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MICROSTRUCTURE AND INTERFACIAL INTERMETALLIC OF Sn-3.0Ag-0.5Cu/Sn-58Bi SOLDER JOINT FOR PACKAGE-ON-PACKAGE TECHNOLOGY

Mohd Izrul Izwan RAMLI[1,2*], Rita MOHD SAID[1,2], Flora SOMIDIN[1,2], Siti Farahnabilah MUHD AMLI[1,2], Siti Nor Atirah MUSTAPHA[1,2]

[1]Faculty of Chemical Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis 02600, Malaysia
[2]Geopolymer & Green Technology, Center of Excellence (CEGeoGTech), Universiti Malaysia Perlis (UniMAP), Perlis 02600, Malaysia

Abstract

In this study, the effect of growth microstructure on diffusion and intermetallic compound of Sn-58Bi/SAC305 solder joint with different of SAC305 size and reflow temperature had been studied. For effect of different size, it used 180°C reflow temperature and 5minute reflow time with the size of SAC305 solder ball was 800µm, 900µm and 1000µm. For the reflow temperature would reflow at 160°C,170°C, 180°C, and 190°C for 5minute reflow time. After the reflow process, a sample would go through a several processes such as molding, grinding and polishing before undergoing material characterization. The diffusion area had shown an inversely relationship with SAC305 size and linearly relationship with temperature and time reflow. Besides, the IMC thickness was thinner with increasing of SAC305 size. In this finding, the area of Sn-58Bi/SAC305 solder joint could be predicted to enhance the package on package technology.

Keywords*:* *package on package, low-temperature solder, Sn-58Bi, interfacial intermetallic.*

Introduction

In package-on-package (POP), fan-out wafer-level packaging is an essential technology that ensures a smaller package footprint with a higher heterogeneous level of integration and input/output density compared to traditional flip-chip packaging. It improved thermal and electrical efficiency compared to general packaging technologies [1]. The thermal warpage level can be reduced by regulating the temperature of the reflow in the range of 180 °C- 200 °C [2-3]. Fig. 1 shows the schematics of the POP system used in industry.

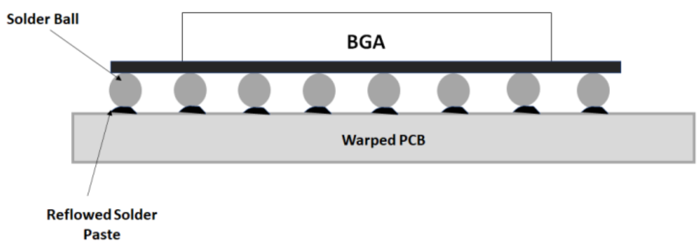

Fig. 1. Package on package system used in industry

*Corresponding author: izrulizwan@unimap.edu.my

Lead (Pb)-free solders such as Sn-Ag-Cu, Sn-Bi and Sn-Cu were dynamically tested as a replacement for traditional Sn-Pb solder. Due to the hazard of Pb to the environment and human health, the Sn-3.0Ag-0.5Cu (SAC305) alloys are the most commonly been using in the development of lead-free solders because of their comprehensive industrialization performance. Nowadays, the Sn-58Bi solder has widened tremendous production opportunities because of its superior performance [1]. Sn-58Bi solder displays a lower melting point, higher ultimate tensile stress (UTS) and low-cost relative to the Sn-37Pb [1]. Due to its lower melting temperature and low coefficient of thermal expansion, Sn-Bi solder is proposed as one of the most promising replacements for lead-containing solder. These characteristics provide useful applications for energy saving, step-soldering and temperature sensitive or thermal damage processes. Sn-58Bi solder also has strong wettability, yield power, cost efficiency, joint strength, and high resistance to creep [2].

During manufacturing, the Sn-Ag-Cu solder alloy causes thermal damage to electronic components. Therefore, in order to save energy consumption when producing electronics, the electronics industry needs a low melting point solder alloy, even though the reliability of such soldering machines has not been adequate. In the electronics industry, Sn-Bi based solder alloys are commonly used among the various low melting point solder alloys [1]. Particularly in multi-chip packages (MCP), package on package (POP) and other thin packages, the warpage problem that occurs in high-temperature processing is critical [4]. Nowadays, the Bi-Sn system was identified as the low temperature metallurgy system of choice. The melting temperature of Bi-Sn eutectic (58%Bi) is 138 °C. Bi-Sn solder system has other benefits, beyond its lower melting temperature. Bi-Sn solders are currently used in items for low-cost consumer electronics [5]. For interconnections and the packaging of almost all circuits and electronic devices, the use of solders has become essential. Since the stability and reliability of the solder joints are necessary for the functionality and durability of electronic devices, it is important that the solder joints used are optimized in terms of their mechanical properties in order to ensure robust interconnections [6].

