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EFFECT OF BISMUTH CONTENT ON MICROSTRUCTURE, MELTING TEMPERATURE AND UNDERCOOLING OF SN-0.7CU SOLDER ALLOY

Mohd Izrul Izwan RAMLI*, Muhamad Syafiq Syakri YUSUF,
Mohd Arif Anuar MOHD SALLEH

Centre of Excellence Geopolymer and Green Technology, School of Materials Engineering,
Universiti Malaysia Perlis (UniMAP), Taman Muhibbah 02600, Jejawi, Arau, Perlis, Malaysia.

Abstract

The aim of this manuscript to study the influence of Bismuth (Bi) addition on the microstructure, melting temperature and undercooling of Sn-0.7Cu solder alloys. In this study, several Bi composition were chosen which is 0 wt.%, 0.25 wt.%, 0.5 wt.%, 1.0 wt.% and 2.0 wt%. The result indicated that with addition of Bi element, it can refine the β-Sn and reduce the size of primary Cu_6Sn_5. The melting temperature of Sn-0.7Cu solder alloy was observed by DSC result and found there is no significant changes of melting temperature by Bi additions. However, with Bi addition, it will reduce the undercooling of the Sn-0.7Cu solder alloys.

Keywords: *lead-free solder, soldering, bismuth, microstructure, thermal.*

Introduction

The usage of Sn-Pb solders in electronic packaging industries has been strictly banned due to human health and environment concern. Therefore, there has effort to develop a new alternative for solder materials in electronic packaging industry due to toxicity of lead (Pb) [1]. Recently, a common alternative as lead-free solders are Sn-Ag-Cu (SAC) and Sn-Cu solder which are nominates for replacement [2-4]. However, with increasing price of silver (Ag) in current market, solder manufacturers are looking into a new lead free solder that not contain silver, making the Sn-Cu solder alloy one of targets choice[5].

Bismuth element has a brittle texture and has a very low thermal conductivity [6]. Bi element has been found can improved solder joint shear strength, thermal fatigue resistance and drop impact performance [7]. With the addition of Bi into Sn-0.7Cu, it believed can improve the mechanical properties of Sn-0.7Cu solder alloys due to solid solution strengthening hardening effect of Bi phase in Sn matrix [2]. However, the research on thermal properties is rarely explored. The Sn-0.7Cu solder alloy has a eutectic melting point of 227°C that has adequate wetting characteristic in an inert atmosphere. In soldering technology, eutectic alloy is preferred to provide best manufacturability as they have a sharp solidification temperature. Melting temperature is a critical in solder application since it can determines the operating temperature of the soldering process. If the melting temperature of new solder alloy is not change, it allows this solder to be used in conventional soldering process with no adjustments to be made in a soldering process. Higher melting temperature of solders will increase the soldering process temperature in the electronic packaging fabrication process that may increase the cost of operation and can cause thermal damage to electronic components during fabrication process.

*) Corresponding author: mohdizrulizwan@gmail.com

In this manuscript we focus on the effect of Bi additions into Sn-0.7Cu solders alloy and investigate their influence on microstructure, melting temperature and undercooling of solder alloy.

Methodology

Sn-0.7Cu solder alloy was used as based material and was supplied by Nihon Superior Co Ltd., Japan. The solder alloy was mixed with different composition (0.5, 1.0, 1.5 and 2.0 wt. %) of Bi by using casting technique. After held for one hour at 350°C, the mixing molten metal was poured into the stainless steel mold. Then the bulk solder mounted, grinded, polished and etched in a solution of 93% methanol + 5%HNO_3 + 2% HCL for microstructure observation. The microstructure were then investigated using Optical Microscope (OM).

The melting and undercooling of the solder alloys was investigated by using Differential scanning calorimetry (DSC). The samples were kept below 10mg and sealed in aluminium pan. The sample were then heated up to 250°C with a rate of 10°C/min under nitrogen atmosphere condition.

Result and Discussion

Microstructure Properties

Fig. 1 shows the bulk solder of Sn-0.7Cu solder alloys that containing 0.5, 1.0, 1.5 and 2.0 wt% addition of Bi microalloying element phases. The typical microstructure of Sn-0.7Cu soler alloy usually consist of primary β-Sn dendrites and surrounded by eutectic intermetallic Cu_6Sn_5. As shown in Fig. 1, the pure Sn-0.7Cu solder alloys consists a large amount of primary β-Sn cells with small intermetallic Cu_6Sn_5. However, with addition of Bi element into Sn-0.7Cu solder alloy, the microstructure of β-Sn was refined and has reduced the number of intermetallic Cu_6Sn_5.

