THE MICROSTRUCTURE AND EFFECT OF RARE-EARTH IN THERMAL-STABLE AL-BASED NANOCOMPOSITE RIBBONS

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ABSTRACT This paper present the microstructure and effect of RE in Al-based nanocomposite ribbons. Results indicated that with the content of Mm element increasing, the scale of α-Al grains and second phase particles were continuously refined, forming particles dispersed Al-based nanocrystalline materials. Moreover, in the rapid solidification process, adding of Mm promoted the formation of Al_8Fe_4Mm and suppressed the precipitation of α-$Al_{13}(Fe,V)_3Si$. During heat treatment, metastable phase Al_8Fe_4Mm was transformed into fine α-$Al_{13}(Fe,V)_3Si$, which improved the thermal stability of nanocrystalline alloy.

Keywords: *Al-based nanocrystalline alloy Microstructure Rare-earth elements Particles dispersed*

1. INTRODUCTION

Many studies indicated that nanocrystalline materials has excellent mechanical, physical and chemical properties[1,2]. However, nanocrystalline materials was in high energy and metastable state, its grain will grow and change the structure character of grain boundary when it is heated. These led to the lost of outstanding performance. If many dispersed distributed second phase particles, which has fine scale, low coarsening ability, and good combination with matrix, can be achieved in nanocrystalline materials, it will suppressed nano-grain growth and maintain excellent properties of nano-materials. To gain new dispersed Al-based nanocrystalline alloy with good properties, suitable amount Mm was added in Al-Fe-V-Si alloy. This paper present the studies on the microstructure and effect of rare earth in rapidly solidified thermal stable Al-based nanocomposite ribbon.

2. SAMPLE PREPARATION AND EXPERIMENTAL METHODS

$Al_{93.3-x}Fe_{4.3}V_{0.7}Si_{1.7}Mm_x$(x=0, 0.5, 1.0, 3.0at%) was smelted in induction furnace with argon shield. Alloy ribbons with 10 ~ 20mm width and 30 ~ 40μm thick was prepared by Single-roller melt spinning method. Alloy thin ribbon was subjected to thermal analysis using Perkin-Elmer Differential Calorimeter(DSC) under argon atmosphere at heating rate of 20K/min. X-ray analysis was carried out on Rigaku diffractometer. TEM observation was carried out on Philips EM-400T.

3. RESULTS AND DISCUSSION

3.1 The Effect of Mm Contents on Microstructure of Rapidly Solidified Ribbon

Seeing from Figure 1, The microstructure of RS $Al_{93.3}Fe_{4.3}V_{0.7}Si_{1.7}$ ribbon are Al grains and fine dispersed α-$Al_{13}(Fe,V)_3Si$, and the scale of Al grains is about 200nm ~ 500nm. α-$Al_{13}(Fe,V)_3Si$ distribute along grain boundary and format particles group. The microstructure of ribbon containing

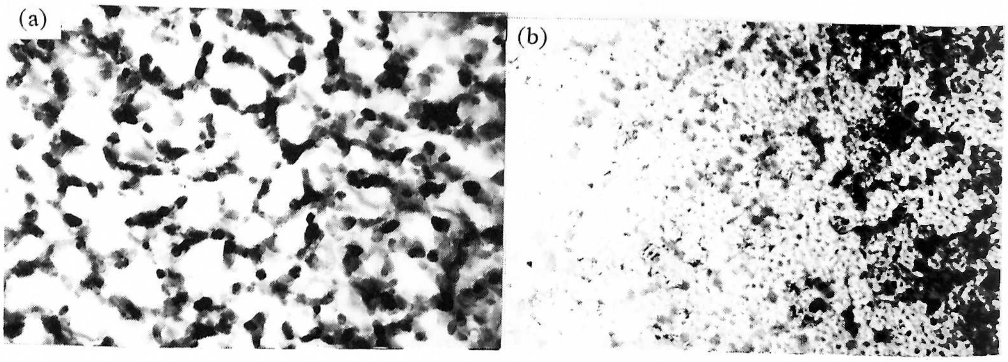
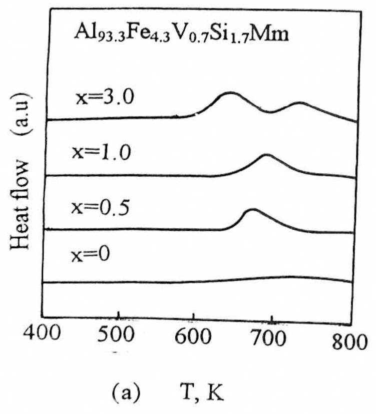


Figure 1 The microstructure of RS ribbons (a) $Al_{93.3}Fe_{4.3}V_{0.7}Si_{1.7}$,(b) $Al_{923}Fe_{4.3}V_{0.7}Si_{1.7}Mm$

0.5at% and 1.0% Mm are both Al grains and fine second phase, and the scale of Al grains are less than 100nm. The scale of grains and particles in ribbon containing 1.0at%Mm is smaller. X-ray analysis after extraction found[3] that the second phases in ribbons containing 0.5at% Mm are Al_8Fe_4Mm and α-$Al_{13}(Fe,V)_3Si$, and that in ribbons containing 1.0at% Mm is only Al_8Fe_4Mm. This was to say that the adding of Mm elements not only promote the refinement of Al grains, but also suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$ and promote the formation of Al_8Fe_4Mm. 1.0at%Mm was enough to suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$ completely. Study also indicated that in ribbon containing 3.0at% Mm Al grains were refined further, and its second phase was $Al_{20}Fe_5Mm$ which has quasicrystal structure[4].