In this research, at solders joint with an SAC305 solder on the top side and an Sn-58Bi solder on the bottom side were reflowed below 200 °C. The bottom-side solder (Sn-58Bi) melts and then forms a mixture of the two solder during the reflow process. We develop a mixture of solder joints with Cu substrates by performing the reflow process at a temperature lower than that used for a SAC solder, thus reducing the thermal warpage and substantial thermal budget [2].

Methodology

A circular sheet of Sn-3.0Ag-0.5Cu with an average diameter of 800 µm and ~1000 µm thick and Sn-58Bi solder paste (~0.0001g) were used for the experiments. The sample will insert into reflow oven and start the reflow process. It was heated in the thermal annealing furnace with the specific temperature and time of heat. The reflow temperatures were set to 160°C, 170°C, 180°C, and 190°C, and the samples were heated for 5 minutes at a heating rate of 10 °C/s.

Then the sample was measured using ImageJ to measure the growth of diffusion area region, growth thickness of IMC and area fraction of Sn-58Bi/SAC305 solder joint. The area fraction of Sn-58Bi/SAC305 solder joint had been quantitative analyzed by using ImageJ software. The area fraction of ß-Sn phase and Eutectic phase on growth Sn-58Bi/SAC305 solder joint had been measured and calculated by using ImageJ software.

Result and Discussion

Fig. 2 had shown the diffusion area of growth Sn-58Bi/SAC305 solder joint effect of different SAC305 size with reflow temperature at 180 °C with reflow time 5 minutes. As SAC305 solder ball increased, the diffusion area solder joint decreased. With 800µm size of SAC305 solder ball could form largest area diffusion after the reflow process. However, at 1000µm solder ball of SAC305 would cause only a small area diffusion. By referring research from Yong-Sung Park et al. [7] with smallest solder ball, the diffusion into molten solder was smaller than larger solder ball due to the high of area/volume.

Fig. 3 had shown the diffusion area of growth Sn-58Bi/SAC305 solder joint effect of different reflow temperature with 800μm SAC305 size with 5 minutes reflow time. As reflow temperature increased, the diffusion area at Sn-58Bi/SAC305 solder joint was increased. At 190°C reflow temperature had formed the largest of area diffusion after reflow process. Besides, the low of reflow temperature caused smallest of diffusion area on Sn-58Bi/SAC305. By referring research from S. Palaniappan et al. [8], lower temperature reflows there has small diffusion between solder ball and paste.

