O-138

Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Grain Refining Efficiency of Al Cast by Novel Al-$Al_{2.7}Ni_{0.3}Ti$ Refiners

Kazunori Maekawa[1], Yoshimi Watanabe[1] and Hisashi Sato[1]
[1] Graduate school of Engineering, Nagoya Institute of Technology
Gokiso-cho, Showa-ku, Nagoya, 466-8555, Japan

In this study, heterogeneous nucleation behavior of $L1_2$ cubic structure of $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particles having small misfit with fcc Al was studied. Al-$Al_{2.7}Ni_{0.3}Ti$ grain refiners were fabricated by spark plasma sintering (SPS) method using gas atomized $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particles. Grain refining efficiency of Al cast by the fabricated grain refiners with $L1_2$ structure nucleation sites was investigated.

Keywords: *aluminum, grain refiner, $L1_2$ structure, $Al_{2.7}Ni_{0.3}Ti$, spark plasma sintering (SPS)*

1. Introduction

Grain refinement is widely used in Al foundries to promote a fine equiaxed grain structure with improved mechanical properties. Generally, grain refinement of Al and Al alloys can be achieved by adding grain refiners, such as Al-Ti, Al-Ti-B and Al-Ti-C alloys with heterogeneous nucleation sites of Al_3Ti, TiB_2 and TiC particles, into the melt. There should be two approaches to enhance the refining performance of grain refiners. One is achieved by increasing the number of heterogeneous nucleation sites in the melt [1]. Another one is achieved by decreasing lattice registry between heterogeneous nucleation site and the Al [2]. Meanwhile, it is known that alloying with a certain amount of transition element such as V, Cr, Mn, Fe, Co, Ni, Cu and Zn causes the transformation from the $D0_{22}$ type tetragonal structure of Al_3Ti into high-symmetry $L1_2$ cubic structure [3-6]. Since the lattice constant of $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound with $L1_2$ structure is a = 0.394 nm [7], disregistry value between $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound and Al can be calculated to be 2.71 % for all planes, which is much smaller than that for platelet plane of Al_3Ti phase [2]. Therefore, it is expected that the $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particle with $L1_2$ structure become favorable heterogeneous nucleation sites for Al cast. In the previous study, grain refining performance of Al-$L1_2$ type $Al_{2.7}Fe_{0.3}Ti$ refiner has been studied [8]. In this study, $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound with $L1_2$ cubic structure was chosen as the heterogeneous nucleation site, since the disregistry value between $Al_{2.7}Ni_{0.3}Ti$ and Al is smaller than that of $Al_{2.7}Fe_{0.3}Ti$ and Al. First, $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particles were prepared by gas atomization. Then, Al-$Al_{2.7}Ni_{0.3}Ti$ grain refiners were fabricated by SPS method. The grain refining performance of fabricated refiners for pure Al cast was investigated.

2. Experimental Procedure

$Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particles with $L1_2$ structure were prepared by gas atomization method. The particles in the range of 75-150 μm were sintered with pure Al particles by SPS method. Volume fraction of $Al_{2.7}Ni_{0.3}Ti$ particles within the refiner was fixed to be 10 vol.%. Microstructural evolution for the $Al_{2.7}Ni_{0.3}Ti$ particles and the refiner was studied by scanning electron microscope (SEM) with energy dispersive X-ray spectrometer (EDS). Phase analysis was carried out by the X-ray diffraction (XRD) technique using Cu Kα radiation. The refiner was added into the pure Al melt at 750 ºC. Subsequently, the melt was stirred for 30 s. After a certain holding time, the melt was poured into a steel mold. Microstructural obsevations were carried out with an optical microscope. The mean size of α-Al grains was calculated by using a mean linear intercept techniqe. The mechanical property of Al cast was evaluated by vickers hardness test.

3. Results and Discussion

SEM microphotograph of $Al_{2.7}Ni_{0.3}Ti$ particles prepared by gas atomization is shown in Fig. 1. As shown in Fig. 1, most of the particles are spherical. Dendrite structure is also observed on the surface. EDS and XRD analyses revealed that these particles have the stoichiometric chemical composition of $Al_{2.7}Ni_{0.3}Ti$ and $L1_2$ structure.

SEM microphotograph of the Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiner fabricated by SPS method is shown in Fig. 2. It is seen from the figure that the spherical shaped particles are successfully embedded within the Al matrix. Also, the clear interface is shown between

$Al_{2.7}Ni_{0.3}Ti$ particles and Al matrix. It was also confirmed that there is no reaction between $Al_{2.7}Ni_{0.3}Ti$ particles and Al matrix by analyses of EDS.