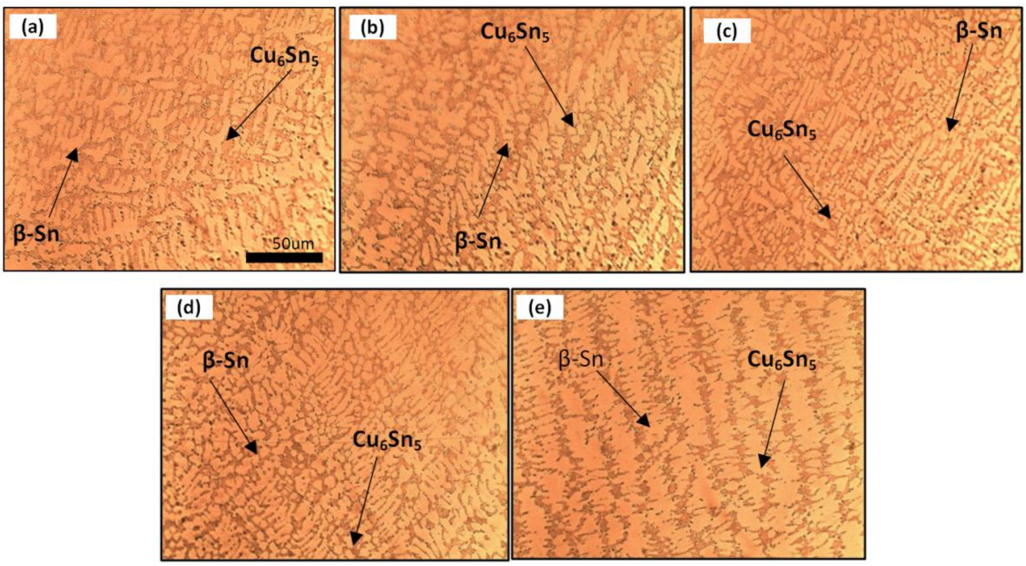

Fig. 1. Optical micrograph of the Sn-0.7Cu+xBi (x=0.0 wt.%, 0.50 wt.%, 1.00 wt.%, 1.50 wt.%, and 2.00 wt.%) on the bulk solder alloys

Based on microstructure, the size of β-Sn in solder matrix increased with the increasing in the weight percentage of microalloying additions. For existence of Bi particles in solder alloy was effectively disturbed the enhancement of β-Sn region and the grain sizes reduced.

According to Ali et. al [8] in their research on SAC105-Fe/Bi, they reported the decreases of grain size attributed to the presence of Bi in the alloy, which act as additional nucleation sites for the formation of grains and thus decrease the grain size. Zhao et al. [9] also investigated the influence of Bi on microstructure in Sn-Ag-Cu solder alloy. They conclude that the microstructures of all solder composed of island-like Sn-rich phase and Sn-Ag-Cu eutectics. In addition of 1 and 3 wt% Bi in Sn-Ag-Cu, it can be seen can refine the Sn-rich phase from 70 μm to 30 μm but not greatly change the microstructure as Sn-rich phase can dissolve large amount of Bi.

Thermal Analysis

The melting temperature of Sn-0.7Cu lead-free solder alloy when added with Bi particles was investigated by differential scanning calorimetry (DSC). The results show there were have no significant changes on melting temperture of the solder alloys. During the heating process of the differential scanning calorimetry (DSC) test, the eutectic Sn-0.7Cu solder alloy shows the melting point is 227.29°C. Meanwhile the melting temperature of Sn-0.7Cu+2.0Bi solder alloy alloy was 227.24 °C.