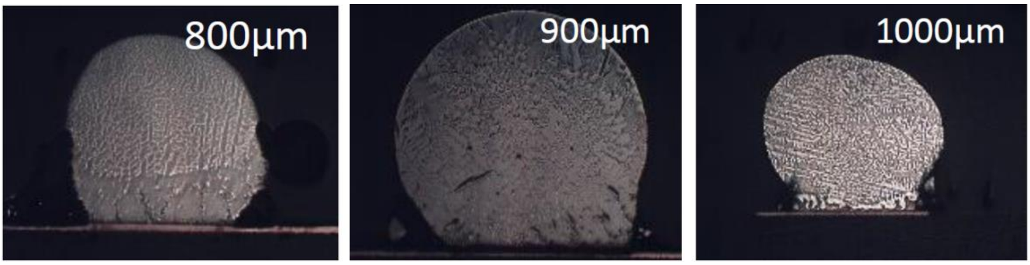

Fig. 2. Diffusion of Sn-58Bi/SAC reflowed with different SAC305 size

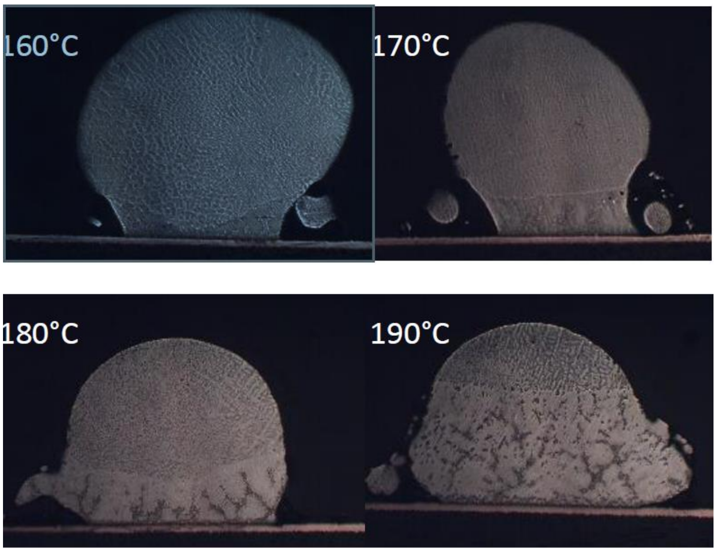

Fig. 3. Diffusion of Sn-58Bi/SAC305 reflowed at 800μm with different reflow temperature

Fig. 4 had shown the thickness of IMC for Sn-58Bi/SAC305 solder joint effect of different SAC305 size at 180°C reflow temperature with 5 minutes reflow time. The thickness of IMC getting thinner when SAC305 size getting bigger. Hence, as the SAC305 solder ball decreased in diameter, the thickness of IMC getting increased. Fig. 5 had shown the thickness of IMC for Sn-58Bi/SAC305 solder joint effect of different reflow temperatures with 800 μm SAC305 size with 5 minutes reflow time. As the reflow temperature increased, thickness of IMC Sn-58Bi/SAC305 were increase. The lowest reflow temperature caused smallest of thickness of IMC on solder joint. By referring research from Kumar et al. [9] intermetallic layer consistently increases with the reaction of reflow temperature.

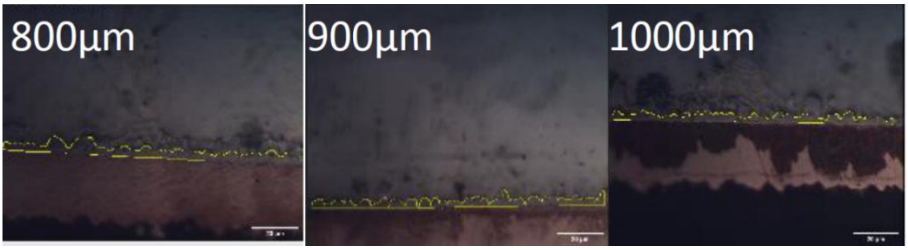

Fig. 4. IMC thickness of Sn-58Bi/SAC305 reflowed with different SAC305 size.

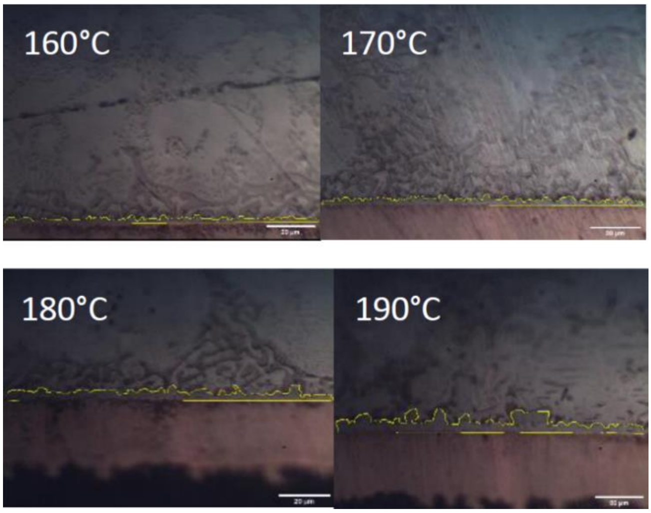

Fig. 5. IMC thickness of Sn-58Bi/SAC305 reflowed with different reflow temperature.

IMC decreases with a decrease of reflow temperature. Several studies also reported that the IMC layer's thickness at the solder/Cu interface increases with increased annealing temperature [10-13].

Conclusions

In this study, the effect of different SAC305 solder ball size on Sn-58Bi/SAC305 solder joint had been investigated. It was found the area diffusion of Sn-58Bi/SAC305 were increase as the diameter of SAC305 size solder ball increased. The effect of reflow temperature on Sn-588Bi/SAC305 solder joint had been studied. The area diffusion of solder joint was increase due to the higher of the reflow temperature. Furthermore, the effect of reflow time on the growth Sn-58Bi/SAC305 solder joint had been evaluated. Area diffusion of solder joint change by changing of reflow time. The area of diffusion was growing up as the reflow time increase. In addition, the thickness of IMC was thinner when the reflow time decreases. Thickness of IMC increase with increases the reflow temperature.

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