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Study of IMC vs Drop Test effect on Leadfree SAC and Polymer Solder Ball

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Abstract – *Leaded solder ball was replaced by leadfree solder ball which is now widely used in semiconductor industries, due to the hazardous effects of lead to human's health and toxicity for environment. Due to this, poor solder joint strength for Ball Grid Array (BGA) packages on leadfree devices is a reliability concern when subjected to reliability stress test. With a polymer core in the solder ball may be a good strategy to dissipate stress better from environment stresses compared to the conventional solder ball. However, polymer core solder ball tends to form a thicker Intermetallic Compound (IMC) layer when subjected to environmental stress. This could affect the drop test performance and caused ball drop. Thicker IMC for polymer core solder ball is due to the diffusion rate of Cu that is faster than Tin (Sn). To reduce IMC layer, the polymer core solder ball can be coated with 1 µm thickness of Nickel (Ni) on the Copper (Cu), thus offer better drop test performance by limit the Cu diffusion. IMC measurement and tray drop test were conducted in this research study under Moisture Stress Level (MSL) 2 and 3 stress to verify the reliability of the solder balls. From this study, it can be conclude that the MSL level 3 perform better performance in drop test and thinner IMC layer than MSL level 2.* **Copyright © 2015 Penerbit Akademia Baru - All rights reserved.**

Keywords: Ball Grid Array, Polymer Core Solder Ball, IMC, Diffusion

1.0 INTRODUCTION

Nowadays, BGA semiconductor chip are widely used by customer for many electronic applications including portable, automotive and telecommunication products that require stringent thermal and mechanical requirements. BGA has the advantages of smaller size and higher pin counts. Solder balls in BGA play an important function to provide electrical interconnections between silicon die and substrate. Lead solders are recommended to be replaced with leadfree solders which is now widely used in BGA packages, when Restriction of Hazardous Substance (RoHS) Regulation came into effect in year 2006 [1] due to the hazardous effects of lead to human's health and toxicity for environment, However, there are many factors that affect the solder joint reliability such as environmental stress. Thus, to improve on the solder joint reliability for lead-free solder balls, leadfree polymer core solder ball with polymer core inside the solder ball is introduced. The main advantage of the polymer core solder ball is the ability of the polymer core to absorb and relieve stress [2]. This could result in an improvement to the solder ball joint, compared to the conventional leadfree solder ball.

In this experiment, the most common surface finish pads of which Nickel-Gold (Ni/Au) is plated over the Cu pad is choose. The layer is commonly used as a protective layer on a Cu conductor in electronic devises and circuit fabrications [3]. Au is to protect the surface finish of Ni from oxidation.

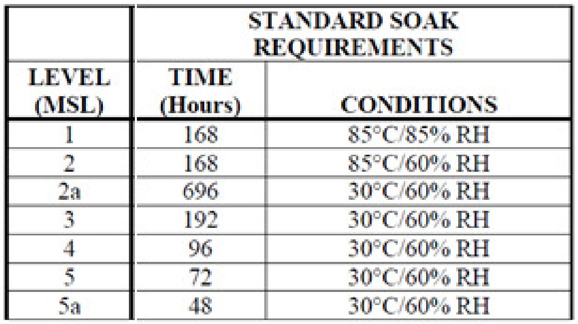
2.0 METHODOLOGY

Polymer core solder ball consists of three layers with a total diameter of 500 µm. The inner core is 400 µm in diameter and is coated by a Cu layer of 20 µm thickness while the outer most layer of solder with 30 µm thickness. As for SAC 387 solder ball, it consists of Sn with 95.5%, 3.8% of Ag and 0.7% of Cu.

In this research, Molded Array Process Ball Grid Array (MAPBGA) substrate with Ni/Au plating was used. The solder ball diameter selected is 500 µm with solder ball pad 0.5 mm. In this project, SAC 387 and polymer core solder balls were investigated via mechanical cross-section observation on IMC thickness measurement and tray drop test. MSL stress tests were performed to study the solder ball properties and internal structure of polymer core solder balls. Both the solder balls were underwent reflow at peak temperature of 235°C to 245°C.