Macrographe of unrefined pure Al sample cast is shown in Fig. 3 (a). Fig. 3 (b) shows the macrostructure of Al cast refined by the Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiner, where holding time is 690 s. The Al cast without refiner has coarse and inhomogeneous grains, as shown in Fig. 3 (a). On the other hand, the grain size becomes smaller and more homogeneous in the Al cast with the Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiner, as shown in Fig. 3 (b).

Fig. 4 shows the effect of holding time on the grain size of α-Al. The grain size of casts added the refiners reaches to minimum at 690 s and then an ascending trend with the holding time. Since $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound phase cannot exist within the Al matrix in equilibrium state, the decomposition of $Al_{2.7}Ni_{0.3}Ti$ intermetallic compound particles occurs during the casting, which may result in the fading behavior.

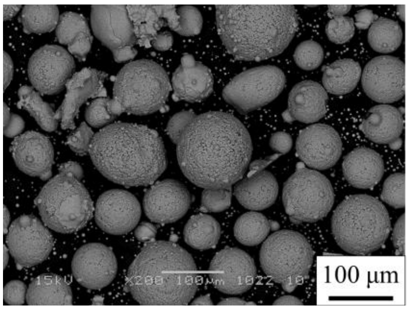

Fig. 1 Backscattered electron composition image of $Al_{2.7}Ni_{0.3}Ti$ powder.

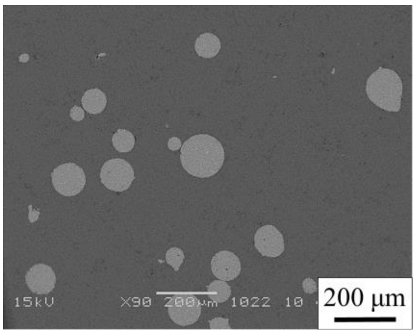

Fig. 2 Backscattered electron composition image of Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiner.

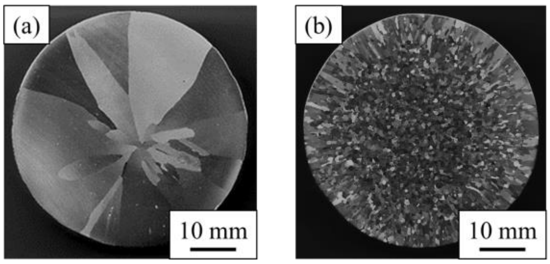

Fig. 3 Photographs of Al casts with and without Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiner. (a) without refiner, (b) with the refiner (holding time 690 s)

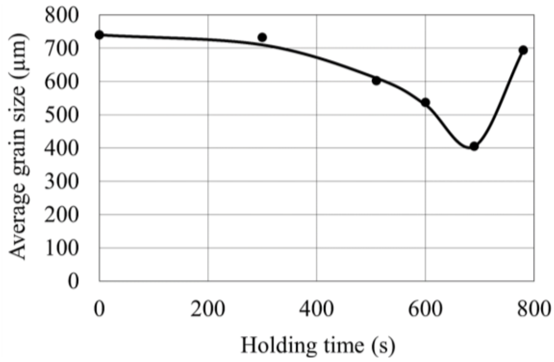

Fig. 4 Average grain size of the Al casts plotted against the holding time.

4. Conclusions

Al-10vol.% $Al_{2.7}Ni_{0.3}Ti$ refiners are able to be fabricated by SPS method. The grain size of Al cast becomes smaller and homogeneous microstructure could be achieved in the Al casts with the refiners. Therefore, usefulness as the heterogeneous nucleants of $Al_{2.7}Ni_{0.3}Ti$ was indicated.

References

[1] Z. Zhang, S. Hosoda, I. S. Kim and Y. Watanabe: Mater. Sci. Eng. A425 (2006) 55-63.

[2] Y. Watanabe and H. Sato: J. Jpn Inst, Light Met. 64 (2014) 157-163.

[3] J. Tarnacki and Y-W. Kim: Scr. Metall. 22 (1988) 329-334.

[4] Y.Nakayama and H. Mabuchi: Intermetallics. 41 (1993) 41-48.

[5] S. Liu, R. Hu and C. Wang: J. Appl. Phys. 74 (1993) 3204-3210.

[6] S. M. Kim, M. Kogachi, A. Kameyama and D. G. Morris: Acta Metall. Mater. 43 (1995) 3139-3149.

[7] P. Villars and L. D. Calvert: *Pearson's Handbook of Crystallographic Date for Intermetallic Phases* (ASM International, Materials Park, OH, 1997).

[8] Y. Watanabe, T. Hamada and H. Sato: Jpn J. Appl. Phys. 55 (2016).