Australian Journal of Basic and Applied Sciences, 8(22) Special 2014, Pages: 1-5

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Pb-Free Solder Ball Robustness Comparison under AC and TC Reliability Test

[1,2]Tan Cai Hui, [1]Yap Boon Kar, [3]Tan Chou Yong, [2]Koh Wen Shi

[1]*Center of Microelectronic and Nanotechnology Engineering (CeMNE), College of Engineering, Universiti Tenaga Nasional, Jln. Uniten-Ikram, 4300 Kajang, Selangor, Malaysia*
[2]*Freescale Semiconductor, (M) Sdn. Bhd., Petaling Jaya, Selangor, Malaysia.*
[3]*University Malaya (UM), Department of Mechanical Engineering, Faculty of Engineering, 50603 Kuala Lumpur, Malaysia.*

ARTICLE INFO

Article history:
Received 15 September 2014
Accepted 5 October 2014
Available online 25 October 2014

Keywords:
SAC 387, Polymer Core Solder Ball, Shear Strength, solder joint, Reliability Test.

ABSTRACT

Background: Poor solder joint in lead-free BGA products caused by reliability stress tends to have dropped balls defect and this are a major concern in the semiconductor industries. A new technology with polymer core inside the solder ball (core/Cu/Sn) is integrated. The core function is to absorb and dissipate the stress better compared to the SAC solder ball. The diffusion rate of Cu is faster than the diffusion rate of Sn, caused the void tends to form in between the interface at the Cu and Sn layer, after subjected to high temperature stress. This could affect the solder joint strength and causing drop ball issue. This research work studies the solder ball joint strength for SAC 387 and polymer core solder ball. Solder ball shear strength test was conducted via Dage 4000 series bond tester. From the research work, it can be concluded that the polymer core solder ball showed better performance than the SAC 387, after subjected to the AC reliability test; while in TC stress test, SAC 387 showed better performance than polymer core solder ball after TC 500 cycles, due to the crack induced in between the Cu and solder layer. To overcome the voids issue, the polymer core solder ball could coat an additional 1 µm Ni layer on the Cu (core/Cu/Sn/Ni) to reduce the diffusion from Cu to Sn, and avoid the voids formation.

To Cite This Article: Tan Cai Hui, Yap Boon Kar, Tan Chou Yong, Koh Wen Shi, Pb-Free Solder Ball Robustness Comparison under AC and TC Reliability Test., ***Aust. J. Basic & Appl. Sci.,*** *8(22): 1-5, 2014*

INTRODUCTION

Semiconductor chip in Ball Grid Array (BGA) products are commonly used by customer for many electronic applications including automotive, microcontroller and telecommunication products that require stringent thermal and mechanical requirements. BGA has the advantages of smaller size, thinner weight and higher pin counts. Solder balls in BGA function as to provide electrical interconnections between silicon die and substrate. Lead solder alloys are used in BGA device at the early stage. However, on July 1, 2006, the European Union (EU) issued the Restriction of Hazardous Substances (RoHS), which regulatory requirement restricting use of lead in electronic assembly, due to the hazardous effects of lead (Hwang, Jennie S., 2004). Therefore, to support on this, many industrial are migrating to lead-free solder ball consisting of tin/silver/copper (SAC) alloy. SAC solder perform similar to eutectic, with adequate thermal fatigue properties, strength, and wettability.

Nevertheless, many research found that the lead-free solder reliability due to the environment stress is still less perform than lead solder balls in semiconductor products. Thus, in order to develop and improve on joint reliability for lead-free solder balls in semiconductor devices, a lead-free polymer core solder ball with polymer core inside the solder ball is introduced. The polymer core inside the solder ball is able to absorb and relieve stress from the environment stress impact (Queck Kian Pin, 2010). This could improve the ball drop reliability as well; result in a significant improvement to the solder ball joint, compared to the SAC lead-free solder ball.

This research work involves using Nickel-Gold (Ni/Au) plated over the Cu pad substrate. The Ni layer is function as a protective layer on a Cu conductor in electronic devises and circuit fabrications (Harper, C., 2000); while Au is to protect the surface finish of Ni from oxidation.

