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Short communication

Experimental and theoretical analysis of the classification of Sn0.3Ag0.7Cu lead-free solders powder

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ABSTRACT

Classification experiments using Sn0.3Ag0.7Cu lead-free solder powder prepared by supersonic gas atomization were conducted by turbo air classifier. The effects of rotor cage rotary speed on the cut size and partial classification efficiency of Sn0.3Ag0.7Cu solder powder were investigated. The relationship between cut size and rotor cage rotary speed was calculated through curve fitting. Results showed that cut size and median diameter of fine powders decreases exponentially with an increasing of the rotor rotary speed. The "fish-hook effect" existed in the turbo air classification process of Sn0.3Ag0.7Cu solder powder. The "fish-hook effect" weakens and classification efficiency increases with the rotor cage rotary speed decreasing. The efficiency of classifier was evaluated with the classification size ratio (CSR) index. It shows that higher rotor cage rotary speed is beneficial to the separation of coarse and fine powders adequately, and the classification is difficult when the size distribution of material fed is narrow.

1. Introduction

Since late eighties many international laws and directives, such as the RoHS in 2006, have tried to ban the use of lead in electronic products, replacing traditional Sn-Pb solders by lead-free solder alloys. All over the world, the research groups have participated to the development and production of lead-free alloys. For example, in Europe Action COST531 was dedicated to the study of low temperature lead-free solders [1] Among low melting lead-free alloys, The Sn-Ag-Cu (SAC) alloys are particularly attractive candidates due to relatively low melting point, good wetting on different substrates [2], good mechanical properties and excellent solder ability [3] and low cost [4,5]. N. Mookam has reported that Sn0.3Ag0.7Cu is a notable member of the Sn-Ag-Cu family [6].

The miniaturization of electronic product has promoted surface mounting technology to be the dominant technology in electronic assembly. Solder paste is one of the key materials in surface mounting technology which is the mixture of solder powder and flux to a certain proportion. Rheological properties of solder paste are significant for the electronic assembly process, which directly affect the stencil printing quality and behavior after print such as slump resistance and tack value. It has reported that rheological and printing properties of solder pastes, in both micro and nano scale [7–9] are closely related to the solder powder particle size and size distribution [10–12].

In addition, M. Xiao et al. [13] have reported that solder paste slump is reduced with decreasing powder size and size distribution. R. Durairaj et al. [14] have revealed that solder powders with wide particle size distribution is more susceptible to format wall-slip, which is usually seen as a source of error in the rheological measurement compared to the narrow particle size distribution powders. With the development of the electronic industry, the finer powder and definite particle size distribution are needed to adapt the fine-pitch pattern design upon the PCB. However, solder powder produced by existing process all have a wide particle size distribution, which cannot satisfy the industry demand well. Therefore, the classification process is necessary to prepare the solder powder with definite particle size distribution and detailed study on the classification of solder powder is needed.

Turbo air classifier is one of the most widely used powder classification equipment [15]. The classification performance of air classifier is

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influenced by the structure of the classifier, the operation parameters, the nature of the particles and also the surrounding environment [16]. There were many theory researches concentrated in the impeller structure, flow field and particle motion simulation [17–19], and the classifier cut size formula were also established. However, there is large gap between the calculated values and measured values due to many actual factors in the classification process. So, the specific classification experiment research is particularly necessary. In view of few classification experiment studies reported about lead-free solder powder, we conducted the classification experiment with the JZF-100 turbo air classifier and Sn0.3Ag0.7Cu solder powder prepared by gas atomization, because this process has many advantages, including narrow particle size distribution, high production yield, less impurities, no need for an atomizing fluid medium, and modest energy consumption [20]. The effects of rotor cage rotary speed on the cut size and part classification efficiency of Sn0.3Ag0.7Cu solder powder were investigated. The relationship between cutting size and rotor cage rotary speed was calculated through the experiment date. The efficiency of classifier is evaluated using the classification size ratio (CSR) index. It is hoped that the work can provide the reference for the classification study and industrial production of solder powder and the manufacture of SAC solder alloys with better quality.

2. Experimental procedures

Sn0.3Ag0.7Cu solder powder (with a purity of 99.99%) prepared by supersonic gas atomization in this work was used as the raw material. The SEM morphologies and particle size distribution are shown in Fig. 1. The JZF-100 turbo air classifier used in this experiment is shown in Fig. 2. For the JZF-100 turbo air classifier, the size of the primary air inlet is 80 × 140 mm, and the secondary air inlet is 60 × 100 mm. The speed of rotor cage is controlled by the frequency converter.

