Hybrid Atomization for Manufacturing Fine Spherical Metal Powder

Kazumi Minagawa[a], Hideki Kakisawa[b], and Kohmei Halada[c]

[1]National Institute for Materials Science, 1-2-1, Sengen, Tsukuba-shi, Ibaraki, Japan 305-0047
[a]MINAGAWA.Kazumi@nims.go.jp, [b]KAKISAWA.Hideki@nims.go.jp, [c]HALADA.Kohmei@nims.go.jp

Abstract

Hybrid atomization is a new atomization technique that combines gas atomization with centrifugal atomization. This process can produce fine, spherical powders economically with a mean size of about 10 m diameter and a tight size distribution.

Keywords : Fine Spherical Powder, Hybrid Atomization

1. Introduction

Needs of fine, spherical and low-oxygen metal powder with a uniform diameter have been increasing in the fields of metal injection molding (MIM), metallic paint, environmental barrier coating (EBC), solid freeform fabrications (SFF) like rapid prototyping, soldering of circuit boards, etc. High pressure water atomization [1] method is a technique which can produce a fine powder with a mean diameter of ~10 m. However, the oxygen content in the obtained powder is high and the shape of the powder is irregular. Gas atomization method [2] can produce low-oxygen, spherical powder but the powder by the method is 5-10 times as large as the powders from the high pressure water atomization, and the size distribution is relatively broad. Powders produced by centrifugal atomization method are spherical, and we can control the size distribution by changing processing parameters. But the size of the produced powder is as large as 100 m. Methods utilizing chemical reaction can produce fine, spherical and low-oxygen metal powder with a uniform diameter but it cannot be applied to alloy powders with an arbitrary chemical composition.

Thus the production of the powder as can meet the demands of new powder metallurgical technologies is very difficult in the conventional powder production methods. We developed hybrid atomization method [3] to produce a fine, spherical, low-oxygen metal powder efficiently as has not been obtained in the conventional methods. In this paper we introduce the concept and the mechanism of the hybrid atomization method. We also show several kinds of powders produced by the hybrid atomization.

2. Experimental and Results

Hybrid atomization was carried out for two kinds of tin alloy for lead free solder used in circuit boards, aluminum, and copper. 2-10kg of the alloys was used in each test. Melting was done using a special tammann furnace in a argon gas atmosphere and heated to the temperature 200-400K higher than the melting point. The melt was supplied from the nozzle with a diameter of 1.5mm. Nitrogen gas was used in gas atomization, with a atomizing pressure of 0.15-0.6MPa. The distance from the nozzle to the disk was 50-150mm. The disk diameter was 70mm and the rotating speed was 524-6282rad/s. Some kinds of disk material were used depending on the alloys. Nitrogen gas was introduced in the chamber to make partial pressure of oxygen less than 50ppm. The powder size were measured using sieving, and the yield of less than 45μm and 25μm was estimated. Size distribution was measured by Coulter Counter method. The shapes and microstructures of the powders were observed by a scanning electron microscope (SEM) and by an optical microscope (OM).

Effect of disk speed. Figure 1shows the size distributions of the powders produced with adisk rotating speed of 524, 1048 or 2094rad/s. The melt temperature was set at the optimum temperature of 673K. With increasing the disk speed, the powder size decreased; a mean diameter of 10.6 m was achieved at 2094rad/s. The primary peak around 15 m became small and the secondary peak around 5 m became remarkable with the increase of disk speed; the size distribution profile with a double-peak was obtained at

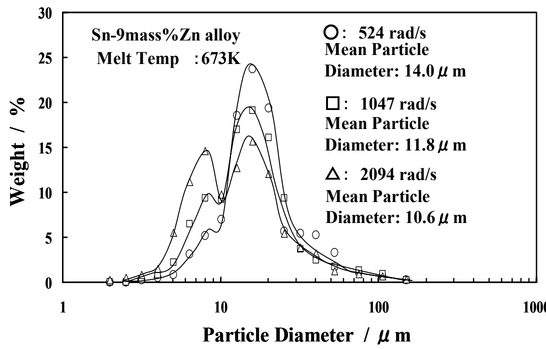


Fig. 1. Particle size distribution of powders under different disk rotation speed and diameter.