2. *Experimental:*

Two types of solder balls were used in this research, as SAC 387 and polymer core solder ball. SAC 387 is a pure metallic solder ball with composition 3.8% Ag, 0.7% Cu and 95.5% Sn. While, the polymer core solder ball consists of three layers. The inner core of the solder ball consist of 400 µm diameter and it is coated by a Cu layer of 20 µm thickness; while the outer most layer of solder consist of 30 µm thickness. Both types of the

Corresponding Author: Yap Boon Kar, Center of Microelectronic and Nanotechnology Engineering (CeMNE), College of Engineering, Universiti Tenaga Nasional, Jln. Uniten-Ikram, 4300 Kajang, Selangor, Malaysia
Ph: +60389212229. E-mail: kbyap@uniten.edu.my

solder balls used in this experiment were 500µm. Mold Array Plastic Ball Grid Array (MAPBGA) substrate with Ni/Au plating was used in this study.

2.1 Reliability Stress Test – AC:

Not many researchers were performed the Autoclave (AC) reliability test to observed the performance of the solder ball especially on the shear strength and the internal structure. Basically, AC is more focus on the moisture resistance evaluations. The unit sample will subject to 100% of atmosphere humidity, under 205kPa pressure with 121°C bake; according to the JEDEC specification, JESD22-A102D (2000) to force the moisture goes into the package. The outcome in this research experiment would be focus on the solder ball shear strength and the internal structure, after subjected to the AC stress test.

Table 1: AC stress test condition.

Stress Test	Stress Test Point	Description
AC	24 Hours	Bake at 121°C with 100% humidity and 205kPa.
	48 Hours	
	96 Hours	
	144 Hours	

Table 1 summarizes the AC reliability test condition with the stress point from 24 up to 144 hours.

2.2 Reliability Stress Test – TC:

Temperature Cycles (TC) stress tests were performed to study the solder joint effect to the very cold and very hot temperature, from -65 and 150°C. There are total 11 test conditions based on different industrial need according to the JEDEC standard specification for TC test, JESD22-A104D (2005). Condition C was used in this experiment with the temperature -65 and 150°C, respectively.

Table 2: TC stress test condition.

Stress Test	Stress Test Point	Description
TC	100 Cycles	Subjected to extremely low and high temperature at -65 to 150 °C.
	200 Cycles	
	500 Cycles	
	1000 Cycles	

Table 2 above summarizes the AC reliability test condition with the stress temperature cycle from 100 up to 1000 hours.

2.4 Solder Ball Shear Test:

In order to access the solder ball joint strength to the solder ball, solder ball shear test is needed. Solder ball shear test is the most common test applied in semiconductor industrial to evaluate the solder shear strength. It is define as the process of removing a solder ball from a package unit at room temperature with a certain force and at a constant rate. Specialized equipment is required to perform the solder ball shear test, which normally known as Dage bond tester. Figure 1 below shows the step to perform solder ball shear test, according to the JEDEC specification, JESD22-B117A (2006).

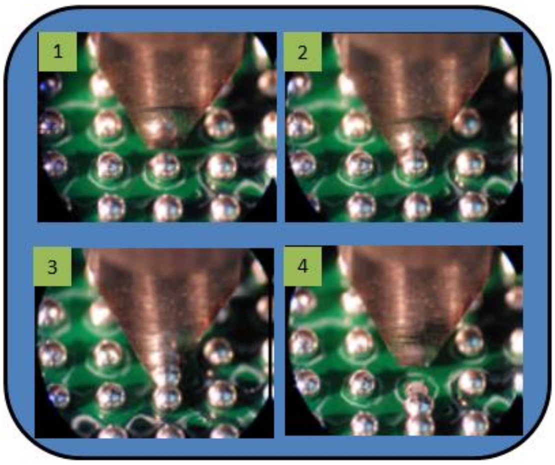

Fig. 1: Step to perform ball shear via Dage bond tester 4000 series.

To perform for the ball shear test, same shear speed should be used for the entire sample unit test. Total 10 units BGA samples were conducted for solder ball shear test after subjected to TC and AC stress test with an average is taken on a total of 100 solder ball shear reading.

3 Results:

3.1 Ball Shear Strength – AC:

Figure 2 below shows the average of ball shear strength for the SAC 387 and polymer core solder ball, after subjected to AC test. In general, the average shear strength of SAC 387 and polymer core solder ball decreased with increasing stress point hours from 24 to 144 hours. Average of SAC 387 shear strength was decreased from about 1165g to 1120g, from 24 to 144 hours. Whereas, polymer core solder ball decreased from about 1190g to 1140g, from 100 to 1000 cycles. In conclusion, the shear strength for polymer core solder ball is higher than the SAC 387 after subjected to AC reliability stress test.

