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Effects of Cooling Rates on Microstructure, Wettability and Strength of Sn3.8Ag0.7Cu Solder Alloy

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Abstract

The aim of this research paper is to study the effects of cooling rates on microstructure and mechanical properties of Sn3.8Ag0.7Cu solder alloy prepared through powder metallurgy (PM) method. They were cooled by different cooling medium such as slow (furnace cooling), normal (air cooling) and fast (water cooling) which was 0.0076℃/s, 0.73℃/s and 31.14℃/s, respectively. Characterisation for each sample was conducted to examine the intermetallic compound formation and solder shear strength. Result indicated that faster cooling rates decreased the IMC thickness but reduced the solder joint strength due to distribution of melted solder on Cu board. This study found that the shape of Cu_6Sn_5 and Ag_3Sn changed according to cooling rates either at the interfacial or in the solder matrix. The study on comparison between three different cooling rates onto properties of Sn3.8Ag0.7Cu solder alloy prepared by PM method is still unknown and the current findings are still unclear. Thus this research would be the fundamental study to investigate the effects of cooling rates onto behaviours of the solder alloy. It is believed that more attentions will be shown onto this superior topic to increase the level of promising reliability of solder alloy in industry and marketplaces.

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Keywords: cooling rate; Powder Metallurgy; solder; microstructure; intermetallic compound(IMC).

1.Introduction

Driven primarily by penetration of electronics usage into virtually every inches of life, everything on earth rely heavily upon electronics throughout the years. The diversity of application and never ending demand for both lower cost and higher performance cannot be achieved without major changes in materials and manufacturing processes.

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But improper metal like lead(Pb) in electronic parts has created public health concerns[1]. This issue has insists the industry to ensure the equally environmental sound of their products.

As for that, in the move to make product designs more environmental friendly, the regulatory trends such as Restriction of Hazardous Subtances(RoHS), Joint Industry Guide(JIG), and some voluntary initiatives from nongovernmental organizations(NGOs) like Electronic Product Environmental Assessment Tool(EPEAT) officially affected products placed on the market world widely[2-5]. The use of Pb has been banned and therefore in the past few years, research and development involving governments, electronic producers and universities have spurred the study of lead free solder[4].

In term of manufacturing for lower cost of electronic products, a new technology in solder fabrication using Powder Metallurgy(PM) method is now ready to be scrutinized genuinely. All the equipment and machine involving PM method can be operated by minimum number, minimal waste and moderate skill of workers due to the manual operations involve[6, 7]. This for sure can benefit the company account profile. To begin, the solder pre mixed powder has to go through the milling, compacting and sintering as the basic process[3, 8, 9]. By virtue of the steps do not contain high temperature for fabricating the solder alloy, PM method also well known as green technology[10].

The solder alloy from PM method is likely to have better performance yet ensuring solder reliability. Literatures reported high functionality and affirmative results of solder fabricated by PM method but not as much are known about effects of cooling rate on those alloys and these have brought attention to conduct further research embracing cooling rate. Cooling rate plays an important understanding in solder alloy study as it has significant effects on the microstructure including solder joint interphase, solder matrix and IMC of solder as well as mechanical properties of the solder due to sensitivity of each element on processing and geometrical parameters[11, 12].

Common microstructures in SnAgCu solder alloy consist of primary β-Sn grains, platelet-type of Ag_3Sn and scallop-type of Cu_6Sn_5[13]. In actual fact, the morphology of microstructures relies on cooling rate because here is the stage where the IMC get solidifies into distinctive shape, size and position then the strength of solder alloy can be predetermined[14, 15]. Yang has experimented Sn3.0Ag0.5Cu solder paste and using oven as reflow method. She reported that as the rate of cooling reduced, β-Sn dendrites coarsened, Cu6Sn5 had a thick stick-like, Ag_3Sn changed from branch-like to large platelet-like at the solder matrix and the IMC thickness also gets increased[16]. As the rate of cooling increased, Mueller found that needle-like Ag3Sn became smaller in size, decreased spacing of β-Sn dendrites but no report on Cu_6Sn_5 and IMC thickness[15].

As a consequence to previous works above, the study different cooling rates on solder alloy is crucial to have better explanation in analysis to obtain specific properties and performance requirements of solder alloy. The Sn3.8Ag0.7Cu solder alloy used in this work performed as a fundamental study for the rest of solder alloy family prepared by PM method. Systematic evaluations on samples are conducted after reflow process to achieve melted solder to form joining on Cu board. The X-Ray Diffraction(XRD) assessment on the solder powder was a analysis to have information about phase formation of the solder after milling process.

2.Materials and methods

The experiment begun with some calculations and pre-weighed the Sn, Ag and Cu powder according to Sn3.8Ag0.7Cu with a analytical balance. It was then milled for 6 hours in a high energy planetary ball mill machine(Nian Hai Tianyang, FM-2 model) with a fixed speed of 1400rpm and 0.7g of it being compacted with 5 tons using a manual hydraulic press machine(Specac UK 15tons model) to make a solder pellet sample. There was no sintering process involved which made the samples as green bodies.