3.2 Phase Transformation and Microstructure of Ribbon during Heat-treatment

Figure 2 were the DSC curves of 1.0at% and 3.0at% Mm ribbons. It is obvious that there are phase transformation during heat-treatment. The ribbons containing 0.5at% and 1at% Mm only have an exothermal peak, the enthalpy value of which are almost same. Their peak temperature has some different They are 673K and 683K respectively. The ribbons containing 3.0at%Mm have two exothermal peaks. The microstructure of ribbons containing 0.5at% and 1.0at% Mm are nano-scale Al grains and α-$Al_{13}(Fe,V)_3Si$ after 673K heat treatment for 1h, shown as Figure 2. It indicated that there are phase transformation from metastable phase Al_8Fe_4Mm to α-$Al_{13}(Fe,V)_3Si$ when ribbons were heated. The ribbons containing 3.0at% Mm after 673K annealing was subjected to X-ray diffraction, and it was found that ribbon is composed of nano-scale Al grains, $Al_{11}Mm_3$ and an unknown phase.



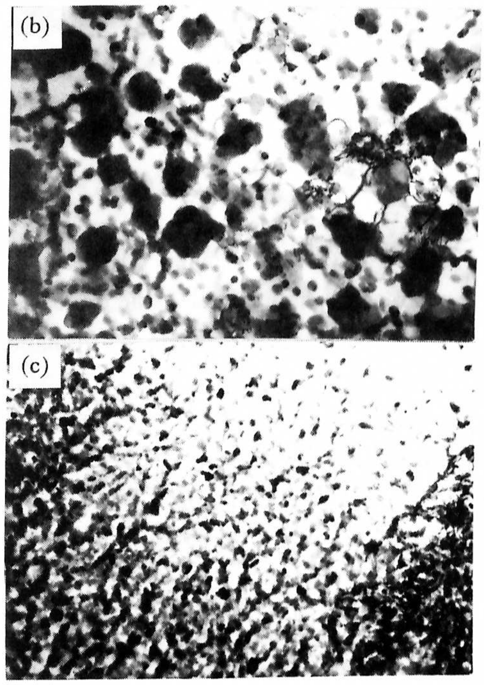


Figure 2 ,(a) The DSC curves of $Al_{92.3-x}Fe_{4.3}V_{0.7}Si_{1.7}Mm_x$ (b),(c) TEM micrographs of $Al_{92.3-x}Fe_{4.3}V_{0.7}Si_{1.7}Mm_x$ annealed at 673K for 1h, (b) for x=0, (c) for x=1

3.3 The Acting Mechanism of Rare Earth

Shown as the results above, rare earth element played important role in preparing RS nanocomposite ribbon process. Its important effects were concluded as: the adding of small quantity Mm refine Al grains and second phase particles, forming particles dispersed Al-based nanometer composite ribbons; with the increasing of Mm, refining effect is much obvious; Mm promote the formation of metastable phase Al_8Fe_4Mm , and suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$, of which 1.0at% Mm can completely suppress; when heating, the transformation from Al_8Fe_4Mm to α-$Al_{13}(Fe,V)_3Si$ increase the thermal stability of nanocrystalline alloys.

The effect of rare earth lies in its effects to thermodynamics and dynamic conditions during rapid solidification. Many studies indicated that suitable rare earth elements, such as La, Ce and so on, can promote aluminum and alloy to form amorphous[5,6], i.e, rare earth element can increase the supercooling ability of liquid Al and alloys. With the under cooling ability increasing, α-Al grains will nucleate under larger supercooling conditions, and were refined continuously till nanograins or amorphous form. As the formation of super-fine grains, the contents of rare earth and iron elements in residual liquid around grains will increase, make strong short-range order (such as Al-Fe, Al-Mm, Fe-Mm and so on) increase, create conditions for the formation of intermetallic compound containing rare earth[3], make the free energy of metastable phase Al_8Fe_4Mm decrease and gain enough drive force for prior nucleation, and suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$. When the contents of Mm reaches 1.0at%, the precipitation of α-$Al_{13}(Fe,V)_3Si$ was completely suppressed. Because

Al_8Fe_4Mm is metastable phase, it will be transformed into stable phase, therefore, α-$Al_{13}(Fe,V)_3Si$ can precipitate. α-$Al_{13}(Fe,V)_3Si$ achieved by such procedure will be much fine and in dispersed distributed state. Once more, because of the low coarsening ability of α-$Al_{13}(Fe,V)_3Si$, the thermal stability of alloys will be improved.

4. CONCLUSION

1. Based on Al-Fe-V-Si alloy, the adding of suitable Mm elements promote the refinement of Al grains and second phase particles, and make it to be particles dispersed nanocomposite materials.

2. The adding of Mm promote the formation of metastable phase Al_8Fe_4Mm, and suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$. 1.0at% Mm can completely suppress the precipitation of α-$Al_{13}(Fe,V)_3Si$.

3. During heat treatment, metastable phase Al_8Fe_4Mm has an transition around 673K, and the precipitation of dispersed particles α-$Al_{13}(Fe,V)_3Si$ improve the thermal stability of nanocrystalline alloys.

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