2094rad/s. It was supposed that the doublepeak profile reflected the direct drop formation. Liu et al. showed an atomization mode diagram in the hybrid atomization method according to the equations proposed by Halada et al. [4]. which predicted the atomization modes in the centrifugal atomization method; they showed that the direct drop formation occurred in the production of the tin alloy powder by this method. These facts suggested that the hybrid atomization method was the first-ever technique which made it possible the transition of atomization mode of the melt metals from conventional ones to those of aqueous solutions and organic solvents.

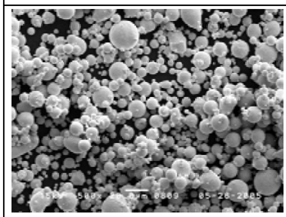
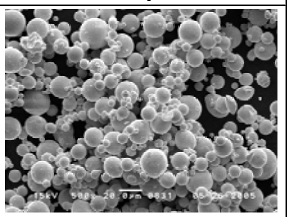
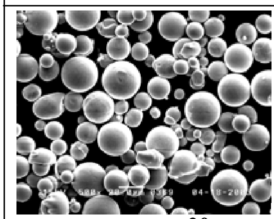
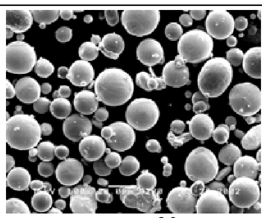
Sn-Ag alloy Powder	Sn-Zn alloy Powder
 20 μm	 20 μm
Melt Temperature :903K	Melt Temperature :733K
Disk Rotation Speed :4188rad/s	Disk Rotation Speed :3141rad/s
Total Yield of –45 μm :89.3%	Total Yield of –45 μm :78.9%
Al Powder	**Cu Powder**
 20 μm	 20 μm
Melt Temperature :1373K	Melt Temperature :1873K
Disk Rotation Speed :6282rad/s	Disk Rotation Speed :2049rad/s
Total Yield of –45 μm :75%	Total Yield of –45 μm :85%

Fig. 2. The SEM photographs of metal powders made by hybrid atomization.

Powders produced by hybrid atomization method. Heretofore it was revealed that the control of the melt properties, the disk speed, and the gas spray distance was the key for obtaining the fine powder. We produced some kinds of alloy powders according to the results of the effect of those factors. Figure 2 shows the SEM photographs of the alloy powders. The process conditions were indicated in the figure. The oxygen content of the powder was very low, 200-350ppm because the process was done in the chamber with a low oxygen atmosphere, less than 50ppm. Hence the produced alloy powders had spherical, smooth surfaces. The powder size was fairly uniform. The yield of the powder under 45μm was high in the alloys with a low melting point: 89.3wt% in a Sn-Ag alloy and 78.9wt% in Sn-Zn alloy. The high yield of 85wt% was obtained in copper, having a relatively high melting point. In aluminum which had constant melt properties at high temperatures, by rotating the disk with a high speed, 75wt% was achieved.

3. Summary

The mechanism of the hybrid atomization method which could produce a fine, spherical metal powder with a uniform diameter was investigated and the following results were obtained:

1. Increasing the disk speed resulted in a fine powder. The Sn-9massZn% alloy powder produced at 2049rad/s had a size distribution profile with a double peak. The shape of the profile suggested that direct drop formation was realized in the atomization of metal in the hybrid atomization method, which had been thought to be formed only in the atomization of aqueous solution and organic solvents.
2. Hybrid atomization method is expected as a new novel processing for powder which can meet the demands of advanced new powder metallurgical technologies

4. References

1. K.Minagawa, K.Chiba and K.Halada: J. of Jpn Soc. Powder and Powder Metallurgy, Vol.40 (1993), p. 1231.
2. K.Tamura: Mech. Industry, Vol.1 (1961), p. 75.
3. K.Minagawa, K.Halada : Japan Patent No. 3511082 (200 5).
4. K. Halada, H. Suga: J. Jpn Powder and Powder Metallurgy, Vol.37 (1990), p. 492.