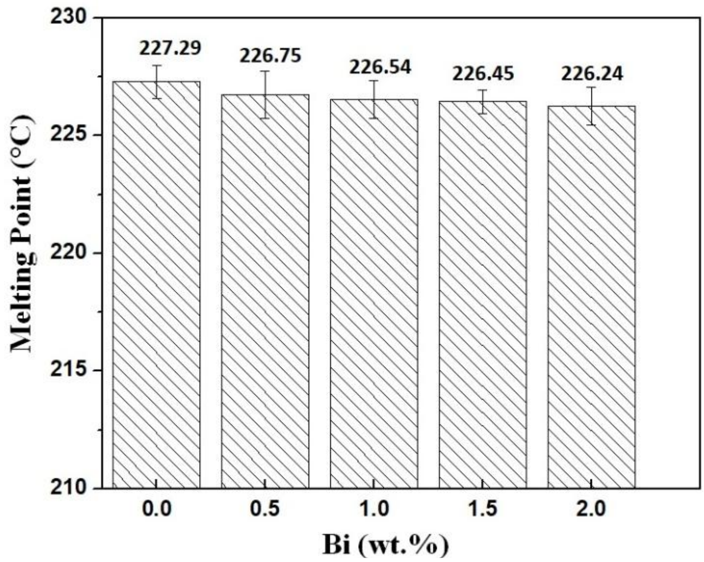

Fig. 2. Effect of Bi to melting temperature in Sn-0.7Cu solder alloy

Melting point temperature is one of the important solder characterization to determine the temperature of the operating system. The high melting temperature may cause thermal damage for electronic packaging if the new solder alloy did not alter melting temperature. The result of the solder alloy showed that no appreciable change in the melting temperature (T_m) of the solder when Bi particles were added into the solder matrix. According to Fig. 2, the result of base solder matrix Sn-0.7Cu is 227.29 ºC as compared to standard temperature which is 227 ºC. However, the slightly changed of melting point temperature is still can be accepted as the used of the DSC equipment in this study with small acceptable tolerant value. By all means, it is signify that the additions of Bi did not slightly change its melting temperature. Similar result were also shown previously by Belyakov [10] when they added Bi into Sn-0.7Cu-0.05Ni solder alloy and found it has no influence the melting temperature of that alloys. This melting point result is crucial, as it implied that when utilizing such solder alloys in fabrication process, there is no essential to make any adjustment to the reflow soldering process.

Table 1. Melting temperature of Sn-0.7Cu+xBi (x=0.0, 0.5, 1.0, 1.5 and 2.0)

Composition of Bi (wt.%)	Melting Temp. T_m(°C)	Liquidus Temp. T_l(°C)	Solidus Temp. T_s(°C)	Undercooling ($T_l - T_s$)(°C)
0.0	227.29	226.6	162.7	63.9
0.5	226.75	225.2	163.1	62.1
1.0	226.54	224.8	164.5	60.3
1.5	226.45	223.7	165.8	57.9
2.0	226.24	223.1	167.1	56.0

Additionally, the addition of Bi element will affect the undercooling of the Sn-0.7Cu solder alloys. For this reason, undercooling is the different between liquid become a solid during solidification. This phenomena related to the difficulties of nucleating a solid phase in a liquid state [11]. From this study, the amount of undercooling was calculated from the different of two onset temperatures in heating and cooling. Fig. 3 shown the effect of Bi to the undercooling temperature in matrix solder alloy. The addition of Bi can decrease the undercooling and this reduction can be attributes to the effect of alloying element on the rate of solidification. According to Hu et al. [11], with Bi alloying element with Sn-Cu solders tend to be related with decreasing undercooling.

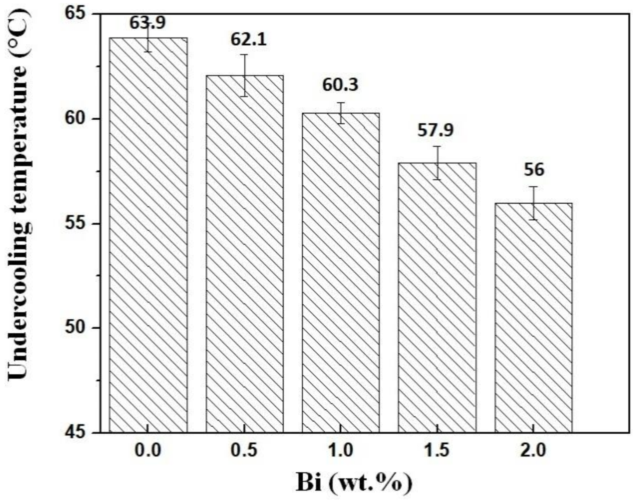

Fig. 3. Effect of Bi to undercooling temperature in Sn-0.7Cu solder alloy

Conclusions

In this study, the Sn-0.7Cu solder alloys with varying wt% of Bi element were successfully investigated. Microstructure analysis show the β-Sn was refined and smaller of intermetallic Cu_6Sn_5 were form when Bi were added. With increasing amount of Bi, there have no significant changes on melting temperture of the solder alloys but it will reduce the undercooling of the Sn-0.7Cu solder alloys.

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