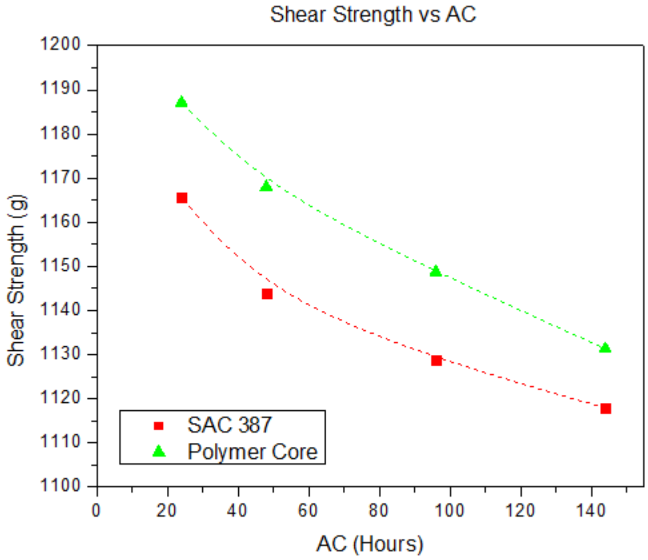

Fig. 2: Ball shear strength after subjected to AC stress condition.

3.2 Ball Shear Strength – TC:

Figure 3 below shows the average of ball shear strength for SAC 387 and polymer core solder ball. From the graph trend, shear strength of polymer core solder ball is significant higher after TC 100 and 200 cycles. There obvious different in solder shear strength observed after 500 in between SAC 387 and polymer core solder ball. The shear strength of SAC 387 was decreased from 1132g to 1040g, from 100 to 1000 cycles test. Whereas for polymer core solder ball, the shear strength decreased from 1200g to 1000g, from 100 to 1000 cycles test. In general, the shear strength for both SAC 387 and polymer core solder ball is decrease with increasing of cycle test.

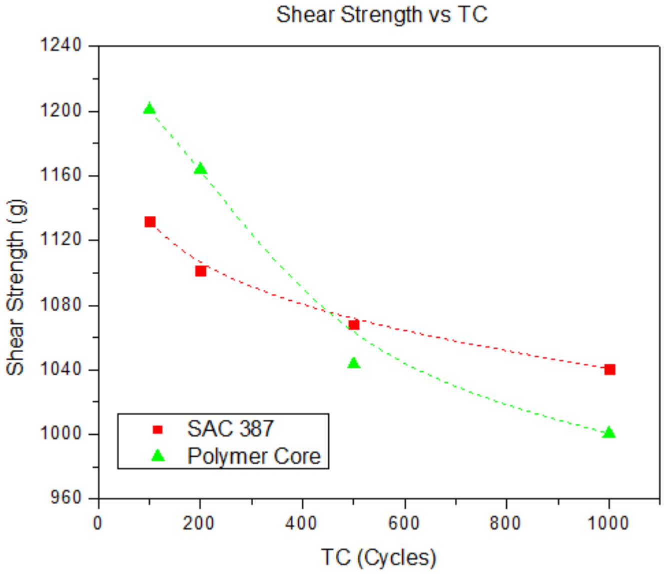

Fig. 3: Ball shear strength after subjected to TC stress condition.

4 *Discussion:*

From the result shown above, the ball shear strength for polymer core solder balls after subjected to AC stress test is significantly higher than the SAC 387. However, for the TC reliability stress test, the SAC 387 is significantly higher than the polymer core solder ball. This is probably due to the rapid Cu diffusion into the Cu core interface resulting in thicker IMC, thus affect on the solder joint strength performance.

From all the test samples, observed the crack is induced in the sample TC 1000 cycles for polymer core solder ball. One of the samples from TC 1000 cycles for polymer core solder ball were examined under high power scope, as shown in Figure 4. From the observation, crack induced in between the Cu and solder layer. This is probably due to the void formation, thus causing crack which could affect the joint. The Kirkendall voids tend to form in between the Cu and Sn when exposed to high temperature, as Cu diffuses much faster into Tin (Sn) than Sn into Cu [7-9]. No crack is observed for AC stress test for both SAC 387 and polymer core solder ball, since AC stress test is only the test to focus on the affect of humidity. As a conclusion, solder joint strength does not affected by high humidity but the high temperature.

