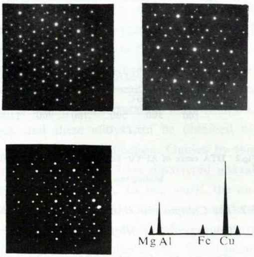

Fig.4 5–3–2 fold symmetry of the electronic diffraction patterns of Al–Cu–Fe–Mg quasicrystal (heat treated sample No.1, 800℃, 30 min)

25~ 40Al–35~ 40Cu–5~ 20Fe–5~ 20Mg. If some component contents are too high or too low, especially when the iron content is too low and the magnesium content is too high, the quasicrystals are hard to be obtained. In general, if one prepares the alloy by adding the two master alloys of $Al_{65}Cu_{20}Fe_{15}$ and $Mg_{32}(Al, Cu)_{49}$ and rapid solidification, when the weight of the two alloys is comparable, the produced powders can form qusasicryatals when heated. Fig.5 demonstrates the XRD patterns of two heat treated Al–Cu–Fe–Mg powders with different iron contents.

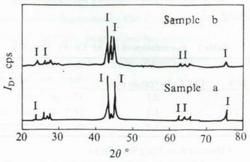

Fig.5 XRD patterns of two Al–Cu–Fe–Mg quasicrystalline powders with different iron content (800 ℃, 30 min)

3.3 *The Structures of* Al–Cu–Fe–Mg *Quasicrystals-related Crystalline Phases*[5]

TEM analysis indicates that at room temperature, the powders are mainly composed of two crystalline phases; a hexagonal phase i.e., (H phase a = b = 5.1 Å, c = 8.5 Å) and a body-centered orthogonal structure (O phase: a = 6.4 Å, b = 7.6 Å, c = 8.5 Å) when heated to 300~ 600 ℃, its crystalline phase structure is very complex. At 600 ℃ the quasicrystalline phase appeared. At about 800 ℃, the crystalline phases disappeared, and the sample remained only quasicrystalline phase; at about 900 ℃, some crystalline phases formed again, the main phases are a hexagonal phase (H Phase: a = b = 5.1 Å, c = 5.5 Å), $Al_{13}Fe_4$ and B_2–base phase[5].

4 CONCLUSIONS

(1). By means of rapid solidification, Al–Cu–Fe–Mg alloy powders were produced. These powders possess crystalline structures at RT, and were transformed into quasicrystalline icosahedral phase when being annealed at about 800 ℃.

(2) In Al–Cu–Fe–Mg alloys, if the iron content is too low, and the magnesium content is too high, the quasicrystalline phase is hard to be obtained when heated.

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(3) Hot extrusion causes great damage to the whiskers, and the average aspect ratio of the whiskers is reduced to 5.3.

(4) The strength and modulus of the 20vol.–% SiCw / 2124Al composite increases by 45% and 76% respectively, over that of unreinforced alloy, and the CTE decreases by 35%.

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