MSL test is an electronic standard for moisture sensitive devices that are exposed to high moisture. There are seven level of MSL test, according to the IPC/JEDEC J-STD-020C specification as shown in Table 1 [4]. Moisture test is important to the electronics devices as damage could occur when moisture from the external stress is absorbed by the devices.

Table 1: Moisture Sensitivity Level.



	STANDARD SOAK REQUIREMENTS	
LEVEL (MSL)	TIME (Hours)	CONDITIONS
1	168	85°C/85% RH
2	168	85°C/60% RH
2a	696	30°C/60% RH
3	192	30°C/60% RH
4	96	30°C/60% RH
5	72	30°C/60% RH
5a	48	30°C/60% RH

MSL 2 and 3 are chosen for this experiment to study on the solder ball reliability performance due to its common tests used for the new product evaluation study for most of the semiconductor factory. Table II shows the setting for the MSL 2 and 3, according to JEDEC standard specification.

Table 2: MSL 2 and MSL 3 Stress Condition.

Test	MSL 2	MSL 3
	Stress Test Condition	
Reflow	Reflow: 260 °C Cycles: 3	Reflow: 260 °C Cycles: 3
Soak	Temperature: 85 °C Humidity: 60% Hours: 168 Hour	Temperature: 30 °C Humidity: 60% Hours: 192 Hour
TC	Temperature-1: -65 °C Temperature-2: 150 °C Cycles: 10	NA NA NA
HTS	Temperature: 125 °C Hours: 24	Temperature: 125 °C Hours: 24

MSL 2 requires Temperature Cycle (TC) stress test and higher soak temperature at 85 °C; while no TC stress test is required for MSL 3. MSL 3 has lower soak temperature at 30 °C. For TC stress test, it is use to determine the ability of parts to resist extremely low and extremely high temperatures, as well their ability to withstand cyclical exposures to these temperature. The result will depend on the factor such as the high and low temperatures and dwell times.

Moisture chamber is capable of operating and maintaining the required moisture soak conditions. The same equipment will utilizes for TC, HTS and reflow. The baking step was carried out under HTS test at 125 °C for 24 hours [4]. This is to remove moisture from the packages before continuing on the moisture soaking test. The reflow test is performed after the soak test in order to investigate if there any effect due to the humidity and high temperature after long term aging.

2.3 Drop Test

Tray drop tests were conducted based on the Freescale Semiconductor standard method to assess the solder joints against the impact shock. Maximum cycles of drop were fixed at 30 cycles for this experiment study. For each time to perform tray drop test, 6 good samples were place on the bottom tray, and the dummy samples were placed on the other top trays for real case simulation of drop. Tray was then dropped onto a hard surface at five different angles as shown by the red arrows in Figure 1. Trays were un-strap after every cycle of drop and samples were inspected at every cycle for any of dropped balls, under high power microscope. The passing criterion is that drop ball does not occur in all the six test samples.

2.4 IMC Measurement

To perform IMC measurement, all the units were cold mounted by epoxy and hardener, then cross sectioned after 8 to 9 hours of cold molding. The sand paper grit size for the cross-section grinding started at 180 grit followed by 400, 600 and 1200 grit. The unit was then polished on the 9 μm and 3 μm polishing wheel to remove all the scratch lines.

IMC thickness were conducted under high power microscope of magnification 50X. Three of the highest IMC points were measured and the final value will be based on the average of these three points. The unit measured was in Micron meter (µm).