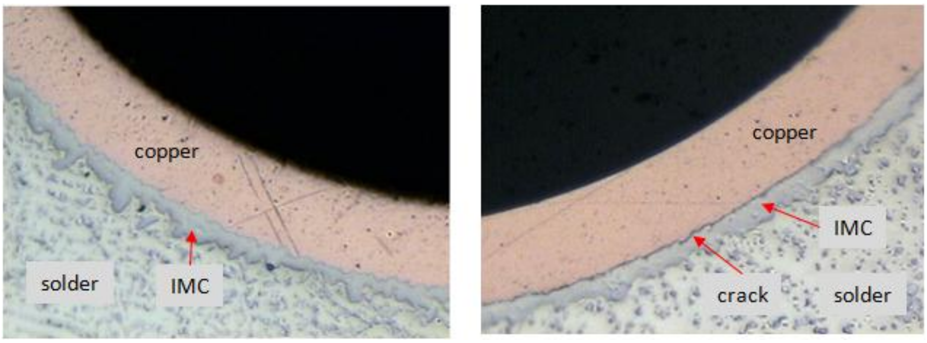

Fig. 4: Image for TC 1000 cycles stress test for SAC 387 (left) and polymer core solder ball (right).

5 *Conclusion:*

As conclusion from this research project, the ball shear strength for polymer core solder balls is significant higher than SAC 387, after subjected to the AC reliability stress. As for the TC reliability stress test, the ball shear strength for SAC 387 is significant higher than polymer core solder ball. This is probably due to the rapid diffusion from Cu to the Sn that could induce thicker IMC layer, hence affect the solder joint strength. Since TC stress test condition exposed to the temperature -65°C and 150°C, this could accelerate the diffusion rate from Cu to Sn and causing crack. However, for the samples of AC stress test, even through the shear strength is decrease from 24 to 144 hours but there is no crack observed up to 144 hours. This could be explained that, the shear strength reducing is due to the 121°C of the temperature, and the affect from 100% humidity with 205kPa would not cause any voids formation.

As a conclusion from this research study, we can conclude that the humidity would not affect much on the solder joint strength, but the high temperature. We might also conclude that, voids form easily after subjected to long TC (1000 cycles) stress test. High humidity would not affect the shear strength performance that caused by voids formation. Even thought the polymer core inside the solder ball function as to absorb and reduce the stress impact, but the crack happened due to the voids formation was because of the rapid diffusion from Cu to the Sn. This would be one of the important area that researcher can focus in further. This problem could solve by implement a coating layer to limit the Cu diffusion.

ACKNOWLEDGMENT

The author would like to thank Freescale Semiconductor and UNITEN for the technical assistance, funding and great support.

REFERENCES

Harper, C., 2000. Electronic packaging and interconnection handbook. 3rd ed. New York: McGraw Hill.

Hermans, M.J.M. and M.H. Biglari, 2006. Void Formation By Kirkendall Effect In Solder Joints, Delft University of Technology, Materials Science and Engineering, The Netherlands, Version 1.1.

Hwang, Jennie S., 2004. Introduction to Implementing Lead-Free Electronics. 2nd ed. McGraw-Hill Professional.

JEDEC Standard, Solid State Technology Association, 2000. Accelerated Moisture Resistance – Unbiased Autoclave, JESD22-A102D.

JEDEC Standard, Solid State Technology Association, 2005. Temperature Cycle Test, JESD22-A104D.

JEDEC Standard, Solid State Technology Association, 2006. Solder Ball Shear, JESD22-B117A.

Kar, Y.B. *et al*., 2012. Comparison study on reliability performance for polymer core solder balls under multiple reflow and HTS stress tests. Microelectronic Reliability, 53: 164-173.

Queck Kian Pin, Heitzer Ludwig and Yong Wei Wei, 2010. 2nd Level Reliability Drop Test Robustness for Wafer Level Packages. Proceedings of IEEE 34th International Electronic Manufacturing Technology Conference.

Yap Boon Kar, Tan Cai Hui, Agileswari, Calvin Lo, 2012. Solder Ball Robustness Study on Polymer Core Solder Balls for BGA Packages. Proceeding of 35th International Electronic Manufacturing Technology Conference.