The primary and secondary air inlets are both full open during the classification process. The weight of raw material is 5 kg. The feeding rate is 20 g/s. The experimental temperature is 310 K, and the air density is 1.3 kg/m^3. High purity argon was used as an atomizing medium. We operated the experiments at rotor cage rotary speeds of 3960, 3520, 3080, 2640, 2200, 1760 and 1320 r/min. In this work, the “fish-hook effect” exhibits that the fine powder could not be adequately classified. So, when we chose the optimal separation speeds, it will inevitably make a large amount of fine powder aggregate and adsorb on the coarse powders if the raw powder undergone one classification cycles was used. In the next classification cycle, the coarse powder exist the un-classified powders, thus results in the decrease of classification efficiency, at the same time, a large amount of agglomeration of fine powder is wasted and can not achieve the goal of fully separating the specified particle size materials. Based on the classification principle of turbo air classifier [16], the magnitude of the centrifugal force can be modified by adjusting the cage rotor rotary speed. So, successive classification of the selected coarse powders not only reduce the waste of agglomeration of fine power, but also gradually improve the precision of classification as well as effectively separate out the fine powder of specified size. As shown in Fig. 2, the raw material at the loading port was added to the classifier by the electromagnetic vibration feeder evenly. Firstly, the raw material was added to the classifier at the rotor cage rotary speed of 3960 r/min. After classification, coarse and fine parts were weighted and samples were taken from the two product streams separately. Then the coarse part was added to the classifier at the rotor cage rotary speed of 3520 r/min. Similarly, the coarse and fine parts were weighted and samples were taken from the two product streams separately. Then the coarse part was added to the classifier at next rotor cage rotary speed. And so on, until the last experiment was finished under the rotor cage rotary speed of 1320 r/min.

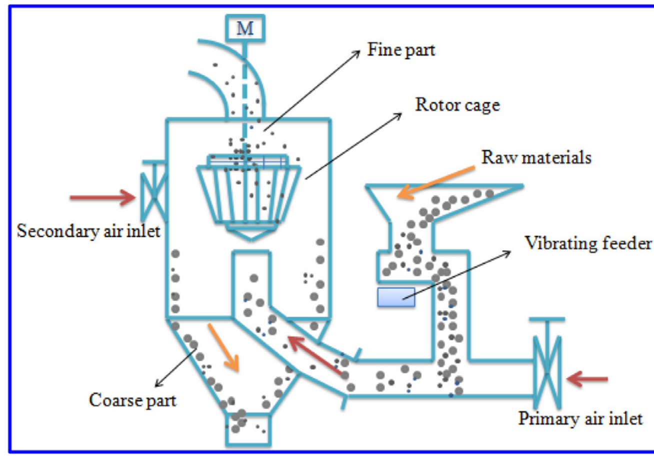

Fig. 2. The schematic of the JZF-100 turbo air classifier.

Oxygen content of SAC powders after classification treatment was measured by an oxygen analyzer (NFOXY-MAT6E/F/EX). The morphologies and particle size distribution of samples were investigated by JSM-6700 F scanning electron microcopy (SEM) and BT-2003 laser particle size analyzer, respectively.

3. Results and discussion

3.1. Effect of rotor cage rotary speed on the cut size

As mentioned previously, the cut size and median diameter of powders are directly affected by operation parameters, such as feeding speed, rotor cage rotary speed, and air inlet velocity. The cut size and median diameter of fine powder decreases with an increasing of the

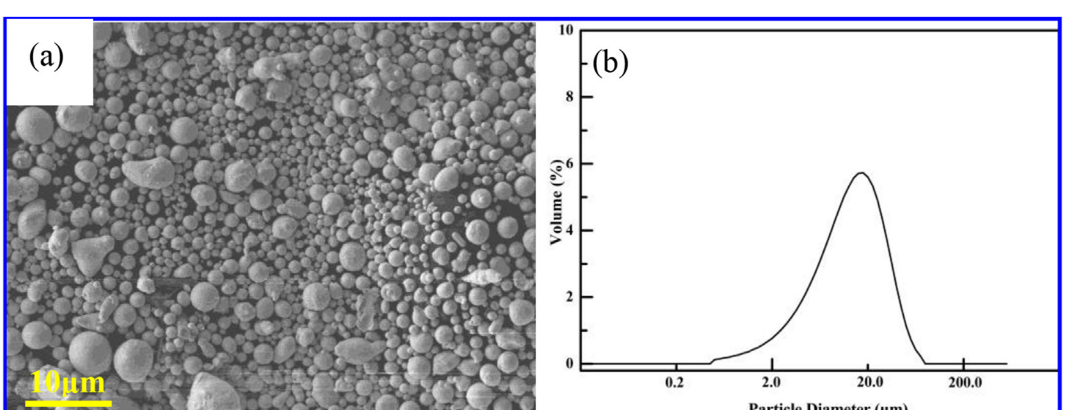

Fig. 1. The SEM morphology (a) and particle size distribution (b) of raw Sn0.3Ag0.7Cu solder powder.