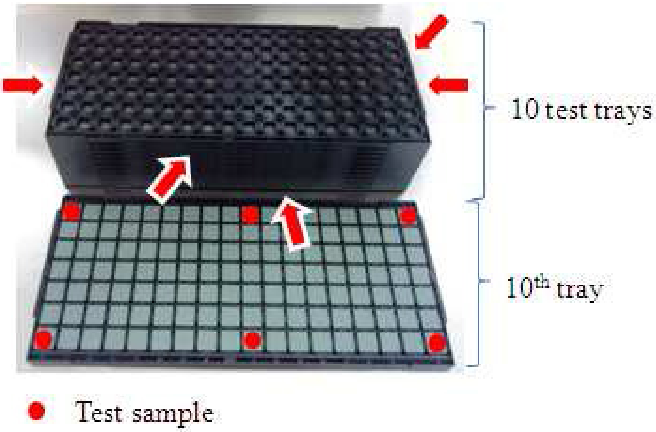


Figure 1: Five different angle of the tray drop test.

3.0 RESULTS AND DISCUSSION

From the tray drop test results in MSL 3, there was no drop ball observed after 30 maximum cycles of tray drop for both the SAC and polymer core solder balls. However, ball drop were observed at after 23 cycles after subjected to MSL 2 stress for polymer core solder ball.

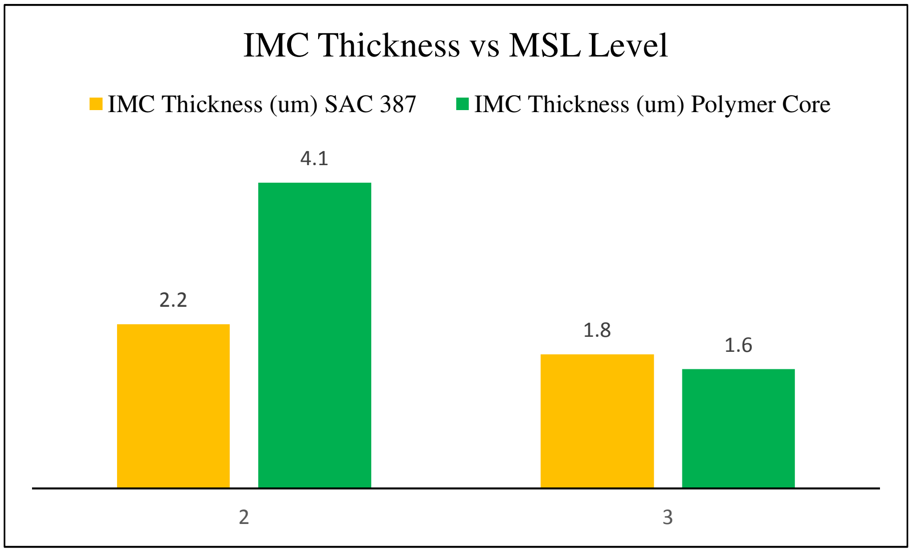


Figure 2: IMC thickness in the polymer core solder ball internal structure after subjected to MSL stress test.

Figure 2 below shows the average of IMC thickness after subjected to MSL 2 and 3 stress test. IMC thickness for SAC 387 after subjected to MSL 2 and 3 were 2.2 µm and 1.8 µm, respectively. As for polymer core solder ball, the IMC layer thickness were 4.1 µm and 1.6 µm, respectively. Observed that, MSL level 2 with thicker IMC on polymer core solder ball. This is due to the additional of TC test and rapid diffusion from Cu to Sn [5]. Thicker IMC are tends to weaker the solder joint and caused ball drop.

4.0 CONCLUSSION

The tray drop test for both SAC and polymer core solder ball after subjected to MSL 3 demonstrates better performance than polymer core solder ball after MSL 2 stress. Samples of polymer core solder ball have much thicker IMC layer after subjected to MSL 2 compared to the other samples. This is probably due to the additional TC stress included in the MSL 2 that could affect the solder joint.

From this research study, we can conclude that the polymer core solder ball is better in MSL level 3 compare to SAC 387. However, the performance for polymer core solder ball after subjected to MSL 2 shows significant weaker joint as compare to SAC 387. An additional coating of Ni layer on Cu could limit the diffusion from Cu to Sn, resulting in better solder joint performance and thinner IMC layer.

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